Econometric models for public transport forecasting

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Although the contributions of all these organisations and people are acknowledged, the responsibility for any errors or omissions arising out of this research lie entirely with the author.

Contents

Abbreviations and acronyms

ACF	autocorrelation function
AR	autoregressive
BOPRC	Bay of Plenty Regional Council
CBA	cost-benefit analysis
CBD	central business district
DMU	diesel multiple unit
ECM	error correction model
KPSS Test	Kwiatkowski-Phillips-Schmidt-Shin Test
MA	moving average
PACF	partial autocorrelation function
PAM	partial adjustment model

Executive summary

This report presents the findings of econometric research, carried out by DMK Consulting, from 2009 to 2012, into public transport patronage growth in the following cities within New Zealand:

- Auckland (bus and rail)
- Wellington (bus and rail)
- Hamilton (bus only)
- Tauranga (bus only).

Due to the time-consuming and data intensive nature of the econometric methods employed for this research, we did not have the resources to include Christchurch or Dunedin. However, we recommend that these cities be included in future extensions of this research.

The primary objective of the research was to examine and explain historical trends in patronage growth and, in doing so, provide up-to-date public transport elasticities.

The econometric approach adopted for this research differed from conventional econometric analysis of public transport patronage because we analysed data at a corridor level (ie by bus route, bus corridor, train line). This disaggregated approach enabled us to control for and estimate the impact of route-specific or line-specific events and factors.

We developed a comprehensive econometric methodology to ensure that the findings were thoroughly researched and statistically robust. This econometric methodology included graphical analysis, data analysis, model building and diagnostic checking stages.

The key findings from the research are as follows:

- On the Auckland bus network, a 10% increase in real fares caused a 3% fall in patronage and a 7% increase in revenue. The impact of fare increases on the Wellington bus network varied by situation and appeared to have been distorted by the introduction of the SuperGold Card. Fare increases on the Hamilton bus network had no discernible impact on patronage.
- On the Auckland rail network, a 10% increase in real fares caused a 9% fall in patronage (during the peak) and hence only a 1% increase in revenue. Similarly, on a Wellington rail network, a 10% increase in real fares caused a 7% fall in patronage and a 3% increase in revenue.
- There was strong evidence of complex and non-linear responses to petrol prices, ie the crossing of the $2.00 nominal petrol price in 2008 was associated with a 'jump' in patronage.
  - After controlling for the 'threshold effects', general petrol price moves had a modest impact on patronage in Auckland and Wellington – a 10% increase in real petrol prices caused a 0-2% increase in patronage.
  - However, the impact of general petrol price movements in Hamilton and Tauranga was greater – a 10% increase in real petrol prices caused a 2%–3% increase in patronage.
- There were a number of findings regarding service elasticities:
  - Peak rail: the impact of additional peak-time rail services was difficult to estimate. This was due to insufficient data on crowding levels and challenges in determining the direction of causation between peak service levels and rail patronage.

- Interpeak rail: a 100% increase in interpeak rail service frequency (ie a doubling of the number of trains running) caused a 30%–40% increase in interpeak rail patronage.
- Peak bus: a 100% increase in peak bus service frequency (ie a doubling of the number of buses running) induced a 30% greater peak-time patronage.
- Interpeak bus: a 100% increase in interpeak bus service frequency caused a 40%–50% increase in interpeak patronage.
- Weekend bus and rail: for weekend service improvements, there was a wide range of impacts depending on the nature and location of the improvement.
- Timetable improvements and extensions of hours: There were, in some cases, high patronage benefits arising from more regular timetables and extension of hours; however, there was also evidence of diminishing returns and some situations in which these elasticities did not produce benefits

Our conclusions from examining and explaining historical trends in patronage growth are as follows:

- For Auckland rail patronage growth from 1992 to 2010, we conclude that the completion of Britomart generated a sustained period of high growth from 2003 through to recent years. Britomart was accompanied by more train services and an improved service timetable and this clearly contributed to observed growth. But the more significant driver appears to have been due to some combination of the less tangible improvements associated with Britomart (ie greater convenience for commuters, publicity and general enhancement of facilities).
- For Auckland bus patronage from 2001 to 2010, we conclude that enhancements to the Auckland train lines detracted patronage from Auckland bus corridors. We also found evidence that the labour strikes might have caused a permanent shift in patronage from bus to rail.
- For Wellington rail patronage from 2005 to 2009, we conclude that petrol price changes, especially around the $2.00 mark, may have had an unusually strong impact on Wellington rail patronage. However, the limitations of the Wellington rail patronage data are noted.
- For Wellington bus patronage from 2005 to 2010, we conclude that fare increases in 2006 and 2008 had a significant impact on patronage growth. But we also note that each of these fare increases had quite differing impacts on patronage (especially when patronage is broken down into peak weekday, offpeak weekday and weekend).
- For Hamilton bus patronage from 2004 to 2010, we conclude that the massive growth in patronage over this time can be attributed to a range of service network improvements, including new routes, route changes, direct services and the introduction of Sunday services. There is also evidence that the introduction of a free two-hour transfer in 2007 may also have played a significant role by encouraging higher levels of offpeak patronage.
- For Tauranga bus patronage from 2005 to 2009, we conclude that the high levels of growth over that period can be attributed to a combination of some quite notable service timetable improvements, along with the introduction of the SuperGold Card.

The current practice in regard to public transport planning puts disproportionate emphasis on 'pre-evaluation': research and modelling of the theoretical patronage gains from proposed public transport investments. But there is less emphasis on 'post-evaluating' how effective those investments actually are and using that feedback to guide future investment.

We recommend that greater priority be given to 'post-evaluating' the impact of service improvements on patronage. Our research has provided some general guidelines regarding service elasticities and fare impacts, but the evidence is that these impacts differ considerably from situation to situation. We envisage a transport planning process in which this variability is accepted as a 'given' and public transport investments are regularly 'post-evaluated' and feedback is used to guide further decisions regarding public transport investment.

Our experience during this research project has been that details of any network or service changes (or other notable events) were often difficult to obtain and/or provided in a form that was difficult to incorporate. Therefore, we strongly recommend that processes be introduced to ensure that the details of any network changes (or other notable events) are recorded and documented in a manner that is amenable to future econometric analysis.

There is evidence from our research of considerable 'network effects' arising from improvements to both the Tauranga and Hamilton public transport networks. We therefore recommend that transport planners take a holistic view of the needs of public transport users and the manner in which they perceive the public transport network.

There is also evidence from our research that a number of relatively minor initiatives (a free two-hour transfer, a free ticket promotion, minor extensions of hours, more regular timetables) may have had a profound impact on patronage. We recommend that these initiatives be given consideration by other regional councils.

The econometric methods demonstrated by this research project have produced interesting and useful insights and findings. However, there are opportunities to extend the research in a number of directions:

- Further 'post-evaluation' of service improvements could be carried out on recent service improvements in Auckland using recent data, or carried out on anticipated service improvements in Wellington as they are implemented.
- The research methods used to 'post-evaluate' service improvements could be modified using cost–benefit analysis (CBA) approaches so we can assess value-for-money obtained from recent public transport investments.
- The research methods could be modified to produce zone-based fare elasticities that would help transport planners increase cost recovery rates.
- The research methods could be modified to produce a more sophisticated analysis of patronage growth by market segments (child, adult, senior, tertiary).
- Further investigation of petrol price impacts could be achieved by extending the research to include petrol price fluctuations that have occurred during recent years.
- The research methods presented here could be extended to include an analysis of the long-term data series available for Christchurch and Dunedin patronage.
- Further research could investigate the net impact on revenue of both:
  - the introduction of the free two-hour transfer in October 2007 for the Hamilton bus network
  - the reduction in that transfer to one hour in November 2011.

Abstract

This paper presents the findings from an econometric analysis of public transport patronage growth for a selection of New Zealand cities: Auckland, Wellington, Hamilton and Tauranga. The primary objective of the econometric analysis was to provide an explanation of historic growth patterns and, in doing so, provide up-to-date public transport elasticities for use by transport planners and policy analysts.

The econometric methods employed differ from conventional approaches because we used panel data models to analyse patronage patterns at a disaggregated level (ie bus route, bus corridor or train line) rather than at a network or city level. We consider that this approach produces more accurate estimates and demonstrates that statistical methods can be used to 'post-evaluate' the effectiveness of past public transport investments and the impacts of fare increases.

The econometric methodology was developed by DMK Consulting and was designed to ensure that the findings were thoroughly-researched and statistically robust. The development and implementation of this econometric methodology took from 2009 to 2012 to complete.

1 Introduction

1.1 The research project

This report presents the findings of econometric analysis of public transport patronage growth in the following cities within New Zealand:

- Auckland (bus and rail)
- Wellington (bus and rail)
- Hamilton (bus only)
- Tauranga (bus only).

The reasoning for the selection of cities above is as follows.

The econometric approach adopted for this research project was innovative and untested at the time; therefore, we wanted to test and refine the econometric methodology using relatively 'simple' case studies (ie small bus networks with only a limited number of routes and network changes). The Hamilton and Tauranga bus networks were selected on this basis.

The econometric methodology, once refined, was then applied to the larger cities. The highest priority was given to improving understanding of the Auckland public transport networks because they receive a significant share of public spending and investment. The next priority was given to the Wellington public transport networks. Due to the time-consuming and data intensive nature of the econometric methods employed, we did not have the resources to include Christchurch or Dunedin. However, we recommend that these cities be included in future extensions of this research.

1.2 The research objectives

The primary objective of the research was to examine historical trends in patronage growth and to build models to explain those trends in terms of a range of explanatory variables and factors (eg petrol price changes, fare increases, service improvements, economic growth, line maintenance, etc). In doing so, the research provided up-to-date public transport elasticities for the cities identified in section 1.1.

The secondary objective of the research was to identify econometric structures and tools for forecasting public transport patronage.

1.3 The econometric approach

The most common approach for econometric analysis in public transport economics is to build a regression model that explains aggregate patronage across a whole city (eg all Wellington city bus patronage).

In contrast, the econometric approach promoted by this research project involved examining, understanding and explaining patronage growth trends at a corridor level (ie by bus route, bus corridor or train line). This approach allowed us to more accurately estimate and control for corridor-specific events and factors (eg service changes on particular routes, line maintenance issues) and in doing so, we can produce more accurate estimates and insights into the key drivers of historic growth.

We also envisage that the approach promoted by this research project has the potential to change the existing mindset within the transport industry. This existing mindset involves assuming there is a single 'service elasticity' and a constant 'fare elasticity' that needs to be identified by researchers. In our judgement, this is an unrealistic assumption; the impact of service improvements and fare changes varies by situation and changes through time.

This uncertainty and variability should be accepted as somewhat inevitable. We advocate engaging in regular scientific 'post-evaluation' of network changes, such as that demonstrated by this research report. This 'post-evaluation' of historic service changes would be used to guide any further investment or disinvestments in public transport. Similarly, the 'post-evaluation' of fare increases could be used to guide the extent and structure of future fare changes.

The approach demonstrated by this report was very data intensive and required thorough examination and explanation of trends in the data. We therefore acknowledge the crucial role played by experts within the following organisations when they provided data and insight: NZ Transport Agency, Auckland Transport, the Waikato Regional Council, Bay of Plenty Regional Council, KiwiRail and NZ Bus Ltd. More detailed acknowledgement of these contributions is provided in the acknowledgements section.

1.4 The structure and content of this report

The report is structured as follows:

- Chapter 2 describes the econometric methodology developed by the researchers. We present the rationale behind the overall methodology and the econometric methods adopted.
- Chapter 3 provides a summary of key findings. We draw on key findings from all the cities and modes studied and identify central themes regarding the impact of fares, petrol prices, economic factors and service improvements.
- Chapter 4 presents an analysis of growth on the Auckland rail system. We introduce the reader to the Auckland rail system and provide a general description and explanation of historic trends. We then provide a summary of key findings, an assessment of our confidence in those findings, recommendations arising from the findings, and opportunities for future research. A similar approach is adopted for chapters 5–9.
- Chapter 5 presents an analysis of growth on the Auckland bus system
- Chapter 6 presents an analysis of growth on the Wellington rail system
- Chapter 7 presents an analysis of growth on the Wellington bus system
- Chapter 8 presents an analysis of growth on the Hamilton bus system
- Chapter 9 presents an analysis of growth on the Tauranga bus system
- Chapter 10 describes the methodology developed for forecasting. This methodology produces a simple forecasting tool that allows transport planners to do the following:
  - forecast the impact of Statistics NZ projections for population growth and demographic changes on route-level patronage
  - forecast the impacts of certain scenarios relating to key explanatory variables (eg rising petrol prices) on route-level patronage
- Chapter 11 provides recommendations – general conclusions and opportunities for further research.

2 Econometric methodology

2.1 Introduction

During the course of the research project, a comprehensive econometric methodology was developed to ensure that the findings of the research were accurate, thorough and robust. This econometric methodology was followed for all the cities and transport modes identified in section 1.1.

For the sake of brevity, the insights and findings for each of those cities and transport modes are presented in chapters 4 to 9, and the detailed econometric analyses supporting those insights and findings are presented in appendices B to G.

2.2 Data collection and data manipulation stage

2.2.1 Dependent variables

Patronage data was obtained from transport operators or regional councils. Where possible, we sought to obtain patronage data that was segregated by a time period (ie weekend, weekday peak, weekday offpeak) because a peer reviewer noted that the NZ Transport Agency had strong interest in isolating and understanding the determinants of peak-time patronage.

Where possible, weekday patronage was divided by the number of weekdays to create average weekday patronage per quarter. This ensured we could make valid 'apples-with-apples' comparisons between quarters that may have a different number of weekdays.

Weekend patronage was more problematic because Saturday patronage is generally higher than Sunday patronage. This makes a comparison between a quarter with, say, five Saturdays and four Sundays and a quarter with four Saturdays and five Sundays inappropriate. To address this problem we created what we call 'weekend equivalents'. We first calculated both average Saturday patronage per quarter and average Sunday patronage per quarter and then added them together to create average weekend patronage per 'weekend equivalent'.

2.2.2 Explanatory variables

There were a number of explanatory variables that were common to all cities and transport modes studied. These explanatory variables are presented and discussed below:

- Service improvements – service improvements (ie new services, increased frequencies on existing routes and extensions of hours) were all anticipated to have a positive impact on patronage growth. We therefore examined service data and/or service timetables so we could identify these service improvements.
- Real fares – fare increases would be expected to discourage patronage so these were calculated and incorporated into modelling. To adjust for the impact of inflation, we transformed nominal fares into real fares using the Statistics NZ CPI deflator.
- Real petrol prices – petrol price rises encourage car commuters to switch to public transport; the reverse happens if petrol prices fall. As with real fares, we calculated real petrol prices using the Statistics NZ CPI deflator.

- The nominal petrol price threshold – we were advised that the ‘crossing’ of the $2.00 petrol price threshold may have been a psychology trigger that encouraged unusually high mode shift to public transport. These dates were therefore identified and incorporated into the econometric modelling as a dummy variable. However, we note that this variable serves as a proxy for a number of events around this time, and the observed relationship will not necessarily continue in the future.
- Real retail sales – retail sales were incorporated into the econometric modelling because they are strongly associated with household perceptions of their own wealth; during economic recessions or times of economic uncertainty, retail spending tends to fall. Furthermore, we expect real retail sales to be positively correlated with public transport patronage because as people engage in more shopping and more entertainment they require more transport to get there. Again, as with the nominal petrol price threshold, we emphasise that real retail sales is being used as a proxy to encompass a collection of complex factors and events.
- Employment – increased employment inevitably generates more public transport because there are more people who need to get to work.

There were other explanatory variables that were examined and considered but ultimately not incorporated into the econometric modelling process:

- Car ownership – we obtained car licensing statistics that were segregated by territorial authority. Unfortunately, there was strong evidence of data corruption in those statistics so we did not feel confident incorporating them into the econometric modelling process.
- Population and demographic factors – we obtained sub-national population estimates but encountered a number of issues when attempting to incorporate them into the econometric modelling process:
  - The sub-national population estimates are only available on an annual basis, whereas the rest of the economic data employed for our modelling was available on a quarterly basis. This would have required us to interpolate the population data, and any findings involving interpolated data would have to be regarded with some caution.
  - Furthermore, sub-national population estimates that are available are only estimates drawn from Statistics NZ modelling processes; therefore, we cannot have too much confidence in the accuracy of the data, even on an annual basis.
  - In addition, sub-national populations exhibit steady growth rates over long periods of time (ie the variance is low). This low variability means that econometric models find it difficult to estimate the impact of populations with much accuracy.
  - Lastly, during our attempts to incorporate population into the econometric modelling process, we developed a process that involved examining public transport route maps and associating each route with populations at a suburban level. This process has a lot of merit to it, but was also very onerous and time-consuming and was not regarded as a priority for the purposes of this research project.
- Reliability – data on reliability was obtained for both rail networks (Auckland and Wellington). However, this data did not go back far enough to cover the whole period studied, so it was not incorporated into the econometric modelling. In addition, the reliability data for Auckland rail did not show any obvious association with rail patronage growth. We found that controlling for line construction and line maintenance explicitly via dummy variables was a more effective means of incorporating these factors. We did not obtain reliability data for most of the bus networks, due to time constraints, but recommend this be considered for future research.

2.3 Graphical analysis stage

The econometric methodology placed considerable emphasis on graphical analysis both prior to and during the model-building stage.

We consider there are risks in entering data into a 'blackbox' econometric model without first looking at the data. Therefore, we place a lot of importance on examining the trends and patterns in the data and attempting to make sense of it before applying an econometric model to the data. This process of graphical examination was introduced for the following reasons:

- Graphical examination allows us to pick up on anomalies that are caused by errors or miscalculations in the data, so these can be addressed as appropriate. For example, our initial examination of the Tauranga bus patronage data allowed us to identify anomalies in that data that were caused by the introduction of holiday services.
- Graphical examination allows us to identify patterns in the data that suggest an event, factor or variable that we might otherwise not have been aware of. For example, examination of the Auckland rail data allowed us to identify losses in patronage that were due to line maintenance.

2.4 Data analysis stage

There are a number of potential statistical problems that can undermine the validity of the econometric analysis. These are discussed in sections 2.4.1 to 2.4.3 below.

2.4.1 Multicollinearity

High correlations between explanatory variables can make econometric estimation challenging. Therefore, we used correlation tables to test for high correlations between explanatory variables. In situations where high correlations were observed we either developed strategies to minimise the problem or took the mulitcollinearity into account when assessing our confidence in the subsequent findings.

2.4.2 Nonstationarity

In simple terms, a variable is regarded as 'stationary' if it tends to revert to a mean level over time; in contrast, any variable lacking this mean-reverting quality will be regarded as nonstationary. Granger and Newbold (1974) warned that many economic variables are nonstationary and showed that regressions involving nonstationary variables can lead to 'spurious' or invalid findings.

Kennedy and Wallis (2007) noted that regressions with nonstationarity data were commonly carried out in the transport economics literature and acknowledged that these regressions often produced plausible estimates. But they also noted there is a risk that the resulting estimates are 'spurious'. They expressed a preference for seasonal differencing because it generally makes the variables stationary and hence mitigates the risk of 'spurious' findings. (See section 2.5.1 for more explanation of seasonal difference models.)

We acknowledge, however, that even seasonal differencing may not be enough to assure 'stationarity'. Therefore we incorporated a range of statistical tests to examine this issue; these tests were generally inconclusive (due to the short periods covered by most of the data) but were useful for identifying extreme violations of nonstationarity.

2.4.3 Endogeneity

Endogeneity or 'reverse causation' is another statistical issue that needs to be given careful consideration. The econometric models adopted in this research project assume that patronage is 'caused' by the explanatory variables. However, it is possible that, in some situations, the direction of causation goes in the other direction and, if this is the case, it could lead to misleading results.

The most obvious risk of endogeneity is in regard to service improvements. We generally assume that service improvements generate extra patronage. However, as Colman (2009) pointed out in his peer review of a draft report by Wang (2011) it is conceivable that transport operators improve service levels as a means of responding to patronage growth or coping with overcrowding.

That said, our econometric methodology minimised the risk of endogeneity quite considerably:

- First, we carried out a graphical analysis of the data before proceeding to econometric analysis. A key part of this graphical analysis is about looking at the impact of service improvements and checking that any 'bursts' in patronage follow the service improvement, rather than the other way around.
- Second, we used 'seasonally differenced' data: both patronage and service trips are expressed in terms of growth between a given quarter and the same quarter in the previous year. This means that the model only attributes patronage growth to a service change based on the extent to which patronage growth 'jumps' within a year of the service change occurring.
- Third, we looked at changes in service trips at a route level, rather than across the whole city. While growth in service trips across a whole city might increase gradually over time, growth in service trips on a particular route is often very 'lumpy'; furthermore, the patronage growth on those routes can be contrasted with 'control routes' where there were no service improvements. The 'lumpiness' and the presence of 'control routes' makes it easier for a panel data model to discern genuine patronage responses to service improvements.

2.5 Econometric method

The two most distinguishing features of the econometric method adopted for this research project are that we employed a seasonal difference model and we analysed patronage data that had been disaggregated by corridor. These features are discussed in sections 2.5.1 and 2.5.2.

2.5.1 The seasonal difference model

We reviewed the international literature relating to econometric modelling of public transport patronage and concluded that our preferred modelling approach was a seasonally differenced model. See *appendix A* for more discussion.

In a seasonal difference model, the dependent variable is the % change[1] in patronage between a given quarter (eg 2007-Q1) and the same quarter in the previous year (eg 2006-Q1). The explanatory variables are the % change in real petrol prices, fares, service levels, etc between the same two quarters.

$$\Delta_{SD}P_t = \propto\ + \beta\Delta_{SD}X_t + e_t \quad \text{(Equation 2.1)}$$

[1] Strictly speaking, seasonal difference models are regressions using the seasonal differences of log-transformed levels of patronage, real petrol prices, real fares, service levels etc. However, the seasonal difference of a log-transformed variable is approximately the same as a % change in that variable.

where: $\Delta_{SD}P_t \approx$ % change in patronage between quarter t and quarter t-4

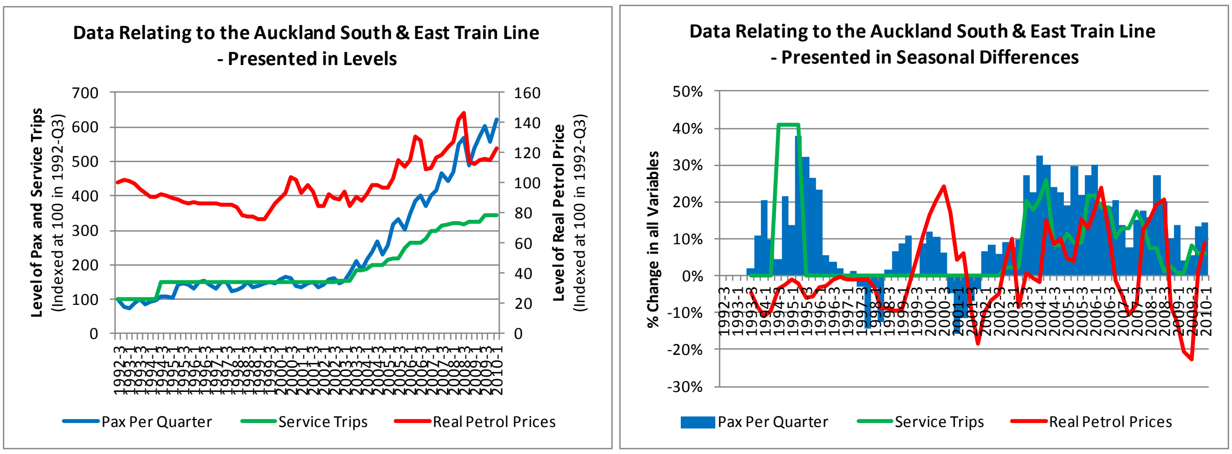
$\Delta_{SD}X_t \approx$ % change in explanatory variable/s between quarter t and quarter t-4

e_t = error term

The benefits of seasonal differences models have been described elsewhere by Kennedy and Wallis (2007) and those benefits are summarised below:

- Compared with more commonly employed models like simple regression models or partial adjustment models, seasonal difference models have a lower risk of producing 'spurious' or invalid results. Econometric theory implies that, as a rule, regression models of variables through time will only provide trustworthy estimates if the data shows a tendency to revert to a mean (ie 'stationarity'). As the example in figure 2.1 demonstrates, this mean-reverting property is clearly lacking in the type of data employed in more common models, but it does become plausible after seasonal differencing.

Figure 2.1 Illustration of how seasonal differencing is required for 'stationarity'



- Seasonally differenced models simplify the analytical process because the process of calculating percentage change between, say, 2007-Q1 and 2006-Q1, filters away any seasonal patterns from the data in a clean and straightforward manner.
- Seasonal difference models are less likely to be affected by multicollinearity because, although explanatory variables may be highly correlated when expressed in levels, the % changes in those variables are usually less strongly correlated.
- Seasonal difference models impose less restrictive assumptions about the impact of explanatory variables on the dependent variables. In contrast, partial adjustment models assume that explanatory variables have an impact that declines exponentially through time and, furthermore, that the ratio of long-run to short-run impacts is the same for all explanatory variables.

One of the disadvantages of a seasonal difference model is that we found the process of seasonal differencing induces autocorrelation in the dependent variable; for example the growth between 2006-Q1 and 2007-Q1 is going to overlap a lot with the growth between 2006-Q2 and 2007-Q2 because both periods share three of the same quarters. To address this, we developed a generalised least squares model and found that this mitigated most autocorrelation problems.

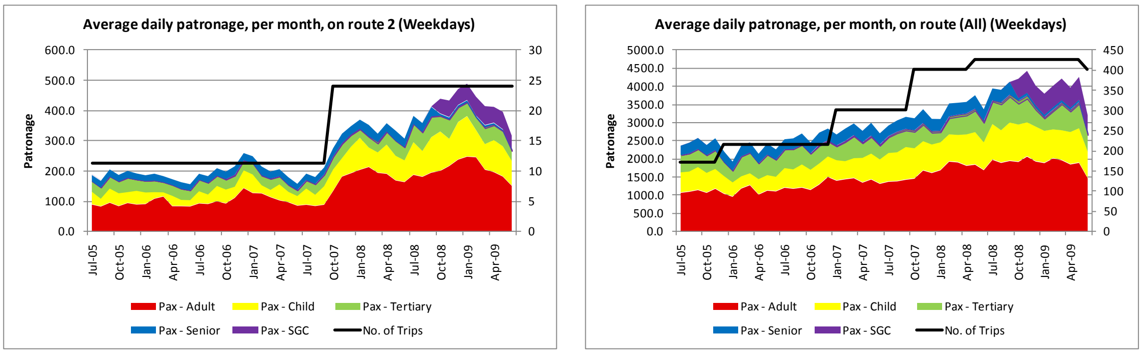
2.5.2 Corridor-level analysis

In the literature review in appendix A, we note that most econometric analyses of public transport patronage use regression models to explain patronage at the level of a city, urban area or network.

However, we see considerable benefits from analysing patronage data that is disaggregated down to the level of the corridor (ie bus route, bus corridor or train-line). This then allows us to use a panel data approach. A panel data model simultaneously examines 1) how patronage growth changes on a given route through time and 2) contrasts routes where there were route-specific changes against 'control routes' where there were no changes.

The main advantage of the corridor-level analysis envisaged by this report is that it enables us to control for the impact of factors that are specific to a particular route or line. For example, consider a service frequency change that only occurred on the Tauranga bus route 3 in October 2007. If we look at the individual data for route 3 (see figure 2.2) we can see a clear impact on patronage on that route. However, if we aggregate route 3 with all the other Tauranga bus routes then the impact of the service improvement is 'muffled' amongst the aggregate data.

Figure 2.2 Illustration of benefit of panel data analysis



The seasonal difference model shown was therefore modified, as shown below, to accommodate a panel data approach:

$$\Delta_{SD}P_{ti} = \propto_i + \beta\Delta_{SD}X_t + \gamma_i\Delta_{SD}Z_{ti} + e_{ti} \qquad \text{(Equation 2.2)}$$

where: $\propto_i =$ time trend on each route/corridor/line i

$\Delta_{SD}P_{ti} \approx$ % change in patronage between quarter t and quarter t-4 for route/corridor/line i

$\Delta_{SD}X_t \approx$ % change in generic explanatory variable/s (petrol prices, retail sales, etc) between quarter t and quarter t-4

$\Delta_{SD}Z_{ti} \approx$ % change in corridor-specific explanatory variable/s (service improvements, line maintenance, etc) between quarter t and quarter t-4 for route/corridor/line i

$e_{ti} =$ error term

We acknowledge in appendix A that there are a number of recent studies that apply a panel data approach to public transport analysis. However, to our knowledge, only one of those studies disaggregated by corridor and none of those studies incorporated corridor-specific events and factors in the manner demonstrated by this report.

2.6 Model building process

The basic model building process started with the development of a general model. This general model was designed to encompass a wide range of explanatory variables and key events, and was influenced by insights from graphical analysis (section 2.3) and data analysis (section 2.4).

The general model was then examined and tested. We examined and assessed the contribution of the explanatory variables, removing those that looked suspect or indeterminate and whittled the model down to its core components.

The decision to keep or remove an explanatory variable had to weigh up the risks of omitting an important variable against the risks of including an explanatory variable that had a spurious or coincidental relationship to patronage growth.

Inevitably, a certain amount of judgement was involved in weighing up these risks, and we drew on our experience with both public transport analysis and statistical analysis. That said, the general approach was to remove explanatory variables if they had an implausible sign or were close to zero. This meant that some explanatory variables were retained as long as they produced plausible coefficients (even if they were statistically significant). This general approach reflected our judgement that some of these explanatory variables could have quite profound impacts on corridor-specific patronage growth and we leant towards keeping them in rather than risk bias due to omitted variable/s.

The model building process overlapped with the diagnostic analysis stage (see section 2.7). If the diagnostic analysis stage shows that there are problems with the residuals then this suggests that the model is not fitting the data to a reasonable degree, and the model may need to be modified accordingly.

2.7 Diagnostic analysis stage

The preferred model will still not be statistically valid unless the residuals of the model meet certain criteria. During the diagnostic analysis stage we examined the residuals to the model to see if they met certain statistical criteria. We used a number of statistical tools to look for evidence of autocorrelation and non-normality.

These statistical tools do more than just ensure statistical validity. They also, more generally, provide guidance as to whether the preferred model is adequately explaining patronage growth. If any of the models had failed to adequately control for an important factor then it would most likely have shown up as an outlier, non-normality or autocorrelation.

3 Summary of key findings

3.1 Introduction

This chapter presents the findings from all the cities and transport modes studied together, so we could ascertain common themes regarding fare elasticities, petrol price elasticities, economic impacts and service elasticities.

3.2 Fare elasticities

Table 3.1 shows the real fare elasticities estimated across all the cities and modes studied. We note that real fare elasticities reflect the impact of an (inflation-adjusted) fare increase. For example, if nominal fares go up by 12% and inflation is 2% then the real fare increase is 10%.

Real fare elasticities provide insights into the amount of revenue that could be obtained from a fare increase. For example:

- A real fare elasticity of -0.9 implies that a 10% increase in the real fare produces a loss of patronage of 9%. Therefore, real fares go up by 10% but patronage goes down by 9% and total revenue only goes up by 1%.
- A real fare elasticity of -0.3 implies that a 10% in the real fare produces a much smaller loss of patronage of only 3%. Therefore, real fares go up by 10% but total revenue goes up by 7%.

Table 3.1 Real fare elasticities

City	Mode	Weekday peak	Weekday offpeak		Weekend
			Interpeak	Evening	
Auckland	Rail	-0.9***	Removed due to implausible and volatile sign	-0.1	Removed due to implausible sign
Auckland	Bus	-0.3***	-0.2***	-0.1	-0.4***
Wellington	Rail	-0.7‘ [2]			
Wellington	Bus (2006)	Removed due to implausible sign	-0.4***		-0.1
	Bus (2008)	-0.7*	Removed due to implausible sign		Removed due to implausible sign
Hamilton	Bus	Removed due to implausible sign	Removed due to implausible sign		-1.2***

Note for symbols of statistical significance: *** → 0.1%, ** → 1%, * → 5%, ‘ →10%

The findings from table 3.1 are variable but a few common themes emerge:

- In Auckland, peak-time rail fare elasticities (-0.9) are higher than peak-time bus fare elasticities (-0.3). This finding has noteworthy implications for future public transport investment because it suggests that higher rates of fare recovery on the Auckland rail system may be difficult to achieve.

[2] For the purposes of comparison with other cities and modes, we have assumed that monthly/quarterly tickets for rail passengers are reflective of the bulk of peak-time patronage.

- Rail fare elasticities are lower during the offpeak, whereas bus fare elasticities are reasonably consistent throughout all periods; this may be because bus users generally have fewer alternative modes of transport and are therefore more of a 'captive' market.

3.3 Petrol price impacts

Table 3.2 shows the estimated impacts of petrol price changes, segregated into a general petrol price cross elasticity and a dummy variable for the 'threshold effect' triggered by the temporary crossing of the $2.00 threshold in 2008:

- The petrol price cross-elasticities show the impact of general movements in real (ie inflation-adjusted) petrol prices. For example, an elasticity of +0.1 implies that a 10% increase in real petrol prices induces a 1% increase in public transport patronage.
- The petrol price thresholds show the 'one-off' impact of crossing the '$2.00' mark. For example, a threshold estimate of 5% implies that public transport patronage increased by about 5% when this threshold was met and that it dropped back about 5% when patronage fell back below that mark.

Table 3.2 Petrol price impacts

City	Mode	Type of impact	Weekday peak	Weekday offpeak		Weekend
				Interpeak	Evening	
Auckland	Rail	Real petrol price cross-elasticity	+0.1	Removed due to implausible sign	+0.5*	+0.5
		$2.00 petrol price threshold dummy	Removed due to implausible sign	Removed due to implausible sign	17%	Coefficient implausibly high
Auckland	Bus	Real petrol price cross-elasticity	+0.0	+0.0	Removed due to implausible sign	Removed due to implausible sign
		$2.00 petrol price threshold dummy	+3%	Removed due to implausible sign	+5%	Removed due to implausible sign
Wellington	Rail	Real petrol price cross-elasticity	+0.1[3]			
		$2.00 petrol price threshold dummy	Omitted due to interaction with real petrol price			
Wellington	Bus	Real petrol price cross-elasticity	+0.1*	+0.1***		+0.1
		$2.00 petrol price threshold dummy	+4%	Removed due to implausible sign		+10%*
Hamilton	Bus	Real petrol price cross-elasticity	+0.2'	Removed due to implausible sign		Removed due to implausible sign
		$2.00 petrol price threshold dummy	+6%'	+8% ***		+2%
Tauranga	Bus	Real petrol price cross-elasticity	+0.3*			Dropped
		$2.00 petrol price threshold dummy	+8%			+41%

Note for symbols of statistical significance: *** → 0.1%, ** → 1%, * → 5%, ' →10%

[3] For the purposes of comparison with other cities and modes, we have assumed that monthly/quarterly ticket passengers are reflective of the bulk of peak-time patrons.

Key findings from table 3.2 are as follows:

- After controlling for the 'threshold effects', petrol price elasticities in Auckland and Wellington are generally quite low – in the range of 0.0 to +0.2.
- However, the petrol price elasticities for peak-time patrons in the smaller cities of Hamilton and Tauranga are estimated to be about +0.2 to +0.3; this suggests that patrons in these smaller cities are more responsive to petrol price changes.
- The 'threshold effects' mostly show up as positive and are quite often also statistically significant; this suggests that the impacts of petrol prices on public transport usage are often non-linear and heavily influenced by psychological 'trigger points'[4].

3.4 Economic cross-elasticities

An economic cross-elasticity shows the impact of the change in an explanatory variable on public transport patronage. For example, an employment cross-elasticity of +0.8 implies that a 1.0% growth in employment generates a 0.8% increase in public transport patronage.

The cross-elasticities produced in regard to economic variables like real retail sales or employment need to be interpreted with some caution for the following reasons:

- Real retail sales and employment exhibit trends through time that are steady and long-lasting; this lack of volatility makes the task of discerning their relationship with public transport patronage statistically difficult.
- Economic variables like petrol prices, real retail sales and employment are generally strongly correlated, so isolating and identifying their individual contributions is challenging.

With those caveats in mind, table 3.3 shows the estimated associations between real retail sales growth and patronage growth. In general, in seems difficult to draw any definitive conclusions from the data.

Table 3.3 Real retail sales cross-elasticities

City	Mode	Weekday peak	Weekday offpeak		Weekend
			Interpeak	Evening	
Auckland	Rail	-0.15	-0.7	+2.3***	+0.2
Auckland	Bus	-0.2**	-0.3***	-0.1	-0.2 *
Wellington	Rail	Omitted due to interaction between real retail sales and employment			
Wellington	Bus	0.0	+0.1‘		+0.05
Hamilton	Bus	0.0	-0.9***		+0.8‘
Tauranga	Bus	+0.1			+1.5‘

Note for symbols of statistical significance: *** → 0.1%, ** → 1%, * → 5%, ‘ →10%

Table 3.4 shows the estimated associations between employment growth and patronage growth. There is a tendency for strong positive associations between employment and peak-time patronage. The associations between employment and offpeak patronage are less definitive, but seem to be generally negative.

[4] We also note that these dummy variables plausibly encompass a wide range of factors and events occurring around this time and should not be assumed to represent an inevitable response to future crossings of these thresholds.

Table 3.4 Employment cross-elasticities

City	Mode	Weekday peak	Weekday offpeak		Weekend
			Interpeak	Evening	
Auckland	Rail	+1.2*	-1.2*	-0.4	-1.2
Auckland	Bus	+0.8***	-0.1	0.5**	+0.1
Wellington	Rail	+1.3‘			
Wellington	Bus	+0.4	-0.2		-0.5‘
Hamilton	Bus	+0.2	+0.2		+0.4
Tauranga	Bus	+1.2***			0.9

Note for symbols of statistical significance: *** → 0.1%, ** → 1%, * → 5%, ‘ →10%

3.5 Service elasticities

A service elasticity shows the impact of additional service trips on public transport patronage. Here are some examples of how service elasticities should be interpreted:

- Suppose a network has a service elasticity of +0.3 for doubling of frequency. This implies that if frequency is doubled (ie a 100% increase) then this will generate a 30% increase in patronage.
- Suppose a network has a service elasticity of +0.5 for additional evening services and that the number of evening services is increased, resulting in a 10% increase in the total number of service trips across the whole day. The service elasticity of +0.5 would imply a 5% increase in patronage as a consequence.

The following tables 3.5 to 3.8 present service elasticities drawn from all the cities and modes studied.

The general practice in transport planning is to attempt to identify generalised service elasticities that can be applied to all situations. Therefore, where possible, we draw out themes from these tables and recommend plausible service elasticities for application elsewhere.

However, we note that we see the approach of identifying and applying generalised service elasticities to all situations as unnecessarily limiting. In our opinion, the impact of public transport service improvements varies considerably from situation to situation; therefore, we recommend ‘post-evaluating’ public service investments on a regular basis and using the feedback from the ‘post-evaluation’ to guide future decisions about public transport investment.

With that caveat in mind, table 3.5 presents peak period service elasticities. The key findings are:

- a service elasticity of about +0.3 seems plausible for express or direct bus services during peak time
- the service elasticities for extending peak-time hours of operation for bus services varies from 0.0 to +1.7, suggesting that the benefits depend on the situation
- the service elasticities for peak-time rail services are difficult to ascertain at this time, due to difficulties with Wellington rail patronage and service data, and challenges in identifying the role of crowding on the Auckland rail service; further research is recommended as more data becomes available.

Table 3.5 Peak-period service elasticities

City	Mode	Type of service improvement	Service elasticity
Auckland	Rail	On the southern and eastern lines, morning hours were extended from 5.40am to 5.00am, and frequencies during the morning and afternoon peaks were increased from every 15 min to an almost continuous service[5]. On the western line, morning hours were extended from 6.00am to 5.30am, and frequencies during the morning and afternoon peaks were increased from every 30 min to every 20 min.	**+0.15 on average in short-run** **+0.7 on average if estimated lagged impacts are included**
Auckland	Bus	Unspecified collection of peak-time service improvements.	Range from -0.3 to +0.9 **+0.3 on average**
Wellington	Rail	Four extra commuting services per working day were added on both the Hutt and Paraparaumu lines.	Not calculable due to insufficient data on service levels
Hamilton	Bus	Introduction of 'direct' services on certain routes. These services were only provided in peak times and only went to limited stops.	Range from 0.0 to +0.4 **+0.3 on average**
Hamilton	Bus	Hours of operation in the morning were improved; the first service moved from 7am to 6.30am.	**No discernible effect**
Tauranga	Bus	Introduction of express service on a particular route.	+0.25 within a yr +0.4 within 2 yrs
Tauranga	Bus	Hours of operation were extended; additional services on one route were added at 6.05am, 6.40am and 7.15pm.	+1.7

Table 3.6 presents interpeak service elasticities. The findings are reasonably consistent:

- For bus services, a service elasticity of around +0.4 to +0.5 seems plausible for most frequency improvements.
- For train services, a service elasticity of +0.3 to +0.4 seems appropriate.
- The high service elasticities for improving the regularity of the Hamilton bus timetables indicate that other cities should consider the merits of making similar improvements.

[5] Headway ranged between 5 minutes and 15 minutes.

Table 3.6 Interpeak period service elasticities

City	Mode	Type of service improvement	Service elasticity
Auckland	Rail	On the southern and eastern lines, interpeak frequency improved from every 30 min to every 15 min. One the western line, interpeak frequency was increased from hourly to approximately every 25 min.	**+0.3 on average in short-run** **+0.4 on average if estimated lagged impacts are included**
Auckland	Bus	Unspecified collection of interpeak service improvements.	Range from -0.2 to +1.4, **+0.4 on average**
Hamilton	Bus	Improvement to offpeak timetables including a more regular timetable and doubling of offpeak frequency from hourly to half-hourly.	Range from +0.2 to +0.8 **+0.5 on average**[6]
Hamilton	Bus	Services added to address gaps during the lunch period and to provide more regular services. Services were also added to make evening services more regular.	**+0.6 on average**
Tauranga	Bus	Doubling of offpeak frequency from hourly to half-hourly.	Range from +0.2 to +0.5 **+0.4 on average**[7]

Table 3.7 presents evening service elasticities. As a general rule, an evening service elasticity of +0.4 to +0.5 seems plausible and represents the average effect both on bus and rail. However, there is considerable volatility around this average and, furthermore, there is a high likelihood of diminishing returns. For example, the extension of evening hours on the Hamilton bus network from 6.00pm to 7.30pm had a big payoff in terms of patronage (service elasticity of +0.8), but there were no further patronage benefits when hours were extended to about 10pm.

Table 3.7 Evening period service elasticities

City	Mode	Type of service improvement	Service elasticity
Auckland	Rail	On the southern and eastern lines, evening hours initially ended at 6.30pm while they ended at 7.00pm on the western line. These were extended, via gradual improvements, to about 11.40pm on both lines.	**+0.4 on average**
Auckland	Bus	Unspecified collection of evening period service improvements.	Range from 0.0 to +1.6 +0.6 on average
Hamilton	Bus	Hours of operation were extended; the last service was extended from about 6.00pm to about 7.30pm.	**+0.8 on average**
Hamilton	Bus	Hours of operation were extended; the last service was extended from about 7.30pm to about 10pm.	No discernible effect

Table 3.8 shows that the impact of weekend service improvements varies considerably depending on the situation:

- A service elasticity of +0.4 for weekend service improvements seems plausible for rail.
- The service elasticities for bus service improvements are much more volatile, ranging from very low averages for Auckland bus (+0.2) to quite high impacts for Hamilton bus (+1.2).

[6] We note that the elasticity could be higher, perhaps about +0.7, if 'network effect' benefits for peak and weekend patronage are taken into account.

[7] Again, we note that the elasticity could be higher if 'network effect' benefits for weekend patronage are taken into account.

Table 3.8 Weekend service elasticities

City	Mode	Type of service improvement	Service elasticity
Auckland	Rail	On the southern and eastern lines, the Saturday service went from hourly to half-hourly. In addition, the final service was extended from 6.15pm to 11.40pm. On the western line, the Saturday service remained hourly but the starting hours were extended from 7.15am to 6.53am and the final service from 6.15pm to 11.53pm.	**+0.3 on average**
Auckland	Rail	Sunday services were introduced on both the southern and eastern lines and the western line.	**+0.5 on average**
Auckland	Bus	Unspecified collection of weekend service improvements.	Range from -3.9 to +1.3 +0.3 on average
Hamilton	Bus	Sunday services were introduced based on the same timetable as the pre-existing Saturday services.	**+0.9 on average, within a yr** **+1.2 on average, within 2 yrs**
Hamilton	Bus	Services added to address gaps during the lunch period and to provide more regular services.	**+2.2 on average**
Hamilton	Bus	Hours of operation on Saturdays were improved; the first service went from about 8am to 7am and the last service was extended from about 6pm to 7pm	No discernible effect
Tauranga	Bus	Hours of operation on Saturdays were improved; on a number of routes there were additional services before 8.00am and after 5.15pm	Range from +0.7 to +1.6 **+1.0 on average**

3.6 Confidence in findings

As a general rule, we have more confidence in the Auckland-based analyses because we had access to more details regarding explanatory variables.The Auckland datasets also use a longer period, as demonstrated in table 3.9.

Table 3.9 Periods for patronage datasets

City	Mode	Period	Number of years	Number of quarters	Number of quarters after seasonal differencing
Auckland	Rail	2001–Q3 to 2010–Q1[8]	8.5	34	30
Auckland	Bus	2002–Q2 to 2010–Q1[9]	7.75	31	27
Wellington	Rail	2005–Q3 to 2009–Q4	4.25	17	13
Wellington	Bus	2005–Q2 to 2009–Q4	4.5	18	14
Hamilton	Bus	2004–Q3 to 2010–Q1	5.5	22	18
Tauranga	Bus	2005–Q3 to 2009–Q2	3.75	15	11

[8] The data for Auckland rail actually goes back to 1992–Q2. However, the time period shown for Auckland rail data represents the period for which data was available that was disaggregated by weekday peak, weekday interpeak, weekday evening and weekend. Our econometric modelling focused on this later period.

[9] The data for Auckland bus actually goes back until 2001–Q2. But the first four quarters of data were regarded as unreliable and therefore omitted from econometric modelling.

We have relatively high confidence in most of the service elasticities because the panel data method adopted here compares patronage growth on routes/corridors with service improvements against ‘control’ routes/corridors where no such improvements occurred. This is a relatively robust method for estimating the impacts on patronage.

We have relatively moderate confidence in petrol price cross-elasticities and thresholds. Petrol prices fluctuated a lot throughout the periods covered and this variability allowed us to obtain reasonably accurate estimates of their relationship to public transport patronage. Furthermore, the general themes and findings were consistent across the cities.

We have relatively moderate to low confidence in real fare elasticities. Generally, real fares change in quite pronounced ‘jumps’ which makes discerning their impact easier. However, in a number of cases in our research, disentangling the impact of these fare increases was challenging because they were accompanied by a number of other events or variables that occurred at the same time.

We have relatively low confidence in the economic cross-elasticities for the reasons discussed in section 3.4. That said, further research that incorporated a market segmentation approach (see section 11.2) would provide more accurate estimates and would mitigate some of these concerns.

We have low confidence in the Wellington rail-based analyses due to the short length of the data, unexplained anomalies in the particular dataset employed, and insufficient information on explanatory factors. There is evidence that the econometric model for the Wellington rail network was not statistically robust, and we suspect this is due to these data problems.

We also have some doubts regarding weekend-based findings. Weekend-based patronage exhibits a lot of volatility and weekend patronage growth rates can vary a lot depending on the timing of holidays, events and weather. This volatility and variability makes econometric modelling less accurate. Improved data collection and refined modelling methods should mitigate these problems in the future.

4 Analysis of growth on the Auckland rail system

This chapter presents our analyses of patronage growth on the Auckland rail system.

4.1 Context

The Auckland rail system consists of three lines: the western line, the southern line and the eastern line. These lines all feed into central Auckland and, since the completion of the Britomart development, have fed directly into the Auckland central business district (CBD).

There have been considerable enhancements to the Auckland rail system over the 18 years from 1992–Q2 to 2010–Q1, with the most prominent being the Britomart development mentioned above: this involved the creation of a large-scale train station in the Auckland CBD and the reorganisation of the train lines so that commuters had a direct pathway into the CBD. The Britomart development was completed in July 2003 and, along with associated improvements and enhancements significantly increased the convenience and appeal of commuting by rail; it appears to have been a significant contributor to patronage growth.

4.2 Analytical issues

We were provided with data on aggregate patronage from 1992–Q2 to 2010–Q1. Unfortunately, this patronage data was not segregated by time period (ie weekday peak, weekday interpeak, weekday evening and weekend). However, data from 2002–Q3 to 2010–Q1 was provided in a form that enabled us to distinguish it by time period.

There has been a prolonged period of rapid growth in patronage on the Auckland rail system since mid-2003. This period of growth has coincided with a number of possible causal factors: the completion of the Britomart development, increased train services and rising petrol prices.

A key challenge in this project has been disentangling and identifying the contribution of each of those factors. However, the econometric methodology developed as part of this research report has assisted in 'making sense' of what has been going on. In particular, the panel data approach has allowed us to isolate and estimate impacts that differ from line to line (eg the impact of Britomart, service improvements, line maintenance). Furthermore, disaggregating the data by time period (ie weekday peak, etc) enabled us to more clearly isolate and estimate the impacts of service improvements that were specific to certain times.

4.3 Analysis of historic growth[10]

Initially, we analysed growth over the 18-year period from 1992–Q2 to 2010–Q1. Figure 4.1 shows patronage growth between 1992 and 2010 on the Auckland rail network.

[10] In regard to graphical interpretation of the graphs provided, we advise the reader to note the distinction between permanent and temporary 'jumps' or 'falls' in patronage levels. A permanent change shows up on a graph as four quarters of unusually high or negative growth. In contrast, a temporary change shows up as a one-off spurt or loss of patronage and is reversed four quarters later.

Figure 4.1 Patronage growth on the Auckland rail network since 1992

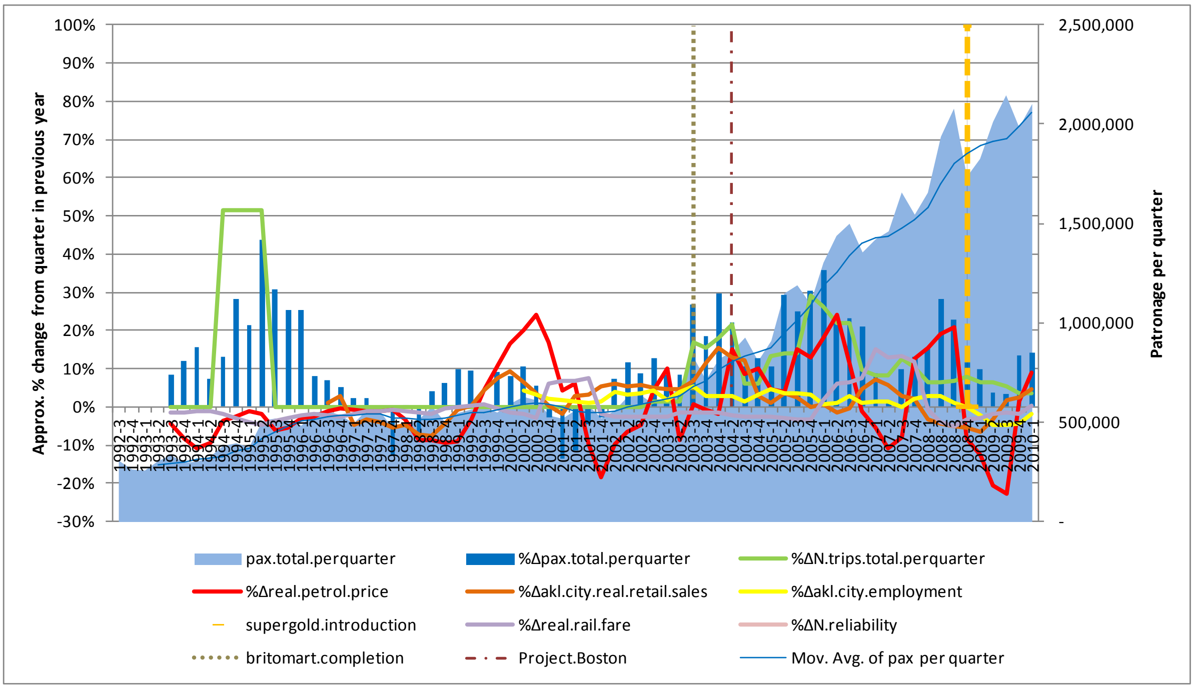


Figure 4.1 shows there were roughly two periods of unusually high patronage growth: the first period was at the end of 1994 and lasted until mid-1996; and the second period was in mid-2003 and appears to have continued through to early 2010.

- The first period of growth can be plausibly connected with service enhancements at the time. There was a considerable increase in the number of services in July 1994 and this appears to have an impact, albeit delayed to some extent, on patronage. That said, we have been informed that the replacement of existing carriages with more improved diesel multiple unit (DMU) carriages in July 1993 may have also played a role.
- The causes of the second period of growth are more difficult to discern: this period was associated with the completion of the Britomart development, increases in service frequency and hours of operation, rising petrol prices, a number of fare increases and economic recession.

The Steering Group for this research project established that there was considerable interest in understanding and disentangling the contribution of various factors to patronage growth over the last seven years of that period (ie 2002–Q3 to 2010–Q1; therefore, priority was given to this task.

Our conclusions regarding the contribution of those factors are as follows:

1. Britomart has been the key influence on patronage growth:
   a. both immediately, and
   b. over the seven-year period following introduction.
2. Improvements to service frequency and hours of operation have also contributed quite discernibly to patronage growth.
3. Peak-time fare elasticities are very high: -0.9.
4. Petrol price elasticities are generally low (+0.1/+0.2 on average).

Point 1 above is worth elaboration: our econometric analysis showed that even after controlling for various explanatory variables (increased services, increased hours of operation, rising petrol prices and fare increases) there were 'other factors' stimulating patronage growth:

- Table 4.1 shows that the completion of Britomart contributed to an immediate jump in offpeak patronage. The completion of Britomart contributed to a jump in interpeak weekday patronage of around 30%–40% on both lines. On the southern and eastern lines, there were also immediate increases in evening and weekend patronage.
- Table 4.2 shows time trends before and after Britomart. These time trends estimate growth after controlling for explanatory variables (including the immediate impacts of Britomart as estimated in table B.1):
  - On the southern and eastern lines, growth rates increased about 5% per annum during most periods and by more than 10% per annum during the evening.
  - On the western line, growth had already been high prior to Britomart and these growth rates continued at much the same rate post-Britomart.

Table 4.1 Immediate impact of Britomart development

	Southern and eastern lines				Western line			
Dummy variable	**Peak**	**Interpeak**	**Evening**	**Weekend**	**Peak**	**Interpeak**	**Evening**	**Weekend**
Spike in patronage in year after Britomart	Removed due to implausible sign	37%***	17%*	11%	Removed due to implausible sign	28%***	Removed due to implausible sign	Removed due to implausible sign

Note for symbols of statistical significance: *** → 0.1%, ** → 1%, * → 5%, ' →10%

Table 4.2 Long-term impacts of Britomart development and other factors

	Southern and eastern lines				Western line			
Time trends (growth rates per annum)	**Peak**	**Interpeak**	**Evening**	**Weekend**	**Peak**	**Interpeak**	**Evening**	**Weekend**
Pre-Britomart (2002-Q3 to 2003-Q1)	5%	8%	-1%	12%	5%	16%**	12%	18%'
Post-Britomart (2003-Q3 to 2010-Q1)	9%***	15%***	10%**	18 ***	5%*	10%***	8%*	14%***

Note for symbols of statistical significance: *** → 0.1%, ** → 1%, * → 5%, ' →10%

It seems reasonable to conclude from tables 4.1 and 4.2 (and from the graphical analysis that follows in appendix B3) that Britomart itself contributed significantly to patronage growth on the southern and eastern lines.

However, the high time-trend growth observed on the western line prior to Britomart suggests there were a number of other factors at play that we have been unable to control for. One possible explanation for this is that a collection of initiatives, such as ongoing station upgrades and additional carriages to reduce crowding, may have also contributed to this period of very high patronage growth.

4.4 Summary of findings

This section summarises some of the key findings from the econometric analysis of the Auckland rail system. For more detail about these findings see appendix B.

Table 4.3 shows the impact of key economic variables on patronage: weekday peak, weekday off-peak and weekend.

Table 4.3 Elasticity estimates for key economic variables

Economic variables	Weekday			Weekend
	Peak	Interpeak	Evening	
Real rail fare elasticity	-0.9 ***	Removed due to implausible and volatile sign	-0.1	Removed due to implausible sign
Real petrol price cross-elasticity	+0.1	Removed due to implausible sign	+0.5*	+0.5
$2.00 petrol price threshold dummy	Removed due to implausible sign	Removed due to implausible sign	17%	Coefficient implausibly high
Real retail sales cross-elasticity	-0.2	-0.7	+2.3***	+0.2
Employment cross-elasticity	+1.2*	-1.2*	-0.4	-1.2
Introduction of SuperGold Card dummy	Not applicable	Removed due to implausible sign	Removed due to implausible sign	Coefficient implausibly high
Increase in tertiary student discount	+3%	+8%	+21%'	Removed due to implausible sign

Note for symbols of statistical significance: *** → 0.1%, ** → 1%, * → 5%, ‘ →10%

The key findings from table 4.3 are:

- The fare elasticity is surprisingly high for peak-time patronage: -0.9.
- The fare elasticity is small or indiscernible for the other periods.
- The low petrol price elasticities indicate that general petrol price fluctuations have only a modest influence on peak weekday or interpeak weekday patronage growth.
- A comparison of petrol price cross-elasticities and $2.00 threshold effects indicates that weekend and evening patronage is relatively more responsive to petrol prices than weekday peak or interpeak patronage.
- The relationship between real retail sales and patronage growth is curious. It appears that economic growth dampens interpeak patronage and stimulates evening patronage.
- The employment elasticity of +1.2 for peak weekday patronage is plausible but we emphasise that there is a large confidence error around this estimate. The negative relationship between employment and offpeak weekday patronage is interesting.

Table 4.4 shows the impact of service improvements on patronage: weekday peak, weekday off-peak and weekend.

Table 4.4 Elasticity estimates for service timetable improvements

Service elasticities for service timetable improvements		Weekday			Weekend
		Peak	Interpeak	Evening	
Weekday	First year	+0.2	+0.3***	+0.4***	
	Subsequent year	+0.6***	+0.1	Removed due to implausible sign	
Weekend	Increased frequency on Saturday timetables				+0.3 '
	Introduction of Sunday services				+0.5
	Increased frequency on Sunday timetables				Removed due to implausible sign

Note for symbols of statistical significance: *** → 0.1%, ** → 1%, * → 5%, ‘ →10%

The key findings from table 4.4 are:

- Additional offpeak weekday services (ie interpeak and evening) have an immediate impact on patronage and the service elasticities are about +0.4. We believe that most of this is due to perceived benefits of increased frequency and/or extended hours of operation.
- Additional peak weekday services appear to have a more complex relationship with patronage growth. They appear to have quite a pronounced impact on patronage growth, with an overall service elasticity of up to +0.8, but only if we allow the model to assume that some of the impact is delayed. For a number of reasons, as discussed in section 4.5, we have some doubts about the reliability of these estimates.
- Additional weekend services also have an impact on patronage, but we were surprised to find that improvements to the Saturday timetable seemed to produce more benefits (per additional trip) than the introduction or enhancement of Sunday timetables.

4.5 Confidence in findings

We looked at two different datasets. The first dataset provided patronage and service data from July 1992 to March 2010 but did not segregate by peak, interpeak, evening or weekend. The second dataset only provided data from July 2001 to March 2010 but it has been given more weight because it disaggregated patronage and service trips by time of day. This disaggregation enabled more accurate estimation of the impacts of service improvements and enabled us to better disentangle the impacts of Britomart from associated service improvements.

We have strong confidence in the offpeak (ie weekday interpeak, weekday evening, weekend) service elasticities, as shown in table 4.4. The graphs shown in appendix B (see sections B3.3 to B3.5) show that service changes during these periods had a clear and immediate impact on patronage growth.

We have relatively less confidence in the peak-time service elasticities shown in table 4.4. There are a number of reasons for this:

- The graphs shown in appendix B (see section B3.2) do not show a clear relationship between peak-time service improvements and peak-time patronage growth
- The bulk of the patronage response to peak-time service improvements only shows up when we allow the model to assume that the patronage impacts are delayed. This is possible: additional peak-time services encourage peak patronage via reduced crowding levels, improved reliability and reduced disruptions; and these factors have a more long-term influence on peak-time patronage. But it is also quite feasible that some other factor encouraged a burst in patronage on both lines more than a year after the service improvements.
- The relationship between peak-time service improvements and peak-time patronage is complex. In particular, we expect that the direction of causation often goes in both directions during peak times. Additional peak-time services reduce crowding, improve reliability, and reduce disruptions and hence encourage higher patronage growth. However, higher patronage growth also prompts transport operators and providers to increase the number of peak-time services.

We generally have moderate confidence in the elasticities produced in table 4.3 for the impact of economic variables. The statistical model employed relates patronage growth over time to changes in these economic variables over time. With such a short period (nine years) there is a risk that the model incorrectly associates patronage trends with coincidental movements in the economic variables.

We have more confidence in the petrol price cross-elasticities because they were shown to be around the +0.1 to +0.2 mark using both the preferred second dataset and also the first dataset going back to 1992.

In general, we have more confidence in the weekday estimates shown in tables 4.1 to 4.4, and less confidence in the corresponding weekend estimates. There was considerable volatility in weekend patronage growth and we suspect that a lot of that volatility was due to factors that we were unable to control for, most notably sporting events and concerts. Weekend patronage on the western line would have been further affected by various engineering upgrades following the completion of Project Boston where the subsequent use of replacement buses may have discouraged patronage.

4.6 Recommendations and policy implications

The fare elasticity estimates indicate that the options for raising revenue in the future from rail fare increases may be somewhat constrained. A peak-time rail fare elasticity of -0.9 implies that a 10% increase in peak-time rail fares increase induces a loss of patronage of 9% and (therefore) an increase in revenue of only 1%. Therefore, the potential for using rail increases to recover the cost of investments in the Auckland rail network may not be as great as one might otherwise have anticipated.

We emphasise that the peak-time fare elasticity estimate of -0.9 is only an estimate so it should not be taken as the 'gospel' truth; alternative modelling methods and/or a longer time series may produce different estimates. But we do recommend that transport planners carefully monitor the impact of ongoing rail fare increases in Auckland to ascertain whether high elasticities are a potential problem.

We also recommend that transport planners consider further econometric research that segments the market by ticket type (see section 4.8.2) and zone (see section 4.8.3). Such research can produce fare elasticities that are segmented by demographics (child, adult, senior) and number of zones travelled. This research would allow transport planners to maximise the revenue from fare increases by imposing the fare increases disproportionately on the market segments that are most likely to absorb the fare increase.[11]

The extensive database of patronage and service data collected by Auckland Transport is impressive given the data limitations of the existing ticketing system. These data limitations include:

- Data on sales of ticket types (ie number zones, child/adult/tertiary/senior, etc) is available but it is not distinguished by lines, hence we cannot fully exploit the potential for panel data modelling.
- Data on crowding levels is not available, but we suspect that information on crowding is necessary to for econometric modelling to accurately reflect the complex relationships between peak-time patronage and peak service levels

Therefore, we support the new technologies to be introduced by Auckland Transport. In particular, from late 2012, a ticketing system will be introduced, which will incorporate a 'tag on, tag off' smart card where the time of use and stations travelled between will be captured and cash sales will be for station to station stamped with time and date of purchase. The electric multiple units that will begin to be introduced from late 2013 will have passenger counting devices at the doors so data on total boardings/alightings by station and by individual service will, in theory, be available.

We strongly recommend that these new technologies be monitored on a regular basis so as to identify possible data corruption problems and ensure that these problems are redressed as soon as possible. Our

[11] This is an example of the economic concept of price discrimination, as applied to fare pricing.

experience from working with patronage data is that data corruption often accompanies changes to ticketing systems.

4.7 Opportunities for further research

4.7.1 Introduction

Section 11.4 provides a comprehensive description of all the possible avenues for further research, taking into account the findings across all cities and modes.

The following sections discuss further research as it applies specifically to the Auckland rail system.

4.7.2 Market segment analysis

Section B2.1 of appendix B notes that we made use of two datasets provided by Auckland Transport. The first dataset showed total patronage, by line, from July 1992 to March 2010. The second dataset showed patronage for each service trip, by line from July 2001 to March 2010.

However, Auckland Transport also provided a third dataset which showed patronage by ticket type from July 2001 to March 2010. This third dataset could be used to produce analysis by market segments, including demographics (ie child, adult, tertiary, senior), length of trip (ie one zone, two zones, etc) and ticket type (ie cash, 10-trip, monthly).

Market segment-based analysis could be used to provide answers to the following questions:

- Where has the growth in patronage in recent years come from? Has that growth come from particular market segments (eg students, long-distance travellers)? Answers to these questions may inform future marketing strategies by identifying the best market segments to target in the future.
- What has been the impact of demographic-specific events, such the increase in the student discount and the introduction of the SuperGold Card?

4.7.3 Zone-based elasticities

The market-segment-based analysis discussed above would also lend itself to the estimation of ticket-based elasticities that are segregated by demographics, length of trip and ticket type. This type of analysis would assist transport operators and providers in improving cost-recovery rates by providing answers to the following questions:

- Can we raise fare recovery rates by engaging in price discrimination?
- Can we charge higher fares to certain market segments and hence improve revenue while minimising the negative impact on rail patronage growth?

4.7.4 Further investigation of mode-shift issues

There is also an opportunity for further research into the interaction between Auckland rail patronage and Auckland bus patronage. Such research will allow us to investigate the following issues:

- The service elasticities shown in table 4.4 most likely overestimate the net impact of rail service improvements on total public transport patronage (ie bus and rail) because some of the patronage generated on the rail system was ‘stolen’ from the bus system. Further refinement of the models for both Auckland rail and Auckland bus patronage would enable us to modify these estimates.

- Similarly, the estimates for the impact of Britomart shown in tables 4.1 and 4.2 most likely overestimate the net impact of this event on total public transport patronage. Again, further investigation and refinement of the models would enable us to modify these estimates.

4.7.5 Further investigation of service impacts

Finally, there is also an opportunity for further research into the relationship between peak-time service improvements and peak-time patronage, due to insights that can be offered from patronage growth both since 2010 and in the near future. Further research would exploit the additional insight offered by peak-time service improvements since 2010, and may also be able to exploit improving data quality in regard to crowding levels, reliability and disruptions.

5 Analysis of growth on the Auckland bus system

This chapter presents our analyses of patronage growth on the Auckland bus system.

5.1 Context

For the purposes of this research project, the Auckland bus system can be segregated into central Auckland, west Auckland, south Auckland and the North Shore.

The bus corridors in Auckland city are serviced by a number of transport operators. We chose, for the purposes of this research project, to focus on bus corridors that are operated by a specific transport operator (NZ Bus Ltd). There are a number of reasons for this:

- NZ Bus Ltd is the most dominant transport operator in Auckland city so any conclusions drawn regarding their bus routes give us a good idea of what is happening to bus patronage in Auckland city more generally.
- The econometric approach employed for this research is novel and, to our knowledge, has not ever been applied at this level of detail to public transport data by other researchers. It therefore makes sense to test the approach on a subset of the data before applying the methods more widely.
- The econometric tools employed in this research are very data intensive so, again, it makes sense to test and refine the approach on a subset of the data before applying it more widely.

5.2 Analytical issues

NZ Bus Ltd provided us with data on patronage and service levels from 2001-Q2 to 2010-Q1. This data was segregated by time period (weekday peak, weekday interpeak, weekday evening and weekends). However, as discussed in section 5.4, we concluded that the first year of data (2001-Q2 to 2002-Q1) was not reliable so it was omitted from the econometric analysis.

We encountered a number of challenges when attempting econometric analysis of patronage growth on bus corridors throughout the Auckland bus system.

The first challenge was to select bus corridors that were suitable for econometric analysis. This selection process involved 1) eliminating corridors that had incomplete or inadequate data on the number of service trips provided and 2) eliminating corridors where there was evidence of data corruption and/or patronage data was not available for the whole eight-year period.

The second challenge was to address the volatility in tertiary student patronage: there was negative publicity in mid-2004 that affected the number of foreign students; similarly, the increase in the student discount in February 2008 triggered a big increase in the number of tertiary student tickets sold. Our approach to address this was to exclude tertiary student patronage from the patronage totals analysed.

The third challenge was to ensure that the six-day labour strikes of May 2005 were taken into account by the model. We noted that the labour strike appeared to have had a permanent impact on patronage demand on certain corridors and, curiously, no impact on other corridors. We examined the data and sought an explanation for the contrasting impacts.

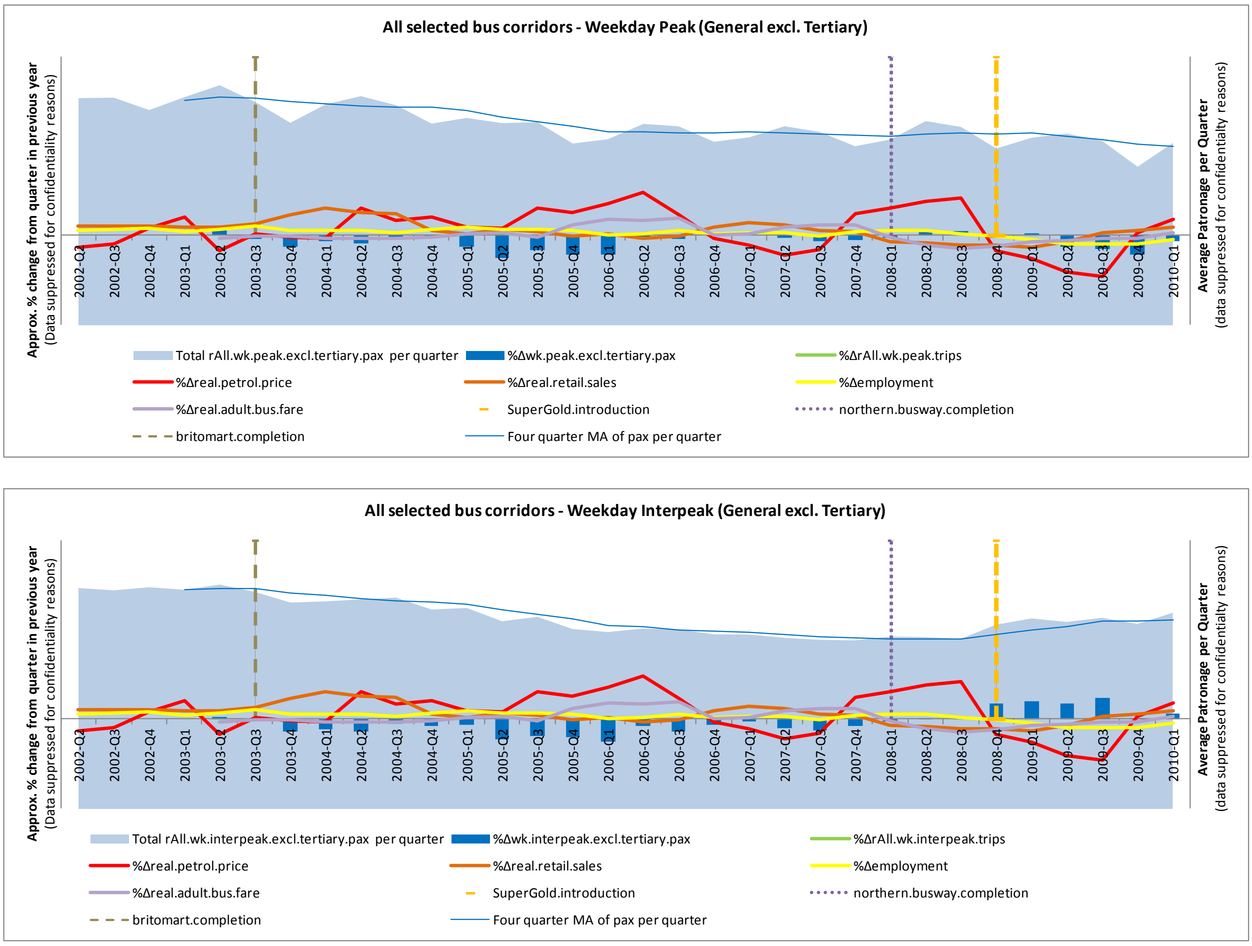
The fourth challenge was to understand, identify and model the interrelationship between the bus corridors and the rail lines. The majority of the corridors in central, south and west Auckland all compete with the rail lines to some extent. There are a few corridors that do not. We categorised corridors accordingly, based on graphical analyses of patronage growth and examinations of network maps.

Interestingly, we conclude that the third and fourth challenges are related. It seems that bus corridors serving catchments some distance away from rail lines were unaffected by the labour strikes while bus corridors that operated in the vicinity of rail lines were affected; it seems that, on the later bus corridors, the bus strikes triggered a permanent mode shift.

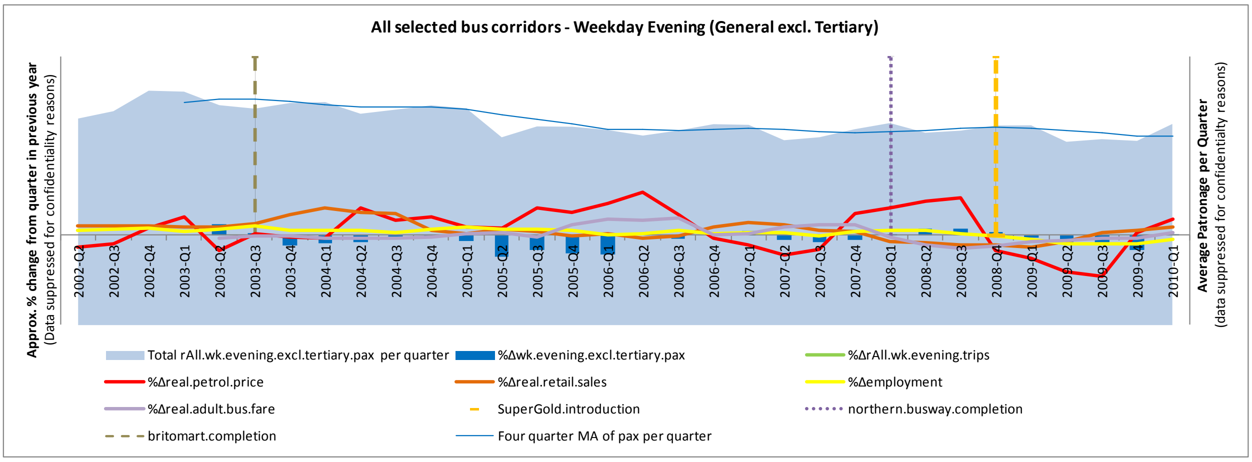
5.3 Analysis of historic growth[12]

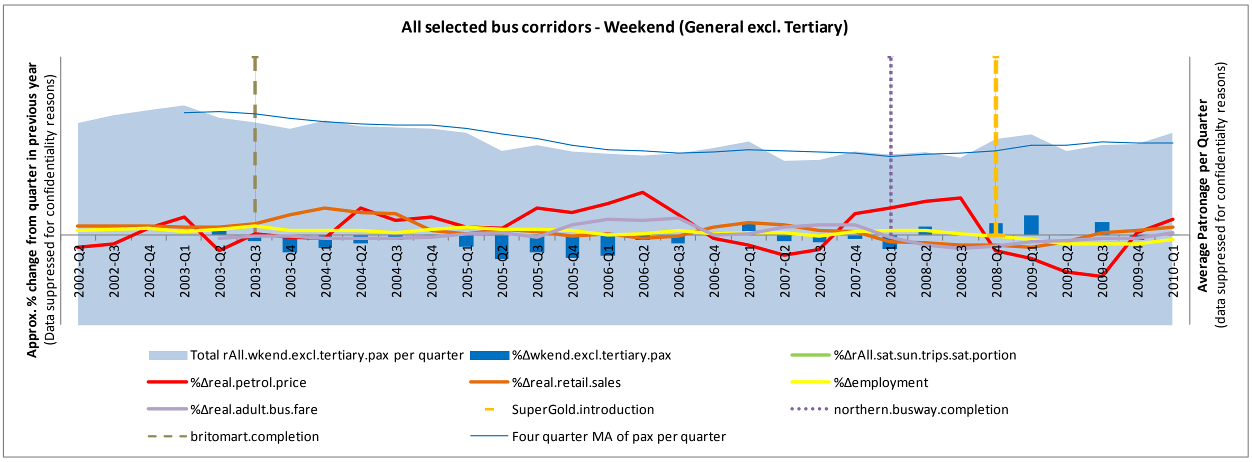
Figure 5.1 shows patronage growth (excluding tertiary students) across all the corridors that were selected for econometric analysis, segregated into peak, interpeak, evening and weekend patronage.

Figure 5.1 Patronage growth on all selected Auckland city bus corridors



[12] In regard to graphical interpretation of the graphs provided, we advise the reader to note the distinction between permanent and temporary 'jumps' or 'falls' in patronage levels. A permanent change shows up on a graph as four quarters of unusually high or negative growth (eg 2005-Q2 in figure 5.1). In contrast, a temporary change shows up as a one-off spurt or loss of patronage and is reversed four quarters later.





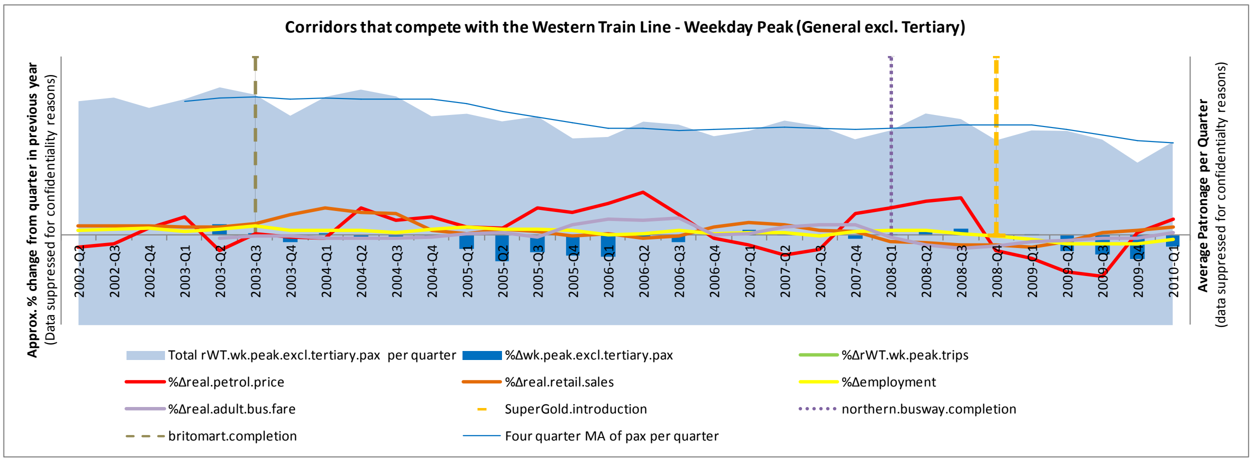
The most prominent features from figure 5.1 are as follows:

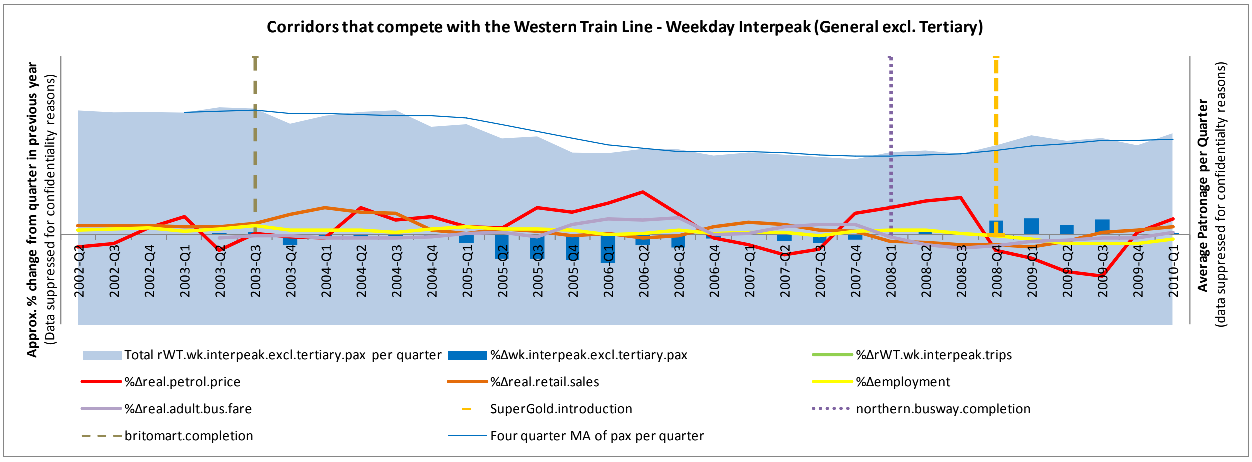
- There was an overall downward trend in patronage from 2003–Q3 onwards and a particularly pronounced fall in patronage in 2005–Q2. We believe this can mostly be attributed to the introduction of Britomart, the partial completion of double tracking on the western line and the interrelated impact of labour strikes. (This is discussed in more detail below.)
- An increase in interpeak and weekend patronage in 2008–Q4. This is almost certainly due to the impact of the introduction of the SuperGold Card.

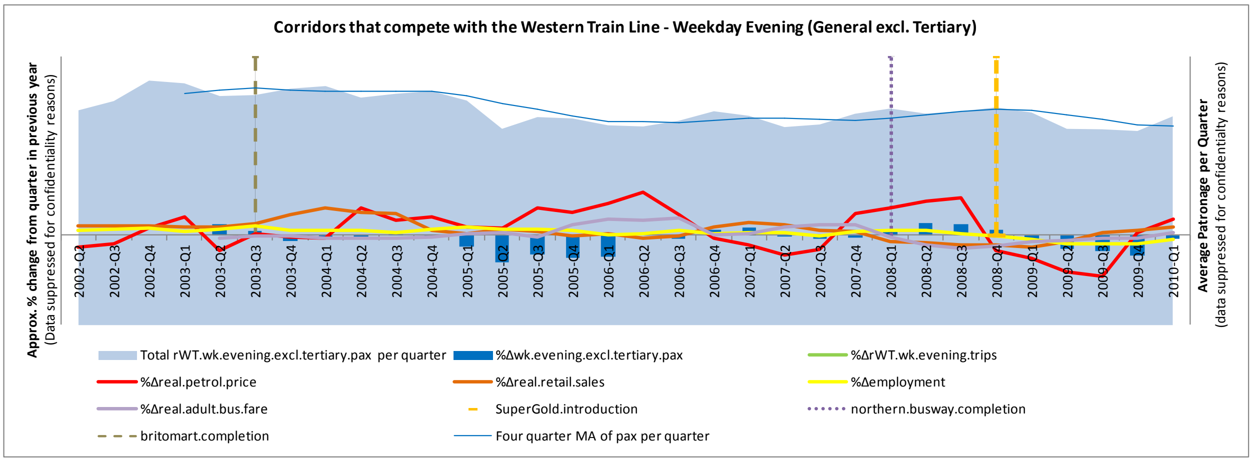
We initially categorised bus corridors into those that ‘competed’ with the western train line, those that ‘competed with the southern and eastern train lines, and those that were some distance away from train lines. Figures 5.2 and 5.3 are provided below to illustrate the impact of the Auckland train lines on ‘competing’ bus corridors.

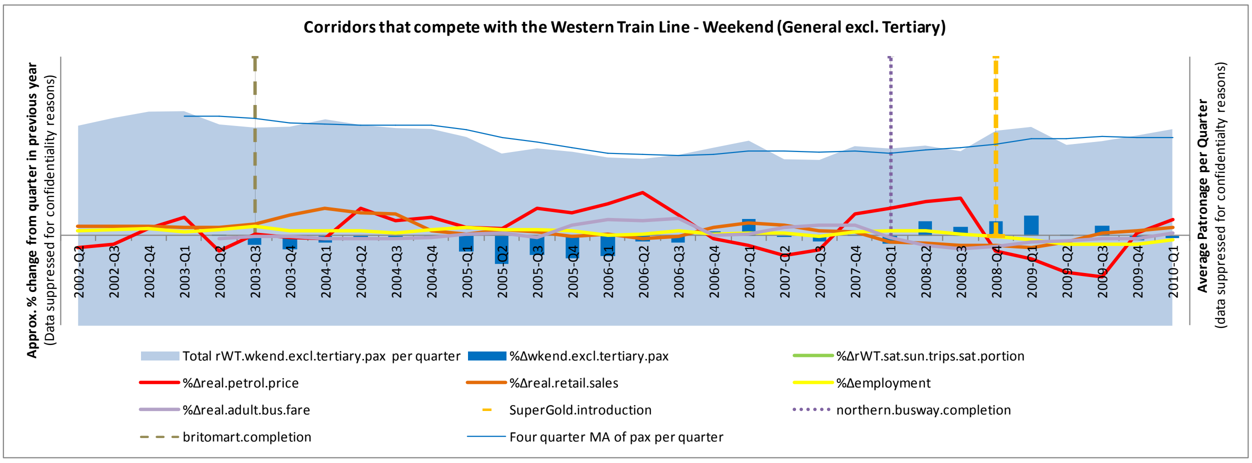
Figure 5.2 shows patronage growth for the bus corridors ‘competing’ with the western train line.

Figure 5.2 Total weekday patronage growth on selected bus corridors that compete with the western train line







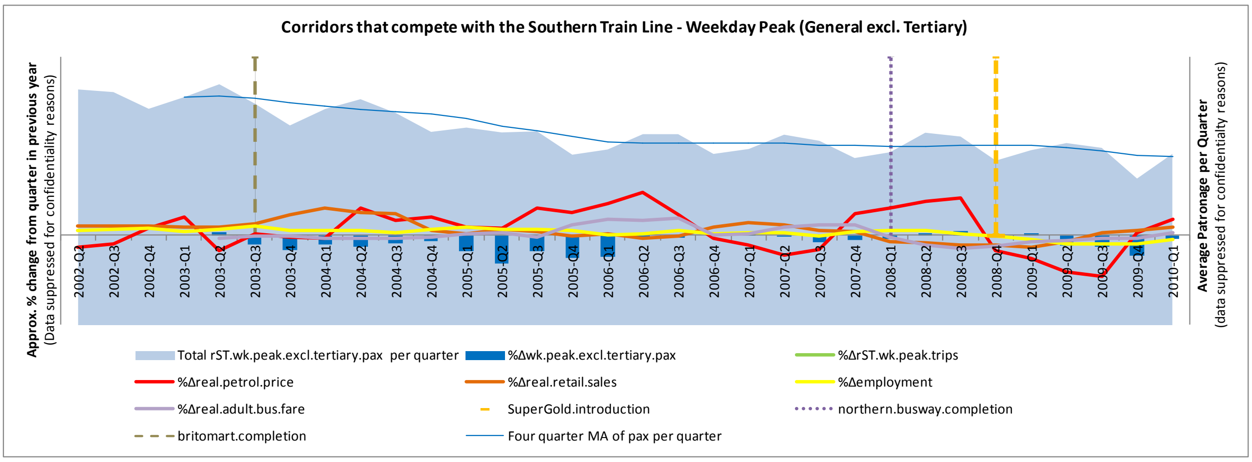


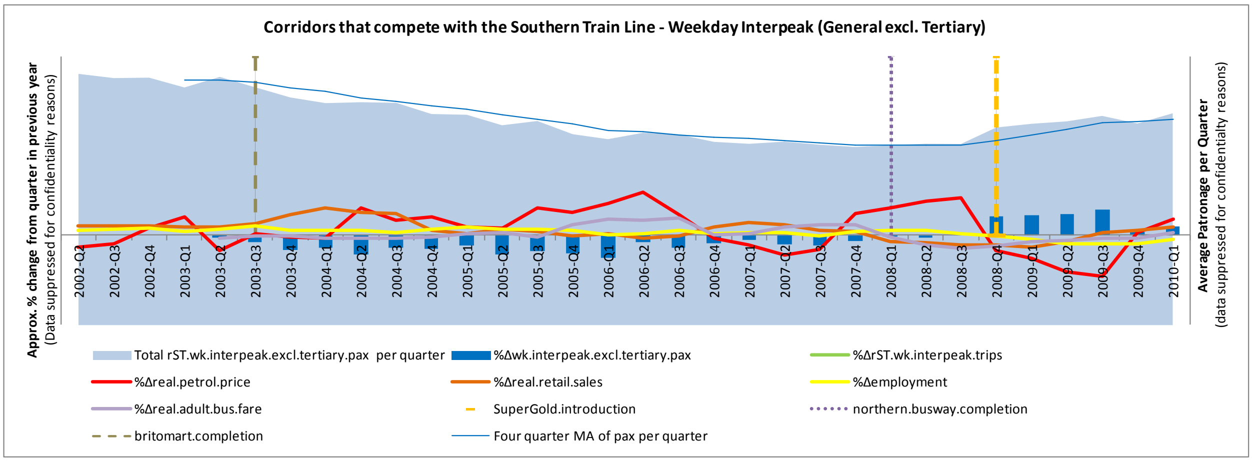
The main patterns observed with bus corridors that 'compete' with the western line were:

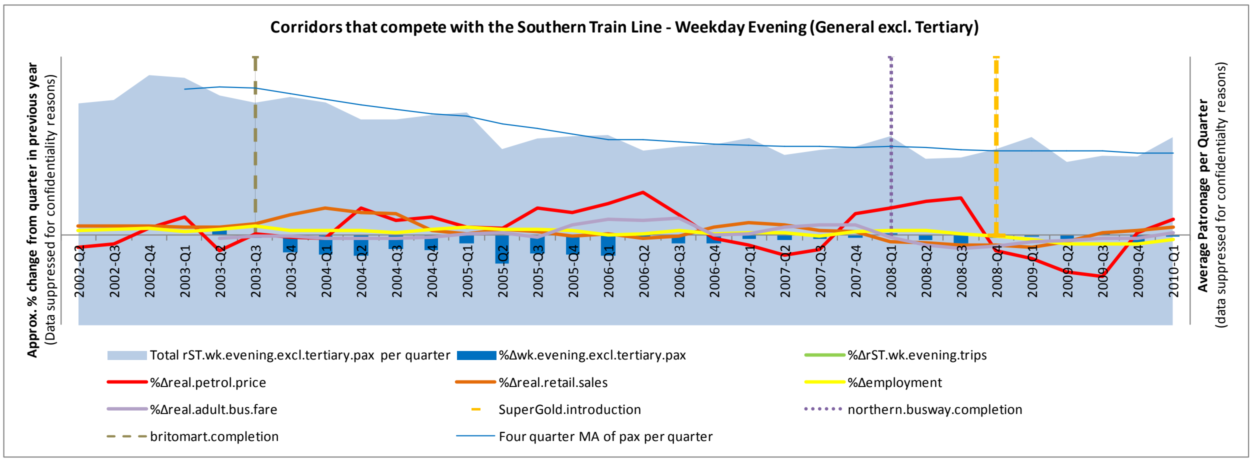
- There was a slight fall in patronage in 2005-Q1; this coincided with the completion of double-tracking on the western train line between Mount Eden and Morningside in February 2005. The completion of double-tracking increased the desirability of rail in many ways: it improved capacity and reliability, and was associated with an improved timetable. It also provided publicity and increased attention of the western train line.
- The fall in patronage was exacerbated in 2005-Q2; this coincided with the six-day labour strike of May 2005. Following our graphical analysis of the data, our conclusion was that the labour strike had a markedly more negative impact on bus corridors that 'competed' with the train lines.

Figure 5.3 shows patronage growth for the bus corridors 'competing' with the southern and eastern train lines.

Figure 5.3 Total weekday patronage growth on selected bus corridors that compete with the southern and eastern train lines







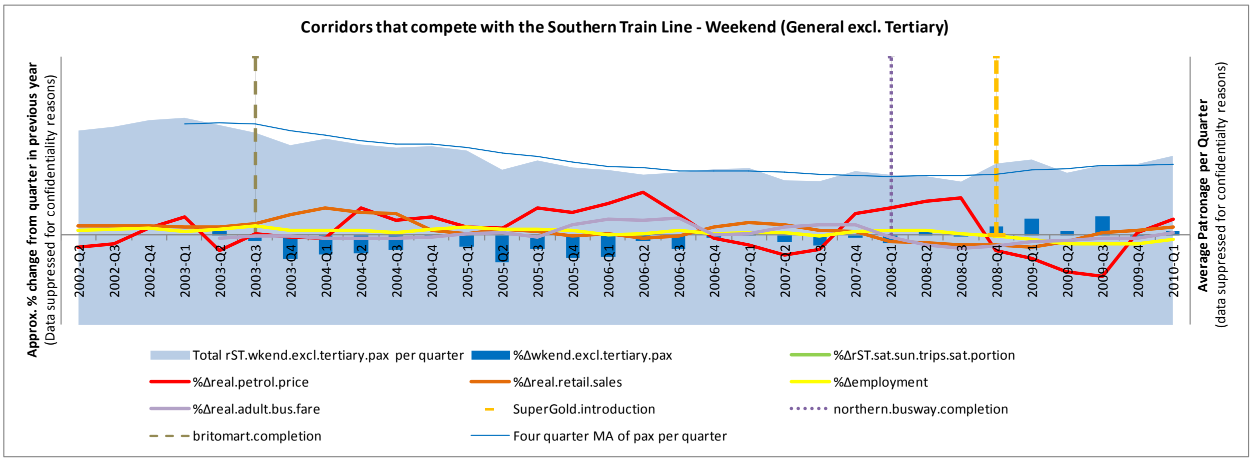


Figure 5.3 shows that the pattern of patronage growth competing with the southern and eastern train lines exhibited a complex and graduated response:

- Bus patronage started falling immediately following the completion of Britomart and exhibited a downward trend that started in 2003-Q3 and lasted until 2006-Q1. The most likely explanation for this is that the Britomart station development provided a more appealing direct route into the CBD for commuters hence, over the next few years, it was able to gradually draw passengers off competing bus corridors.
- Bus patronage expressed a particularly sharp drop in 2005-Q2, coinciding with the six-day labour strikes in May 2005. Again, we conclude that the labour strikes triggered a mode shift from bus to rail.

Booz Allen Hamilton (2005), in their appraisal of Auckland bus patronage trends, noted a number of bus corridors (01, 02, 03 and 04) that, prior to Britomart, transferred rail passengers to the CBD by bus. Subsequently, these bus corridors lost a considerable amount of their bus patronage after Britomart was completed. We therefore chose to also model for this impact.

Table 5.1 shows how our econometric model disentangled and estimated the impact of the train system and the labour strikes on bus corridors that 'compete' with the train system.

Table 5.1 Econometric estimates of the Impact of Britomart, double-tracking and the labour strike on bus corridors that relate to the train lines

Impact of train-related events and the labour strike		Weekday			Weekend
		Peak	Interpeak	Evening	
Impact of Britomart (July 03) on bus corridors that had previously transferred passengers into the CBD:	01	-42%***	-26%***	-10%*	-2%
	02	-16%***	-16%***	-6%	Removed due to implausible sign
	03	-14%**	-5%	-2%	-6%
	04	-14%**	-1%	-6%	-11%
Impact of Britomart (July 03) on bus corridors that 'compete' with the southern and eastern train lines:	Immediate impact	-8%***	-9%***	-8%***	-6%*
	Impact in second year	-6%***	-3%*	-6%***	-8%***
	Impact in third year	Removed due to implausible sign	Removed due to implausible sign	Removed due to implausible sign	-2%
Impact of completion of Project Boston/double tracking (Feb 05) on bus corridors that 'compete' with the western train line:		-16%***	-6%**	-8%**	-15%***
Impact of the six-day labour strike (May 05) on bus corridors that 'compete' with the western, southern and eastern train lines:		-4%**	-8%***	-10%***	-10%**

Note for symbols of statistical significance: *** → 0.1%, ** → 1%, * → 5%, ' →10%

5.4 Summary of findings

This section summarises some of the key findings from the econometric analysis of corridors operated by NZ Bus within the Auckland bus system. For more detail about these findings see appendix C7.

Table 5.2 shows the impact of key economic variables on patronage (excluding tertiary students).

Table 5.2 – Elasticity estimates for key economic variables

Economic variables	Weekday			Weekend
	Peak	Interpeak	Evening	
Real bus fare elasticity	-0.30***	-0.24***	-0.12	-0.42***
Real petrol price cross-elasticity	0.03	0.02	Removed due to implausible sign	Removed due to implausible sign
$2.00 petrol price threshold dummy	3%	Removed due to implausible sign	5%	Removed due to implausible sign
Real retail sales cross-elasticity	-0.19**	-0.27***	-0.09	-0.21*
Employment cross-elasticity	0.79***	-0.08	0.52**	0.07
Introduction of SuperGold Card dummy	Not applicable during peak	11%***	2%	Removed due to implausible sign

Note for symbols of statistical significance: *** → 0.1%, ** → 1%, * → 5%, ' →10%

The key findings from table 5.2 are:

- The fare elasticities range from about -0.1 during the evening up to -0.4 during the weekend.
- The low petrol price elasticities indicate that general petrol price fluctuations have only a modest influence on Auckland bus patronage growth; however, there is evidence that the crossing of the $2.00 petrol price threshold triggered 'jumps' in evening patronage but even this evidence is not statistically significant.
- There is a negative relationship between real retail sales and patronage growth across all periods. The exact reasons for this are difficult to establish; one possible explanation is that bus transport is seen as an inferior good by consumers.
- The employment elasticity is estimated to be +0.8 for peak-time patronage and +0.5 for evening patronage. This seems plausible, given that a lot of peak-time patronage (and perhaps some evening patronage) is employment driven.
- The introduction of the SuperGold Card is estimated to have increased weekday interpeak patronage to increase by about 11%.

One of the advantages of the econometric approach pioneered by this research project is that it disaggregates patronage and service information by corridor and by period. This has allowed us to estimate service elasticities disaggregated by corridor, period and the date of the service change.

We made inquiries regarding whether NZ Bus or Auckland Transport had documented the details of those service changes (eg pre-service frequency, nature of extensions to hours operated, etc). The people we made contact with were not aware of such documentation.

However, if such documentation were made available in the future then that information could be combined with the estimates shown in tables 5.3 to 5.6 and could be used to produce a scientific 'post-evaluation' of which types of service changes provided the best (or worst) value for money.

Table 5.3 shows our estimates of the service elasticities for service improvements during the weekday peak, disaggregated by corridor and date of service change.

Table 5.3 Corridor and date-specific service elasticities for peak-time service improvements

Corridor		Date	Peak service elasticity
005	Herne Bay	Jul 04	0.28
13	Ranui – Swanson	Aug 03	-0.33
15	Glen Eden	Aug 03	0.00
47	Papakura	Dec 09	0.32
		Feb 09	0.09
81	Devonport	Jul 05	0.42***
83	Beach Road	Nov 02	0.22
		Feb 08	0.85**
87	East Coast Rd	Oct 02	0.61*
		Jul 05	-0.10
	Weighted average		**0.27**

Note for symbols of statistical significance: *** → 0.1%, ** → 1%, * → 5%, ' →10%

Key findings from table 5.3 are:

- The average (weighted[13]) peak-time service elasticity is +0.3
- The peak-time service elasticities are distributed very widely around the average, with some corridors even exhibiting service elasticities that were negative[14].

Table 5.4 shows our estimates of service elasticities for service improvements during the weekday interpeak, disaggregated by corridor and date of service change.

Table 5.4 Corridor and date-specific service elasticities for interpeak service improvements

Corridor		Date	Interpeak service elasticity
17	Titirangi	Aug 03	1.40***
47	Papakura	Aug 05	0.34
		Oct 06	-0.17
81	Devonport	Jul 05	0.43
83	Beach Road	Nov 02	0.16
		Feb 06	0.09
		Feb 08	0.58*
87	East Coast Rd	Oct 02	0.35***
		Feb 06	0.60‘
		Feb 08	0.82***
	Weighted average		**0.35**

Note for symbols of statistical significance: *** → 0.1%, ** → 1%, * → 5%, ‘ → 10%

Key findings from table 5.4 are:

- The average interpeak service elasticity is +0.35.
- The interpeak service elasticities are distributed widely around the average, but the overall distribution of values is narrower and more robust than it was for peak service elasticities.

Table 5.5 shows our estimates of service elasticities for service improvements during the weekday evening, disaggregated by corridor and date of service change.

[13] We used a weighted average to prevent the average from being unduly distorted by service improvements on bus corridors with relatively low patronage levels.

[14] Note that the presence of a negative service elasticity does not mean that the service improvement had a negative impact on patronage on this bus corridor. The correct interpretation is that this particular corridor exhibited lower than average growth following the service improvement but this could be due to other factors at play; similarly, a positive service elasticity indicates higher than average growth but could also be due to other factors. When we take a weighted average of all estimates (including those that are outliers for whatever reason) we get a better sense of the average effect of the service improvements.

Table 5.5 Corridor and date-specific service elasticities for evening service improvements

Corridor		Date	Evening service elasticity
13	Ranui – Swanson	Aug 03	0.08
17	Titarangi	Nov 08	1.61***
81	Devonport	Jul 05	0.67***
83	Beach Road	Oct 02	0.51*
		Jul 05	1.26**
		Dec 09	0.82
87	East Coast Rd	Oct 02	0.26
		Jul 05	0.03
		Feb 08	0.27
	Weighted average		**0.61**

Note for symbols of statistical significance: *** → 0.1%, ** → 1%, * → 5%, ' →10%

Key findings from table 5.5 are:

- The average evening service elasticity is +0.6.
- The evening service elasticities are distributed widely around the average, but again the overall distribution of values is narrower and more robust than it was for peak service elasticities.

Table 5.6 shows our estimates of these service elasticities for service improvements during the weekend disaggregated by corridor and date of service change:

Table 5.6 Corridor and date-specific service elasticities for weekend service improvements

Corridor		Date	Weekend service elasticity
007	Pt Chev – St Heliers	Apr 09	0.39
11	Glendene	Aug 03	-0.64
13	Ranui - Swanson	Aug 03	0.22
15	Glen Eden	Aug 03	-0.04
17	Titirangi	Aug 03	-3.94***
30	Manukau Rd	Nov 03	1.29
47	Papakura	Oct 06	-0.45
83	Beach Road	Jul 02	0.98
		Jul 05	0.28
87	East Coast Rd	Jul 02	0.48
		Jul 05	0.86
		Feb 08	-0.73
	Weighted average		**0.27**

Note for symbols of statistical significance: *** → 0.1%, ** → 1%, * → 5%, ' →10%

The key finding from table 5.6 is that the average weekend service elasticity is about +0.3.

5.5 Comment on mode-shift modelling issues

The most contentious aspect of the econometric analysis relates to the modelling of the impacts of the bus patronage-losses attributable to the Auckland train lines and the May 2005 labour strikes.

The relationship between patronage growth on the train lines and patronage growth on the bus corridors is complex. There have been improvements to the train service timetables that, in theory, would have encouraged a mode shift from bus to rail. However, after looking at the data, our judgement is that events (such as the completion of Britomart, the completion of double-tracking and labour strikes) contributed more to mode shift.

For the purposes of this research project, we have chosen to deal with this complexity by taking a parsimonious[15] approach: we used dummy variables to act as a proxy for particular patterns on bus corridors without necessarily delving into the detail of why those patterns occurred. For example, compared with 'control' bus corridors, the bus corridors that competed with the southern train line exhibited 1) a loss of patronage in the year after Britomart, 2) a further loss in the subsequent year, and 3) an even more pronounced drop during the May 2005 labour strikes; this pattern was incorporated into the econometric model via three dummy variables.

We envisage that future research could delve into this issue in more depth and could potentially develop more complex models.

5.6 Confidence in findings

As mentioned in section 5.5, there could be criticism of our approach for modelling the impacts of the bus patronage losses attributable to the Auckland train lines and the May 2005 labour strikes. However, the patronage growth patterns represented by the estimates in table 5.1 were observed consistently across a number of bus corridors and we think they are a reasonable representation of those patterns.

The fare elasticity estimates shown in table 5.2 should be regarded with some caution because they relate primarily to a fare increase that occurred in 2005–Q4. This fare increase occurred at a similar time as a fall in patronage was observed across a number of corridors in 2005–Q2; disentangling the impacts of fares from the 2005–Q2 fall in patronage is challenging.

The service elasticity estimates shown in tables 5.3 to 5.6 have very desirable statistical properties; these estimates are produced by comparing the patronage growth on a corridor with a service change against 'control routes' (corridors without such service changes) – this approach produces unbiased estimates. We note that the elasticity estimates shown do vary considerably by corridor and date of service change. But this may very well just represent reality; it is possible that the effectiveness of service changes do vary considerably from situation to situation.

We generally have only moderate confidence in the elasticities produced in table 5.2 for the impact of economic variables. The statistical model employed relates patronage growth over time to changes in these economic variables over time. There is a risk that the model incorrectly associates patronage trends with coincidental movements in the economic variables.

[15] A parsimonious model explains patronage growth in the simplest manner possible.

5.7 Recommendations and policy implications

The improvements to the Auckland rail network have generated considerable growth in rail patronage, but our research indicated that a reasonable portion of that additional rail patronage has come at the expense of the bus network. During 2005, a number of bus routes that were previously commercially viable had to be 'contracted over' and supported through government subsidies; this may have been, at least in part, a consequence of the rail improvements. Therefore, we recommend that decisions about investments in rail should take into account both the direct costs of funding new rail improvements and the potential indirect costs of directing further subsidies to the Auckland bus network.

Our research also suggested that the mode-shifts between bus and rail can be sudden and quite dramatic. Therefore, we recommend that transport planners consider the possibility that integrated ticketing could also generate quite dramatic mode-shifts as transferability between modes increases.

The estimate for peak-time bus elasticity (-0.3) is low compared with the estimate for peak-time rail elasticity (-0.9). This means that, even though investments in the bus network may have less popular appeal, the scope for recovering the cost of those investments via fare increases is potentially higher.

The service elasticities presented in tables 5.3 to 5.6 were aggregated together to produce averages. However, the considerable variation around those averages suggests that the effectiveness of service improvements varies considerably from situation to situation. If this is correct then it strengthens the case for doing an econometric 'post-evaluation' on a regular basis, following the introduction of new services and/or network reconfigurations.

5.8 Opportunities for further research

5.8.1 Introduction

Section 11.4 provides a comprehensive description of all of the possible avenues for further research, taking into account the findings across all cities and modes.

The following sections discuss further research as it applies specifically to the Auckland bus system.

5.8.2 Market segment analysis

The dataset provided by NZ Bus is very detailed and provides patronage data by ticket type; therefore, the econometric methods demonstrated by this research project could be expanded to enable disaggregated analysis by demographics (ie child, adult, student, senior) and length of trip.

More detailed analysis would enable us to more accurately answer the following questions:

- What has been the impact of demographic-specific events, such as the increase in the student discount and the introduction of the SuperGold Card?
- Where has the growth in patronage in recent years come from? Has that growth come from particular market segments (eg students, long-distance travellers)? Answers to these questions may inform future marketing strategies by identifying the best market segments to target in the future.

5.8.3 Zone-based elasticities

The market-segment-based analysis discussed above would also lend itself to the estimation of ticket-based elasticities that are segregated by demographics, length of trip and ticket type. This type of analysis would assist transport operators and providers in improving cost-recovery rates by providing answers to the following questions:

- Can we raise fare recovery rates by engaging in price discrimination?
- Can we charge higher fares to certain market segments and hence improve revenue while minimising the negative impact on rail patronage growth?

5.8.4 Further post-evaluation and incorporation of cost–benefit analysis

Further research could be done that replicates the 'post-evaluation' demonstrated in this report, but with a number of enhancements:

- The econometric analysis could potentially be broadened to include all bus operators, not just NZ Bus Ltd. This would include Ritchie's Transport, Howick and Eastern Buses, Birkenhead Transport, Urban Express and Bayes Coachlines.
- Further 'post-evaluation' using updated time series would provide information on the effectiveness of service enhancements to the Auckland bus system since early 2010.
- If details can be provided by Auckland Transport on the types of service enhancements carried out then a more sophisticated 'post-evaluation' could be carried out that categorises payoffs by type of service improvements (eg extension of hours, new routes, high frequency, low frequency).
- Similarly, the 'post-evaluation' could be modified to incorporate a cost–benefit analysis (CBA) of past investments. We can envisage a process in which cost data is used to calculate the average cost of each extra patron generated by a service improvement. That cost can then be assessed against the social and economic benefits arising from the extra patronage.

6 Analysis of growth on the Wellington rail system

This chapter presents our analyses of patronage growth on the Wellington rail system:

6.1 Context

The Wellington region is composed of the main city – Wellington – and is connected to a number of neighbouring cities – Porirua, Lower Hutt and Upper Hutt – via roads and train lines. The train line also connects the Wellington region with the Wairarapa region.

The Wellington train system is mostly commuter driven and transports patrons between Wellington city and its neighbouring cities and, in some cases, the more distant suburbs of Wellington city.

The Wellington rail system, during the period covered consisted of the following lines:

- the Johnsonville line
- the Upper Hutt/Melling line
- the Paraparaumu line (currently Kapiti)
- the Capital Connection
- the Wairarapa line.

The latter two lines were excluded from further analysis, for the purposes of this research project, because they represent a distinctly different market (ie long-distance commuting and/or travel) and it seemed inappropriate to group them together with the other lines.

6.2 Analytical issues

After initial discussions with KiwiRail, we decided in favour of using sales of specific ticket types as a proxy for patronage. KiwiRail provided us with ticket sales data for the Wellington rail system between 2005–Q3 and 2009–Q4.

Our analysis of ticket sales data shows that approximately 80% to 90% of non-cash ticket patronage arises from four ticket types:

- adult (single) tickets
- 10-trip tickets
- monthly tickets
- quarterly tickets.

We therefore chose to build models of each of these ticket types, in turn, and then build a model for ‘aggregate’ patronage. ‘Aggregate’ patronage reflects sales of each of these ticket types added together (but weighted by the number of patron trips per ticket sale).

The Wellington rail system was improved during the period studied but the improvements were of an incremental nature and involved a number of stages. We were informed that documentation on all of these improvements was not immediately available. However, KiwiRail did note that the most significant improvement during the period studied was in November 2008: four extra commuting services per working day were added on both the Hutt and Paraparaumu lines.

There was an unusual dip in sales in 2006-Q1 and again in 2008-Q1, and ascertainingthe exact causes of this dip was challenging. The dip could be attributed either to line maintenance or to data quality issues but, as we discuss in section 6.4, we cannot make definitive judgements regarding this issue.

6.3 Analysis of historic growth[16]

Figure 6.1 shows growth in monthly and quarterly ticket sales. These sales exhibit a strong seasonal pattern with lower sales during the first and fourth quarters. The most likely explanation for this is that most purchasers of monthly and quarterly tickets are commuters and they are less inclined to purchase these tickets during the holiday seasons (ie December, January).

Figure 6.1 Growth in monthly and quarterly ticket sales

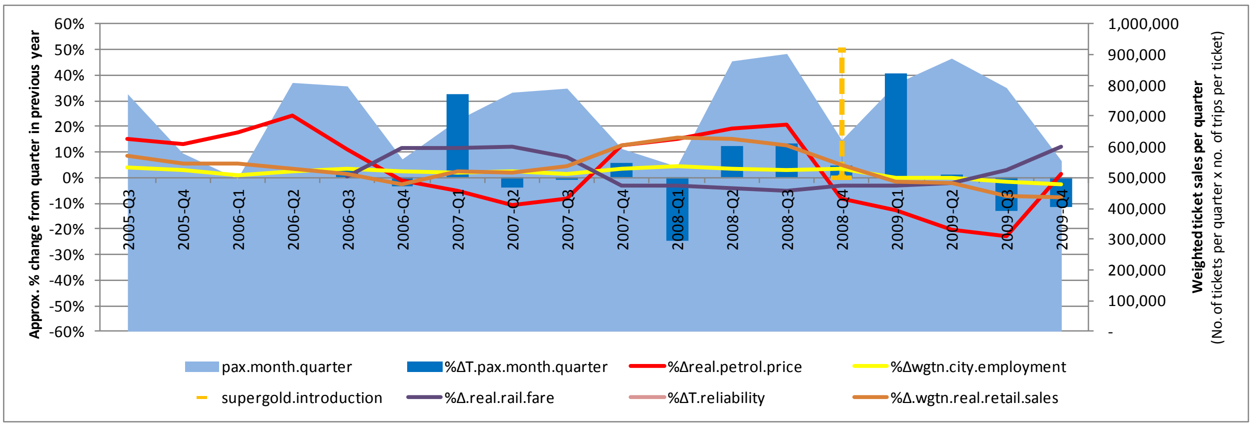


Figure 6.1 shows an unusual dip in sales in 2006-Q1 and again in 2008-Q1. The exact reasons for this could not be ascertained but closer examination of the data revealed that it was concentrated in January and February, which suggests that line maintenance may be the culprit. (That said, it is surprising that we did not see any corresponding increase in sales of other ticket types – if our hypothesis is correct, this implies that line maintenance was causing monthly and quarterly ticket holders to give up on the rail for the entire month that line maintenance occurred).

Figure 6.1 also shows a 10% jump in patronage in 2008-Q2 and 2008-Q3, which could feasibly be due to the crossing of the $2.00 nominal petrol price 'threshold' around this time.

Figure 6.2 shows growth in 10-trip ticket sales. The trend for sales of 10-trip tickets has been flat: overall sales have remained much the same throughout the period observed and growth rates have been close to zero. The only exception is that the crossing of the $2.00 nominal petrol price 'threshold' again appears to have caused a jump in patronage in 2008-Q2 and 2008-Q4, which was later reversed.[17]

[16] In regard to graphical interpretation of the graphs provided, we advise the reader to note the distinction between permanent and temporary 'jumps' or 'falls' in patronage levels. A permanent change shows up on a graph as four quarters of unusually high or negative growth (eg in figure 6.3, the introduction of SuperGold seems to have caused a permanent loss of patronage in 2008-Q4). In contrast, a temporary change shows up as a one-off spurt or loss of patronage and is reversed four quarters later (eg in figure 6.1, the dip in sales in 2008-Q1 is reversed back in 2009-Q1).

[17] One Steering Group member noted that the rising petrol prices around mid-2008 were also associated with overcrowding on trains, and ticket conductors were finding it difficult to check all tickets. Some patrons may have anticipated this and intentionally purchased 10-trip tickets, knowing that the conductor would be unable to clip the ticket and hence they would get a free ride.

Figure 6.2 Growth in 10-trip ticket sales

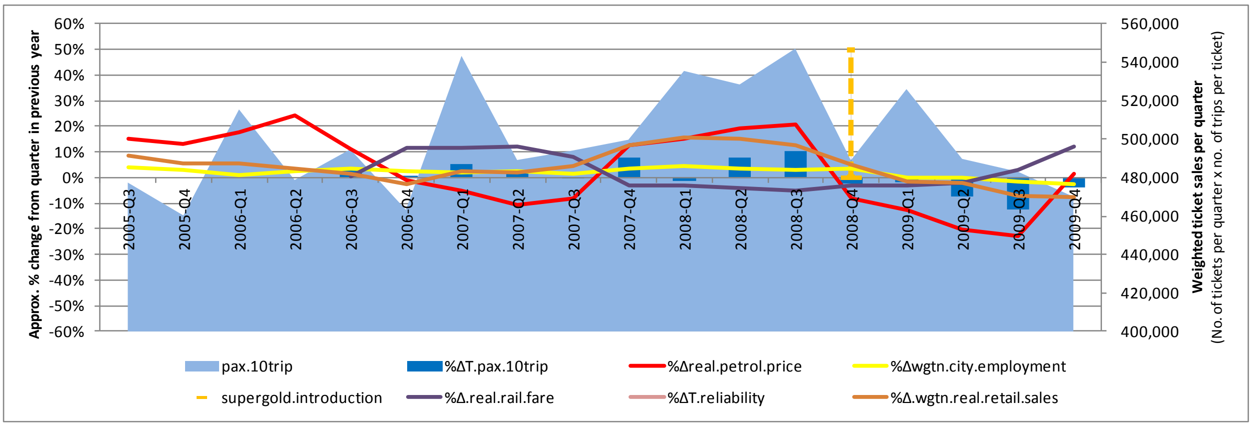
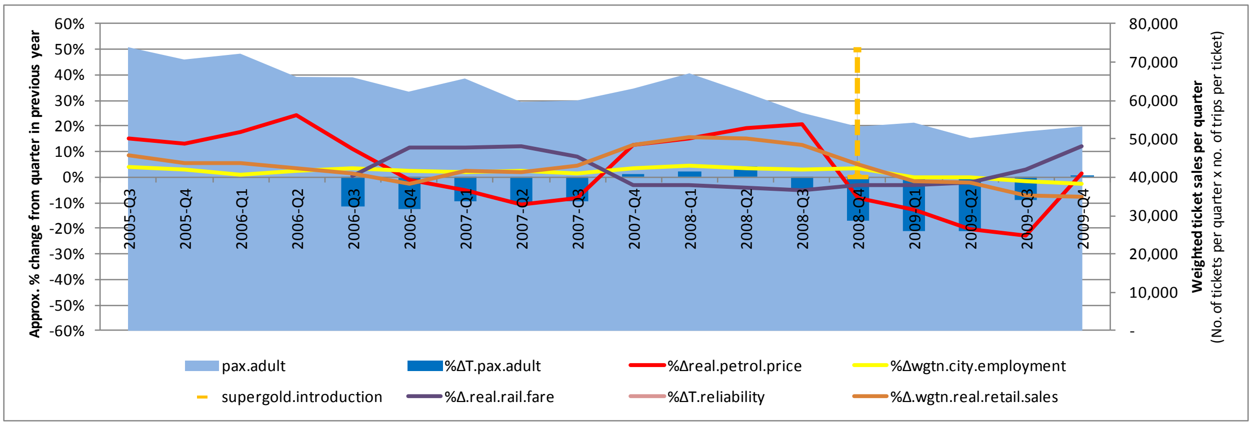


Figure 6.3 shows growth in adult (single) ticket sales. Trends in these ticket types should not be given much weight because they represent only a small portion of total ticket sales (ie about 5% to 7%). However, it is interesting to note that sales of these ticket types appear to have fallen in response to both the 2006 fare increase and the introduction of SuperGold[18].

Figure 6.3 Growth in adult ticket sales



6.4 Summary of findings

This section summarises some of the key findings from the econometric analysis of the Wellington rail system. For more detail about these findings see appendix E.

Table 6.1 shows the impact of key economic variables on sales of different ticket-types: monthly and quarterly (combined), 10-trip, adult (single) and the (weighted) aggregation of all those.

[18] We remind the reader that the ticket sales data shown above do not explicitly include senior patronage, but it is possible that some of them were purchased by seniors prior to the availability of free travel via SuperGold. Therefore, the introduction of SuperGold could plausibly have caused a drop in sales of some of these tickets.

Table 6.1 – Elasticity estimates for key economic and service variables

Economic and service variables	Monthly/quarterly	10-trip	Adult single	Aggregate
Real rail fare	-0.65*	-0.73*	Removed due to implausible sign	-0.60**
Real petrol price	0.14	0.01	0.28*	0.16
Nominal $2.00 petrol price threshold	Omitted due to interaction with real petrol price	15%'	Removed due to implausible sign	Omitted due to interaction with real petrol price
Real retail sales (Wellington city)	Omitted due to interaction with employment	Omitted due to interaction with employment	Omitted due to interaction with employment	Omitted due to interaction with employment
Employment (Wellington city)	1.33'	0.77	1.01'	1.44*
Introduction of SuperGold Card (Oct 2008)	Removed due to implausible sign	-28%***	Removed due to implausible sign	-13%'
Extra commuter services (Nov 2008)	7%	26%**	3%	15%*

Note for symbols of statistical significance: *** → 0.1%, ** → 1%, * → 5%, ' →10%

The key findings from table 6.1 are:

- The fare elasticity is -0.6 overall and -0.65 for the monthly/quarterly tickets, which make up the bulk of total patronage.
- The conventional real petrol price elasticities range from 0.0 to +0.3, with +0.16 for aggregate ticket sales. However, some of these elasticities could be attributed to the $2.00 petrol price thresholds when alternative modelling structures are employed (see table 6.2 below for illustration of this).
- The introduction of the SuperGold Card caused a fall in 10-trip ticket sales, which is entirely plausible given that a lot of seniors would have switched from these to SuperGold.
- The employment elasticities are plausible but we should note that there is a large confidence error around these estimates.
- The introduction of extra commuter services in November 2008 appear to have had a significant impact on patronage, apparently causing aggregate ticket sales to increase by about 15%; however, we caution against reading too much into this.

We note that the fare elasticities presented in table 6.1 correspond to relatively large fare increases (in the order of about 14%) in both 2006 and 2009. Since then, there have been much smaller fare increases (in the order of 3% to 5%). Analysts at KiwiRail consider that the fare elasticities associated with those smaller fare increases would probably have been much lower.

Table 6.2 provides more detailed analysis of the petrol price impacts. Table 6.2 shows that when the $2.00 petrol price threshold is excluded (ie final model B) we get real petrol price cross-elasticities around +0.10 to +0.30. However, if the $2.00 threshold hold is included and real petrol prices excluded then we get 'jumps' in patronage of around 10% to 30%.

We conclude that, particularly in the case of Wellington rail, the impact of petrol price changes on patronage is not as straightforward as that commonly envisaged in econometric patronage analysis. There are important threshold points and psychological decision points that play an important role.

Table 6.2 Exploration of different model structures for representing petrol price impacts

Final model variations		Monthly/quarterly	10-trip	Adult	Aggregate
Model A	Real petrol price	-0.16	0.01	0.38*	-0.07
	Nominal $2.00 petrol price threshold	24%***	15%‘	-2%	16%**
Model B	Real petrol price only	0.14	0.13	0.28*	0.16
Model C	Nominal $2.00 petrol price threshold only	21%***	15%‘	9%	15%**

Note for symbols of statistical significance: *** → 0.1%, ** → 1%, * → 5%, ‘ →10%

Table 6.3 outlines some of the other events or effects that we controlled for in our econometric analysis. Unfortunately, there has not been any documentation of historical service changes so any explanations identified for observed patterns are inevitably educated guesses:

- We noted in section 6.3 that there was a dip in monthly ticket sales, across all lines, in January/February 2006 and January/February 2008; it seems most likely that this was due to line maintenance.
- There was also a dip in adult and 10-trip ticket sales on the Johnsonville line in January/February 2009. This seems to be due to the closure of the Johnsonville line from 28 December 2008 to 7 February 2009. This was done to enable a lowering of the track and a widening of the tunnels, hence enabling newer and bigger trains to run on this line.

Table 6.3 Miscellaneous events and effects

Miscellaneous events	Monthly/quarterly	10-trip	Adult	Aggregate
Dip in monthly ticket sales (Jan/Feb 06)	-40%***			-21%***
Dip in monthly ticket sales (Jan/Feb 08)	-44%***			-25%***
Dip in adult and 10-trip ticket sales due to closure of Johnsonville line (Jan/Feb 09)		-46%***	-37%***	-28%**
Easter	Removed due to implausible sign	1%	-3%*	Removed due to implausible sign

Note for symbols of statistical significance: *** → 0.1%, ** → 1%, * → 5%, ‘ →10%

6.5 Confidence in findings

We do not have as much confidence in the findings for Wellington rail patronage as we do in the analysis of patronage in other cities and modes, due to two limitations:

- The period covered is quite short: we were only provided with data from 2005–Q3 through to 2009–Q4; this meant we were only able to estimate growth rates for a three-year period.
- We were unable to access documentation of events and service changes throughout this period; this meant that we had to make educated guesses about these things and had to control for them using relatively simplistic approaches (ie dummy variables).

We have low-to-moderate confidence in the fare elasticities. One of the advantages of the panel data approach employed in this research project was that it allowed us to disaggregate both by train line and by zone; since the fare increases differed by zone this provided more data variability that the model exploited when estimating fare elasticities.

We have less confidence in estimates associated with the remaining explanatory variables, mainly due to the short period covered.

6.6 Recommendations and policy implications

We recommend that policy makers and transport planners keep in mind that petrol prices seem to have an impact on rail patronage, at least in Wellington, which is more complex than that assumed in most of the transport economics literature. It appears that psychological barriers and thresholds play a crucial role.

We recommend and encourage initiatives to improve the quality of data collection in regard to the Wellington rail network. There are two aspects to improving data collection:

- To the extent that it is possible, patronage should be disaggregated by line, origin, destination, number of zones travelled, ticket type, demographic characteristics (child, adult, senior) and period (ie weekday peak, weekday interpeak, weekday evening and weekend). However, we acknowledge that obtaining data disaggregated at this level of detail may not be fully achievable until electronic ticketing is introduced.
- We recommend that processes be introduced within Greater Wellington and/or KiwiRail so that key service changes and events can be recorded and documented. This would enable more sophisticated econometric modelling and research in the future.

We also recommend that further research of the ticket sales data is done in the near future, when a longer series of data is available.

6.7 Opportunities for further research

6.7.1 Introduction

Section 11.4 provides a comprehensive description of all the possible avenues for further research, taking into account the findings across all cities and modes.

The following sections discuss further research as it applies specifically to the Wellington rail system.

6.7.2 Further investigation using head-count statistics, longer time series and/or analysis using monthly data

As discussed in section 6.3, we used sales of specific ticket types as a proxy for patronage. The main advantage of this approach is that we were able to distinguish tickets by line, number of zones travelled and origin/destination. This additional information helped us discern the impact of fares because the magnitude of fare increases differed by origin/destination. For example, the 2008 fare increase for the five-zone trip between Wellington and Taita/Pomare was 20% while the nine-zone trip between Wellington and Paraparaumu was only 11%.

The main disadvantage of using ticket types as a proxy for patronage is that only a portion of ticket sales can be assigned into origin/destination. Furthermore, sales of some ticket types are necessarily excluded (eg cash fares). Also, ticket sales data may be distorted by events that have nothing to do with patronage (eg errors in recording ticket-type). These limitations imply that the ticket types being employed as a proxy may not be representative of the broader population of rail patrons.

In addition to ticket sales data, KiwiRail also records a ‘head-count’ of the number of patrons at the start and end of each rail service. The main disadvantage of these ‘head-counts’ is that they do not distinguish patrons by origin and destination. Also, people who get on and off at intermediary stations are excluded.[19] However, the main advantage of 'head-counts' is that they are probably a more robust measure of overall patronage.

We see merit in further analysis in the near future that looks at both these datasets in combination and in greater depth.

This further analysis would also enable analysis over a longer period. The ticket sales dataset employed for this research project ended in 2009–Q4. Extending the analysis to include a longer period would enable analysis of a number of key events since 2009.

- There have been reliability and punctuality issues on the Wellington rail lines but these have been most pronounced since 2009, and appear to have been alleviated somewhat. Further analysis could examine the impact of these trends on rail patronage and sales.
- There have been ongoing petrol price fluctuations since 2009, including further breaches of the $2.00 petrol price 'threshold'. Further analysis could explore the impacts of these price fluctuations on rail patronage and sales.
- There have been further fare increases since 2009, but only in the order of about 3%–5%, and KiwiRail consider that their impact on patronage has been relatively subdued. Further analysis could explore whether these fare increases are associated with lower fare elasticities.
- The findings from this research project suggest that employment is a key driver of rail patronage. Further analysis of the relationships between employment and rail patronage and sales could examine whether this relationship is consistent through time.

This further analysis could also examine ticket sales data and head-count statistics at a monthly level. The ticket sales data exhibits a lot of volatility and an examination at a monthly level may allow us to better identify the causes of this volatility or to clean up data problems. An examination at the monthly level might also enable us to more accurately model the impacts of events like line maintenance and the $2.00 petrol price thresholds (especially if it incorporates a longer data series, as suggested above).

6.7.3 Zone-based elasticities

An opportunity also exists to replicate this research and to segregate the analysis by zone. This means that we could estimate separate fare elasticities by the number of zones travelled.

Zone-based fare elasticities would create options for improved fare recovery because they would allow transport planners to price discriminate more effectively; for example, if patrons travelling four zones are shown to have lower fare elasticities than those travelling shorter distances then an argument could be made that their fares could be increased disproportionately without a detrimental effect on patronage or revenue.

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[19] In production of their patronage statistics, KiwiRail use modelling methods to estimate the number of trips between intermediary stations.

7 Analysis of growth on the Wellington bus system

This chapter presents our analyses of patronage growth on the Wellington bus system:

7.1 Context

The Wellington region is composed of the main city – Wellington – and is connected to a number of neighbouring cities – Porirua, Lower Hutt and Upper Hutt – via roads and train lines.

The bus network that serves the Wellington region can be broadly broken down into two categories:

- The 'Go Wellington' buses operate within the boundaries of Wellington city; these bus services primarily transport patrons between the central business and shopping district and surrounding suburbs.
- The 'Valley Flyer', 'Airport Flyer', Runcimans and Newlands bus services transport patrons to and from the neighbouring cities and, in some cases, provide bus services within those neighbouring cities.

For the purposes of this research project, we focused on bus services that operate within the boundaries of 'Wellington city'. But we envisage that this research could be expanded in the future to accommodate analysis of bus services relating to neighbouring cities.

7.2 Analytical issues

NZ Bus Limited provided us with bus patronage data over the five-year period from April 2005 to March 2010. This bus patronage data was segregated by route and time period (peak weekday/offpeak weekday/Saturday/ Sunday).

We aggregated the bus routes together into bus 'corridors', with each 'corridor' consisting of all bus services that follow a similar route. Some 'corridors' were excluded due to data problems and/or because they did not operate for the whole five-year period.

We note that none of the bus corridors selected experienced any notable increases in the number of services operated. This made econometric analysis relatively simple (compared with other cities and modes) and ensured that any patronage growth patterns observed could be attributed to other explanatory factors like fare increases, petrol prices and key events.

The main analytical issues arose when interpreting and disentangling the causes of historic growth patterns. These challenges are discussed in more depth in section 7.4:

- The September 2006 fare increase overlapped considerably with the punctuality/congestion problems encountered in February 2007.[20]
- The September 2006 and September 2008 fare increases appear to have had quite different impacts on patronage.

[20] These punctuality/congestion problems were caused by an unfortunate combination of factors that created the 'perfect storm': rescheduling of routes around this time, driver shortages and congestion created while traffic adjusted to the new city bypass.

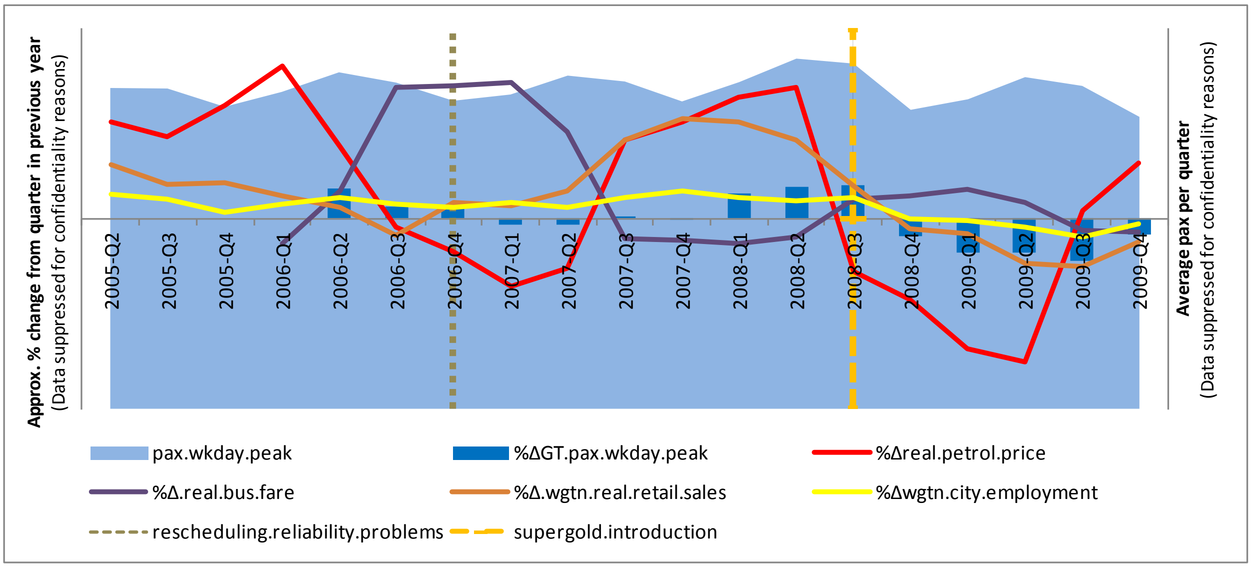
- The September 2008 fare increase coincided with the introduction of the SuperGold Card in October 2008, making it difficult to disentangle the two effects.

7.3 Analysis of historic growth[21]

Patronage growth on the selected bus corridors in Wellington city is shown in figures 7.1 to 7.4, along with key events and growth in various explanatory variables. The key patterns observed are as follows:

- There were two fare increases (September 2006 and 2008) but they did not both have the same impact on patronage:
  - The September 2006 fare increase appears to have had a negative impact on interpeak weekday and weekend patronage yet no discernible impact on weekday peak patronage.
  - The September 2008 fare increase appears to have had a negative impact on peak weekday patronage but no impact on interpeak weekday or weekend; that said, the indiscernible impact on interpeak and weekend could be due to the countervailing impact of the introduction of SuperGold Card in October 2008.
- There is some evidence that petrol prices have an impact on patronage demand, but the evidence for this is not overwhelming.

Figure 7.1 All selected bus corridors – analysis of weekday peak patronage



[21] In regard to graphical interpretation of the graphs provided, we advise the reader to note the distinction between permanent and temporary 'jumps' or 'falls' in patronage levels. A permanent change shows up on a graph as four quarters of unusually high or negative growth. In contrast, a temporary change shows up as a one-off spurt or loss of patronage and is reversed four quarters later.

Figure 7.2 All selected bus corridors – analysis of weekday offpeak patronage

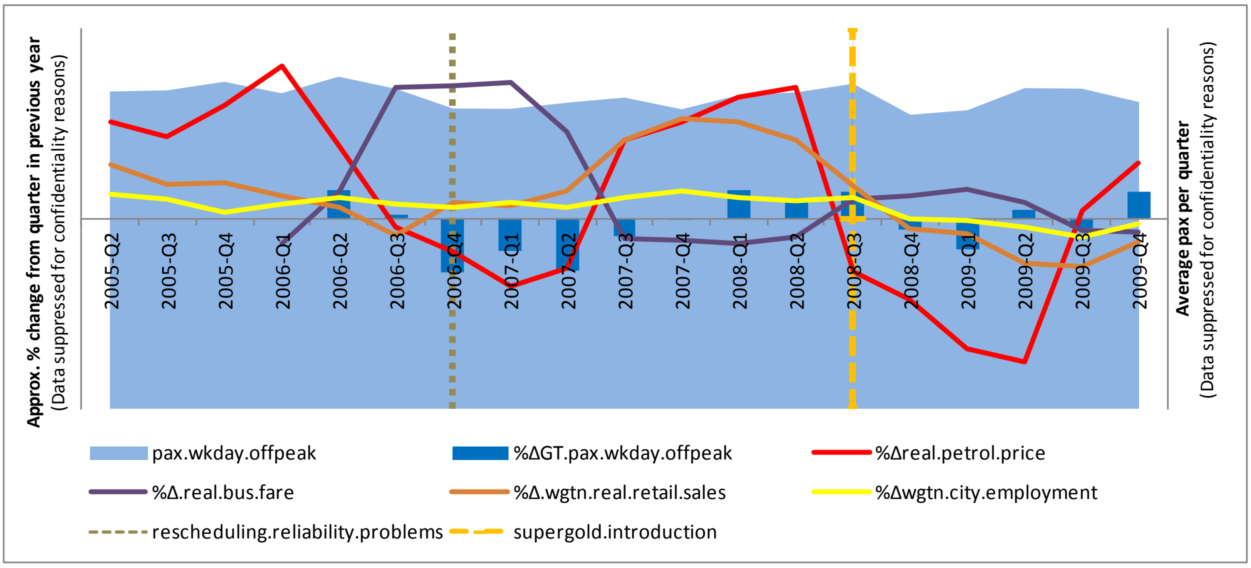


Figure 7.3 All selected bus corridors – analysis of Saturday patronage

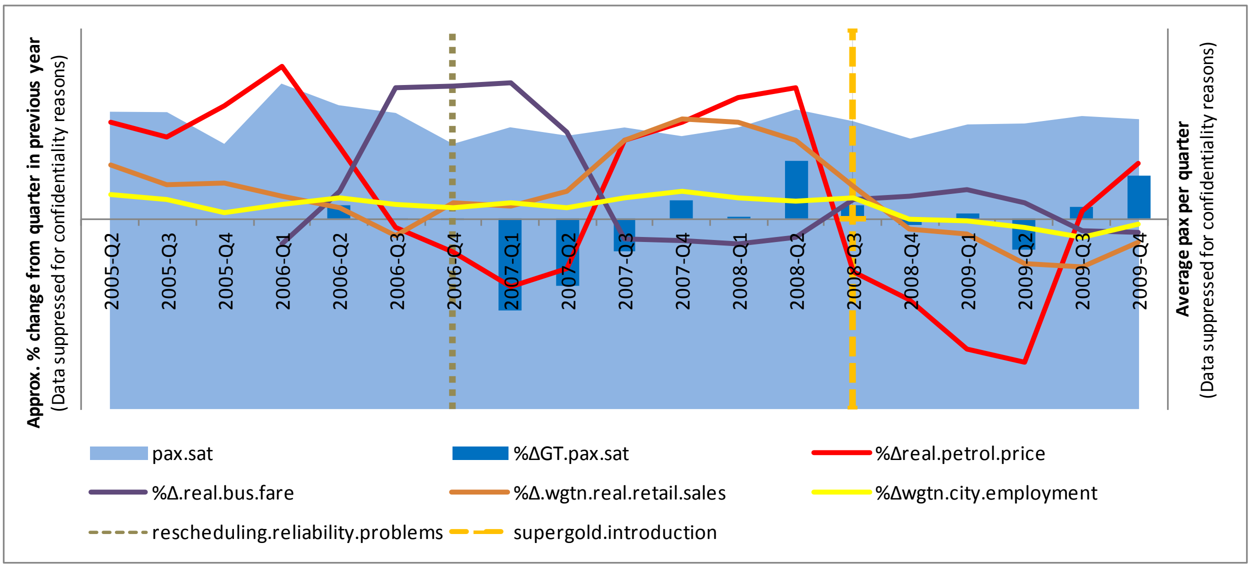
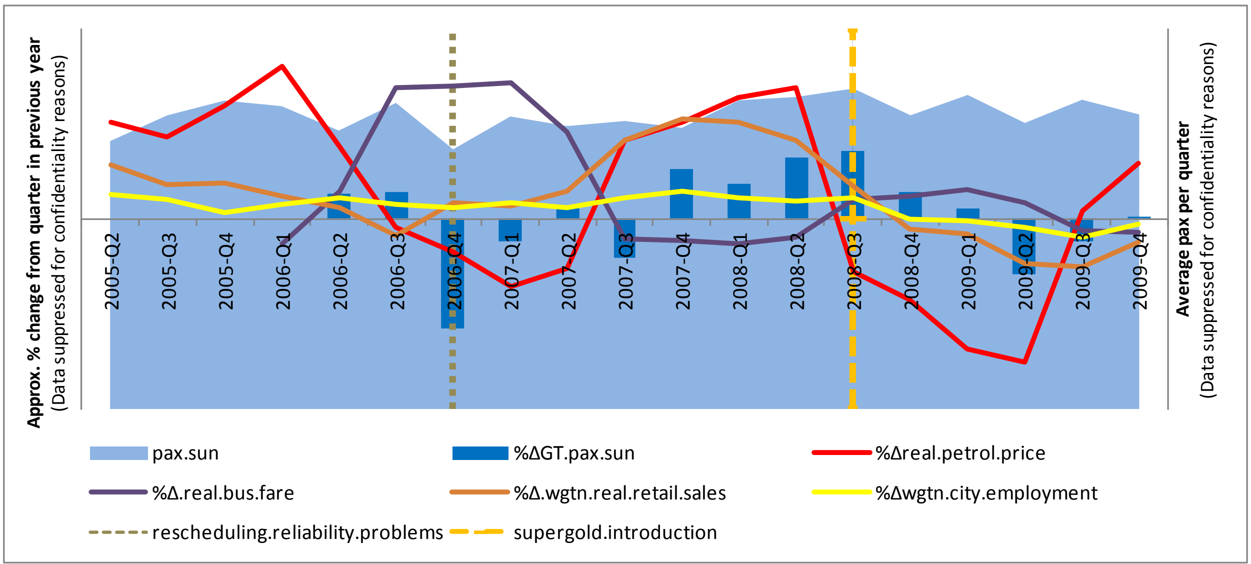


Figure 7.4 All selected bus corridors – analysis of Sunday patronage



In addition, there were unusual spikes in the weekend data. Patronage on Saturdays exhibited a temporary spike in 2006-Q1, hence contributing to negative patronage growth in 2007-Q1. Similarly, patronage on Sundays exhibited a temporary spike in 2005-Q4, hence contributing to negative patronage growth in 2006-Q4. The exact reasons for these spikes are not clear although any combination of the timing of holidays, public events, unusual weather and data errors is a possible explanation. We decided in favour of controlling for these spikes using arbitrary dummy variables.

The econometric analysis of patronage growth presented a number of challenges, all of which are related to disentangling, isolating and understanding the impact of fare increases. We developed a number of approaches to address and mitigate these problems:

- The September 2006 fare increase overlapped considerably with the punctuality/congestion problems encountered in February 2007. Both of these events would have feasibly had a negative impact on patronage and distinguishing those impacts from each other is important. Our solution was as follows:
  - First, we closely examined monthly patronage data for all bus corridors and used our judgement to identify the period in which the February 2007 punctuality/congestion problems might feasibly have had an impact on patronage growth. We concluded that, if rescheduling did have an impact on patronage, it most likely caused a fall in patronage from March 2007 to August 2007.
  - Second, we incorporated the rescheduling impacts into the econometric model by making the assumption that the impacts of the rescheduling, driver shortages and city bypass were temporary; therefore, any impact on patronage that was reversed in the subsequent year was due to punctuality/congestion problems and any permanent impacts were attributed to the September 2006 fare increase.
- The September 2006 and September 2008 fare increases appear to have had quite different impacts on patronage, as discussed earlier. To address this, we discarded the conventional assumption of a single 'fare elasticity' throughout time, and instead estimated a separate fare elasticity for each fare increase.
- The September 2008 fare increase coincided with the introduction of the SuperGold Card in October 2008, making it difficult to disentangle the effects. Since both events occurred at the same time we

were unable to estimate their impacts separately; therefore, the fare elasticity estimates for the 'Real bus fare (September 2008)/+SuperGold (October 2008)' variable represents the combined effect of both the fare increase and the introduction of the SuperGold Card.

7.4 Summary of findings

This section summarises some of the key findings from the econometric analysis of the Wellington city bus system. For more detail about these findings see appendix E.

Table 7.1 shows the impact of key economic variables on patronage during specific periods.

Table 7.1 Elasticity estimates for key economic variables

Economic variables	Weekday		Weekend
	Peak	Offpeak	
Real bus fare (Sep 06)	Removed due to implausible sign	-0.44***	-0.12
Real bus fare (Sep 08)/ +SuperGold (Oct 08)	-0.66*	Removed due to implausible sign	Removed due to implausible sign
Real petrol price	0.13*	0.13***	0.07
Nominal $2.00 petrol price threshold	4%	Removed due to implausible sign	10%*
Real retail sales (Wellington city)	-0.04	0.11 '	0.05
Employment (Wellington city)	0.36	-0.16	-0.46'
Rescheduling/driver-shortage/bypass (Feb/Mar 07)	Removed due to implausible sign	Removed due to implausible sign	-8%'

Note for symbols of statistical significance: *** → 0.1%, ** → 1%, * → 5%, ' →10%

The key findings from table 7.1 are:

- The first fare increase in September 2006 had a negative impact on offpeak weekday and weekend patronage but not on peak weekday patronage.
- The second fare increase in September 2008 reduced peak weekday and weekend patronage but had no discernible impact on offpeak weekday or weekend patronage; however, this was most likely due to the countervailing impact of the introduction of the SuperGold Card in October 2008.
- Petrol prices had a discernible impact on patronage, via some combination of price fluctuations and the $2.00 nominal petrol price threshold.
- The employment elasticity of +0.3 for peak-time patronage is plausible but we note it is not statistically significant and there is a wide confidence interval around it.
- We note that the punctuality/congestion problems that arose in February 2007 appear to have had an indiscernible impact on weekday patronage, and the impact on weekend patronage is not statistically significant. That said, the discovery of reliability data relating to this time and/or alternative means of modelling those reliability problems could potentially change this finding.

7.5 Confidence in findings

Our attempts to estimate the impacts of the September 2008 fare increase and the economic problems of 2008 were complicated by the introduction of the SuperGold Card around the same time (October 2008):

- There was a drop-off in peak-time patronage coinciding with the September 2008 fare increase and the drop in employment around the same time. We estimate a peak-time fare elasticity of -0.4 and regard that as plausible. However, a portion of this could also be attributed to seniors shifting trips from the peak to the offpeak to take advantage of free travel.
- The September 2008 fare increase appeared to have no impact on offpeak weekday or weekend patronage. But we think this may be due to the countervailing effect of the introduction of the SuperGold Card in October 2008.

We recommend that the problems mentioned above would be mitigated by incorporating a market segmentation approach (see section 7.8.3) in future analyses. A market segmentation approach would separate out senior patronage from adult patronage and hence enable us to isolate and control for the contribution of SuperGold.

We have less confidence in our approach to control for the impact of punctuality/congestion problems in February 2007. Due to a lack of data on reliability around this time, we had to assume that the reliability problems had the same effect across all bus corridors; this assumption may not be correct and it may explain why we were unable to estimate a discernible impact of the punctuality/congestion on patronage. To some extent this problem may have been mitigated by the removal of a number of corridors with unexplained behaviour in the residuals (notably Seatoun, Newtown Park and Khandallah). This may be because these corridors experienced more dramatic responses to the rescheduling/driver shortages/city bypass problems, but our econometric modelling approach was unable to accommodate this.

We have less confidence in the September 2006 fare elasticity estimates because the September 2006 fare increase overlapped with the punctuality/congestion problems in February 2007 and, as mentioned above, we are not confident that the assumptions made about the impact of rescheduling are correct.

We have moderate confidence in the overall story told by the estimates for petrol price elasticities and petrol price thresholds. The overall story is that petrol price impacts are a combination of a general petrol price elasticity of +0.1 and a $2.00 nominal petrol price threshold of about +5%. This is plausible and consistent with findings elsewhere.

7.6 Recommendations and policy implications

The research project was held back by lack of data on the punctuality/congestion problems in February 2007. Therefore, we commend Greater Wellington for their initiative in introducing real-time information systems and recommend that any reliability data being collected by Greater Wellington be monitored on a regular basis to ensure that a lack of data is not a problem in the future.

The fare elasticity estimates presented in table 7.1 appear to have been distorted by the introduction of the SuperGold Card. To address this problem, we recommend further analysis of the fare increases involving disaggregation by demographics (adult, child, senior, etc), ticket type and number of zones covered. Such analyses would produce fare elasticities broken down by market segment; these fare elasticities would provide Greater Wellington with tools to target fare increases so as to increase cost recovery without unduly impacting on patronage.

We recommend that policy makers and transport planners keep in mind that petrol prices seem to have an impact on bus patronage, at least in Wellington, that is more complex than that assumed in most of the transport economics literature. It appears that psychological barriers and thresholds play a crucial role.

7.7 Opportunities for further research

7.7.1 Introduction

Section 11.4 provides a comprehensive description of all of the possible avenues for further research, taking into account the findings across all cities and modes.

The following sections discuss further research as it applies specifically to the Wellington bus system.

7.7.2 Post-evaluation of proposed changes to the Wellington bus network and incorporation of cost benefit analysis

Section 7.5 did not present any service elasticities because there have not been any major changes to service levels on the Wellington bus network during the five-year period observed. However, a number of major changes to the network and service levels have been recently announced by Greater Wellington and will be carried out, on a staggered basis, over several years. This presents an exciting opportunity to apply the econometric methods demonstrated by this research project to 'post-evaluate' the effectiveness of those network changes *as they are being implemented*. However, to do this effectively there needs to be accurate and effective data collection systems in place, and details regarding network and timetable changes need to be recorded and documented. We strongly recommend that Greater Wellington and/or NZ Bus monitor their data collection systems to ensure that this occurs.

The 'post-evaluation' could be modified to incorporate a cost–benefit analysis (CBA) of past investments. We can envisage a process in which cost data is used to calculate the average cost of each extra patron generated by a service improvement. That cost can then be assessed against the social and economic benefits arising from the extra patronage.

7.7.3 Market segment analysis

The dataset provided by NZ Bus is very detailed and provides patronage data by ticket type; therefore, the econometric methods employed in this research project could be expanded to enable disaggregated analysis by demographics (ie child, adult, student, senior), length of trip and other ticket-based characteristics.

Ticket-based analysis would allow us to better isolate and control for demographic factors and ticket-based changes. Ticket-type analysis would enable us to more accurately answer the following questions:

- What has been the impact of demographic-specific events, such as the introduction of the SuperGold Card?
- What has been the impact of changes to ticket options (eg the introduction of Snapper) and changes to the fare structure (eg increases in cash fares relative to electronic ticketing) on ticket sales?
- Where has the growth in patronage in recent years come from? Has that growth come from particular market segments (eg students, long-distance travellers)? Answers to these questions may inform future marketing strategies by identifying the best market segments to target in the future.

7.7.4 Zone-based elasticities

The market-segment-based analysis discussed above would also lend itself to the estimation of ticket-based elasticities that are segregated by demographics, length of trip and ticket type. This type of analysis would assist transport operators and providers in improving cost-recovery rates by providing answers to the following questions:

- Can we raise fare recovery rates by engaging in price discrimination?
- Can we charge higher fares to certain market segments and hence improve revenue while minimising the negative impact on rail patronage growth?

7.7.5 Broadening of coverage

The research presented here has focused on Wellington city bus patronage. However, the econometric analysis could potentially be broadened to include bus patronage in the wider Wellington region, including the ‘Valley Flyer’, ‘Airport Flyer’, Runcimans and Newlands bus services.

7.7.6 Further investigation using longer time series

As noted in section 7.8.1, there is an opportunity to update this research on an ongoing basis over the next few years. This updated research will present the following benefits for the NZ Transport Agency and Greater Wellington:

- This research project investigated fare elasticities for both the 2006 and 2008 fare increases, and the dataset ended in 2010–Q1. However, there have since been further changes to the fare structure in late 2010, 2011 and 2012. Further research could investigate the impact of these changes and consequently examine what the general trends are in regard to fare elasticities.
- The impact of the $2.00 petrol price threshold can be re-investigated. We note that this threshold has since been ‘breached’ again recently and it would be interesting to see if it has had a similar impact as before.

8 Analysis of growth on the Hamilton bus system

This chapter presents our analyses of patronage growth on the Hamilton bus system:

8.1 Context

The Hamilton city bus network consists of city-based services that connect the suburbs of the city with the central business and shopping district. There are also regional services but we have chosen not to focus on them for the purposes of this research project.

Over recent years, the Hamilton city bus network has been modified and expanded considerably via a combination of the following: improved service levels, changes to existing routes, route restructuring and new services. These improvements have been associated with considerable growth in patronage.

8.2 Analytical issues

A number of the improvements to the Hamilton city bus network came via new services. Isolating and estimating the impacts of these new services was problematic because the catchment areas for these new services often overlapped with other existing services. We judged that this would overcomplicate the process of econometric analysis and that, given the seminal nature of this research project, we would focus on 'selected routes' that had a consistent history throughout the period studied.

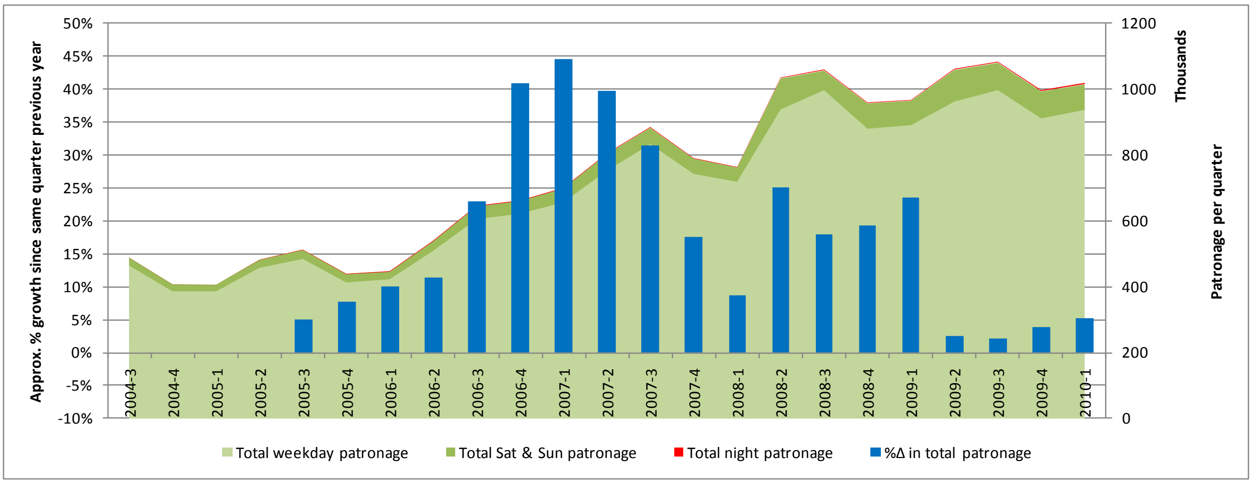
The other analytical challenge involved explaining a number of growth spurts throughout the period studied. The explanations that we identified are discussed in section 8.4.

8.3 Analysis of historic growth[22]

The Hamilton city bus system has been characterised by rapid patronage growth from 2004 to 2009, as shown by figure 8.1. Total patronage per quarter roughly doubled from about 500,000 to 1,000,000 during this period.

[22] In regard to graphical interpretation of the graphs provided, we advise the reader to note the distinction between permanent and temporary 'jumps' or 'falls' in patronage levels. A permanent change shows up on a graph as four quarters of unusually high or negative growth (eg in figure 8.2, there were four periods of positive growth from 2006–Q4). In contrast, a temporary change shows up as a one-off spurt or loss of patronage and is reversed four quarters later.

Figure 8.1 Patronage and patronage growth across all routes



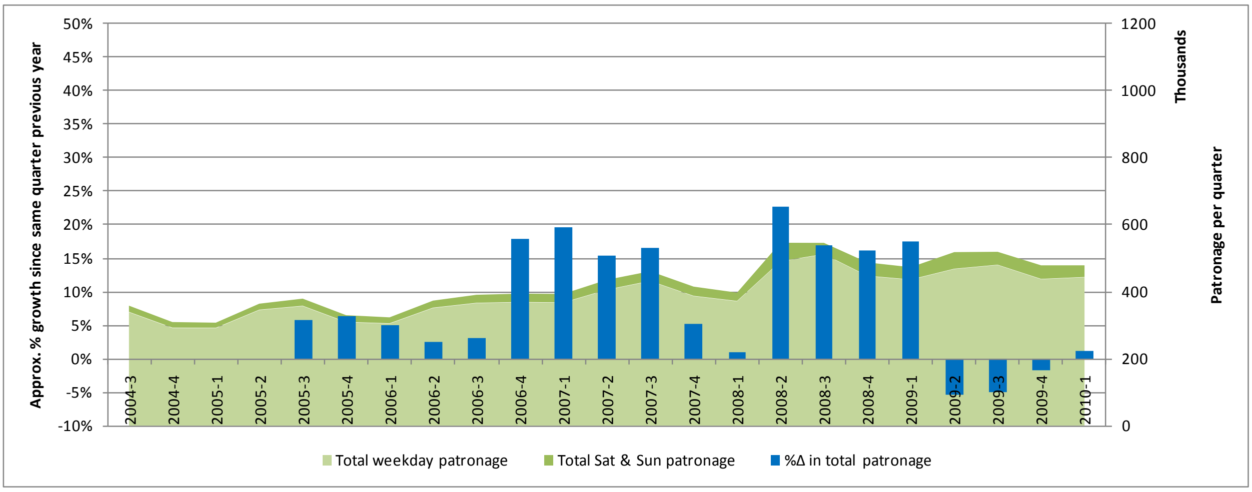
A key factor behind this patronage growth has been the introduction of new routes such as the Orbiter, the CBD shuttle, the Rototuna (16), the Hamilton East Uni (17), and the City Express (55).

The existence of new routes and route restructuring complicates econometric analysis. Therefore, for the purposes of this seminal piece of research, we chose to focus on routes that meet the following criteria:

- The route existed throughout the six-year period.
- The route was not in the 'catchment area' of any of the new routes, and was hence unaffected by the introduction of any of the new routes.

Figure 8.2 shows total patronage and patronage growth for these 'selected routes'.

Figure 8.2 Patronage and patronage growth across 'selected routes'



Patronage growth is not as extreme as before, but there are still two periods of rapid growth:

- The first growth spurt was in 2006-Q4. The year-on-year patronage growth figures in figure 8.2 provide evidence that something happened around 2006-Q4 that caused a permanent jump in patronage: for the whole 'year' from 2006-Q4 through to 2007-Q3 patronage was 15% to 20% higher than it was in the previous year.

- The second growth spurt was in 2008–Q2 when patronage again jumped by about 15% to 20%. Again, there is evidence in figure 8.2 that this was a permanent increase in patronage.

One of the key challenges of this project has been to understand and disentangle the possible causes of these growth spurts.

We conclude that the first growth spurt was most likely due to some combination of the following factors:[23]

- In September-October 2006 and February 2007, a number of service trips were added to enhance off-peak weekday timetables; these additional service trips appear to have had not only a direct impact on off-peak weekday patronage but also an indirect impact on peak weekday patronage and also weekend patronage. See section F2 in appendix F for a summary of the impacts of these and other service enhancements.
- In October 2007 it appears that the two-hour free transfer initiative was introduced. This enabled patrons to make unlimited trips on Hamilton city buses using the same ticket within two hours of original purchase. This meant that patrons could make short-duration trips (eg shopping trips) on a single ticket.
- In October 2007, there was a free ticket promotion. Vouchers were sent out in local papers entitling patrons to free trips on Hamilton buses. This would have encouraged some people to 'try out' the Hamilton buses and could have had both a temporary and permanent impact on patronage.

Even after controlling for the impact of the improvements to offpeak timetables there was still a permanent 9% jump in off-peak weekday patronage and a 16% jump in weekend patronage in the year following October 2007. It seems plausible to us that the free ticket promotion was the main cause of the temporary jump in patronage, while the two hour free transfer was the main cause of the permanent jump in offpeak patronage.

We conclude that the second growth spurt was most likely due to some combination of the following factors:

- The V8 races in April 2008 placed considerable demands on the public transport system, especially during the weekend, and this shows up as higher than usual patronage growth in 2008–Q2.
- During the period from 22 May 2008 to 13 August 2008 (roughly corresponding with 2008-Q3) the nominal price of regular petrol crossed the $2.00 threshold. There is reason to believe that the crossing of this threshold may have been a key trigger for behavioural change. Indeed, we estimate that this event caused patronage to jump by about 2% to 8%.
- In July 2008 and Feburary 2009 (ie 2008–Q3 and 2009–Q1) the Pukete Direct and the Silverdale Direct were introduced to supplement the Pukete (1) and Silverdale (2) routes These enhancements had a significant impact on peak-time patronage.
- In September 2008 (ie 2008–Q3) Sunday services were introduced on certain 'key routes' based on the same timetable as the pre-existing Saturday services. Weekend patronage on these 'key routes' more than doubled over the next year or so.

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[23] One other explanation largely discarded included the introduction of the Orbiter in July 2006. This explanation was dismissed for the following reasons:

- The introduction of the Orbiter predates the growth spurt, which did not occur until at least October 2006.
- The Orbiter exhibited gradual growth in patronage which is inconsistent with the sudden jump in patronage shown in figure 8.2

Of course, there may be other factors that we have not been able to identify or control for. In particular, the graphical analysis in section F3 of appendix F notes that a number of routes still exhibited jumps in patronage during the 2008–Q2 to 2009–Q1 period that cannot be explained completely by the factors above.

8.4 Summary of findings

This section summarises some of the key findings from the econometric analysis of the Hamilton city bus system. For more detail about these findings see appendix F.

Table 8.1 shows the impact of key economic variables on patronage (excluding SuperGold), weekday peak, weekday off-peak and weekend.

Table 8.1 Elasticity estimates for key economic variables

Economic variables	Weekday		Weekend
	Peak	Offpeak	
Real bus fare elasticity	Removed due to implausible sign	Removed due to implausible sign	-1.20***
Real petrol price cross-elasticity	0.20‘	Removed due to implausible sign	Removed due to implausible sign
$2.00 petrol price threshold dummy (2008–Q3)	6%‘	8%***	2%
Real retail sales	0.03	-0.86***	0.80‘
Employment	0.17	0.24	0.36
Introduction of SuperGold Card (Oct 2008)	Not applicable to peak	Removed due to implausible sign	Removed due to implausible sign
Generic dummy for temporary growth spurt in 2006–Q4 (ie ticket promotion)	9%***	-4%	Removed due to implausible sign
Generic dummy for permanent growth spurt in 2006–Q4 (ie two-hour free transfer)	Removed due to implausible sign	9%*	16%***

Note for symbols of statistical significance: *** → 0.1%, ** → 1%, * → 5%, ‘ →10%

The key findings from table 8.1 are:

- There were a number of fare increases during the period observed, and yet these did not have a discernible impact on offpeak weekday patronage. However, weekend patronage did seem quite responsive to fare increases with an estimated elasticity of -1.2.
- Real petrol price elasticities were +0.2 during the weekday peak and the $2.00 petrol price thresholds had a discernible impact on weekday patronage (both peak and offpeak).
- Real retail sales seemed to have a negative association with offpeak patronage but a positive relationship with weekend patronage.
- The relationship between employment and patronage was positive across all periods, but modest and not statistically significant.
- Even after controlling for all other factors, there was still a jump in patronage in 2006–Q4.
  - The jump in peak weekday patronage was largely temporary and can probably be attributed to the free ticket promotion around this time.
  - The jump in offpeak weekday and weekend patronage can probably be attributed to some extent to the free ticket promotion but mostly to the free two-hour transfer that appears to have been

introduced around this time. This transfer essentially offered a half-price discount to patrons making trips of a short duration and we would expect it to be popular during the offpeak and, in particular, on the weekend.

Table 8.2 shows the impact of service improvements on patronage. One interesting finding from this research has been evidence of ‘network effects’: changes to a timetable during a certain time period (peak, off-peak, Saturday, Sunday) have a direct impact on patronage during that time period and an indirect patronage impact on patronage during other time periods. Direct impacts are shown in table 8.2 in orange shading. Indirect impacts are shown unshaded and in *italics*. For example, we estimate that the doubling of off-peak weekday frequency on the Bremworth/Temple View (26) had a direct impact on offpeak weekday patronage represented by the elasticity of +0.76, but it also had an indirect impact on peak weekday patronage and weekend patronage, as represented by the cross-elasticities of *+0.40* and *+0.34*.

Table 8.2 – Elasticity estimates for service changes

Service trip elasticities		Weekday		Weekend
		Peak	Offpeak	
Peak weekday service improvements	Intro. of Pukete direct (Jul 08)	0.43***		
	Intro. of Silverdale direct (Sep 08)	0.40**		
	Intro. of Dinsdale direct (Jul 08)	Removed due to implausible sign		
	Extra peak morning services (Oct 06, Feb 09)	Removed due to implausible sign		
Offpeak weekday service improvements	Doubling of frequency on route 9 (Oct 06)	*0.03*	0.22‘	*0.20*
	Doubling of frequency on route 12 (Feb 07)	*0.13*	0.60***	*Omitted*
	Doubling of frequency on route 26 (Sep 06)	*0.40***	0.76***	*0.34‘*
	Extension of evening hours on Mon-Wed from (about) 6pm to 7.30pm (Oct 06, Feb 07)	Removed due to implausible sign	0.82‘	
	More regular hours lunchtime and evening (Feb 07)	*0.83**	0.60‘	
	Further extension of evening hours on Mon-Thur from (about) 7.30pm to 10pm (Feb 09)		Removed due to implausible sign	
Weekend service improvements	Provision of more regular lunch hours on Saturday (Sat, Feb 07)			2.18***
	Introduction of Sunday services (Sep 08)			
	• impact during first month			0.81**
	• impact after 2-4 months			0.97***
	• impact after 5-12 months			0.95***
	• impact during subsequent year			0.30***
	Extension of hours (Sat, Sun, Feb 09)			Removed due to implausible sign

Note symbols of statistical significance: *** → 0.1%, ** → 1%, * → 5%, ‘ →10%

The key findings from table 8.2 are:

- The introduction of the direct services had service elasticities of around +0.4 in two instances and zero impact in the other instance.
- The doubling of offpeak frequency on a selection of routes had service elasticities ranging from +0.2 through to +0.8. However, there was evidence of considerable 'network effects' because these offpeak weekday timetable improvements seemed to have a positive impact on both peak weekday patronage and weekend patronage.
- The extension of hours for weekday services from about 6pm to about 7.30pm had a positive impact on patronage. But there was also evidence of diminishing returns: the further extension of hours from about 7.30pm to about 10pm did not have the same effect.
- The refinement of timetables to make them more regular was well received and was associated with high service elasticities both during the weekday and on weekends.
- The Sunday service elasticities imply that the introduction of the Sunday services (ie a 100% increase in weekend service trips) was associated with a 95% increase in weekend patronage within a year and another 30% increase in patronage within the subsequent year. This meant that, overall, weekend patronage increased by about 125% upon the introduction of Sunday services.

8.5 Confidence in findings

For statistical reasons, we have relatively strong confidence in the service elasticities presented in table 8.2. Our statistical model estimates these elasticities by contrasting patronage growth on the routes with service enhancements against 'control' routes in which there were no service enhancements – this approach produces reasonably accurate estimates.

We have moderate confidence in the elasticities produced in table 8.1 for the impact of economic variables. The statistical model employed relates patronage growth over time to changes in these economic variables over time. With such a short period (six years) there is a risk that the model incorrectly associates patronage trends with coincidental movements in the economic variables. For example, the fare increases in April 2009 and December 2009 are associated with a fall in weekend patronage across the bus system, but this relationship could be purely coincidental or, in truth, related to variables that have been omitted from the model.

We have the lowest confidence in estimates of the impact of one-off 'events' such as the impact of the free-ticket promotion. The statistical model can show that there was a discernible jump in patronage, across a number of routes, that occurred at the same time as these events but there is always the risk that there is another event or factor that is actually causing the jump in patronage.

8.6 Recommendations and policy implications

The findings in table 8.1 suggest that future fare increases will have a minimal impact on peak and offpeak patronage. But future fare increases could have some serious implications for weekend patronage; taken at face value the weekend fare elasticity of -1.4 implies that fare increases will actually decrease weekend fare revenue. This result may be an anomaly, but attention should be given to studying the impact of any future fare increases to see if this trend persists.

The findings in table 8.2 suggest that some of the recent extensions of hours have not been very effective at increasing patronage; there appear to be diminishing returns to these sorts of service improvements.

However, table 8.2 also points towards service improvements that have been effective at increasing patronage, including direct services and doubling of frequency. However, the biggest gains appear to come from minor changes to timetables to improve regularity around lunchtime and in the evening.

8.7 Opportunities for further research

8.7.1 Introduction

Section 11.4 provides a comprehensive description of all of the possible avenues for further research, taking into account the findings across all cities and modes.

The following sections discuss further research as it applies specifically to the Hamilton bus system.

8.7.2 Further post-evaluation of service improvements

As section 8.4 notes, we chose to focus only on ‘selected routes’ that were not complicated directly or indirectly by the presence of new routes or route restructuring. However, we can envision an extension of this research in which the analysis is broadened to include all routes in Hamilton city; this would be a more challenging task but it would allow us to control for and to assess this contribution of new routes and route restructuring to total patronage.

8.7.3 Incorporation of cost–benefit analysis into post evaluation

Similarly, the ‘post-evaluation’ could be modified to incorporate a CBA of past investments. We can envisage a process in which cost data is used to calculate the average cost of each extra patron generated by a service improvement. That cost can then be assessed against the social and economic benefits arising from the extra patronage.

8.7.4 Further investigation using a longer time series

One opportunity exists in replicating this research at some point in the near future, so as to exploit the longer time series that will available. One of the key objectives of such research would be to keep an eye on fare elasticities. The research in this report shows that fare increases do not have a discernible impact on patronage; however, we expect that if fares continue to rise then this situation may change and it would be worth monitoring the response.

8.7.5 Market segment analysis

Another avenue of further research would involve obtaining route-level patronage data segregated by ticket type, which would enable market segment analysis. At the time of this project, such data was not being made available due to tension between the Waikato Regional Council and their data provider. However, if such data can be made available then more sophisticated analysis can be done, such as segregation by ticket type (child, adult, senior).

8.7.6 Research into the impact of free transfers on revenue

From what we can ascertain, a two-hour free transfer was introduced in October 2007, and this seemed to have contributed to a 6% jump in off-peak weekday patronage and a 16% jump in weekend patronage.

To us, this seems plausible because the free transfer is (in effect) offering a half-price return trip for short-duration trips. This means that patrons can go down town for, say, a short shopping trip or coffee with a friend but they only pay for one way. This was possibly not the intention of the original initiative but it is quite plausibly a consequence.

The two-hour free transfer was reduced to one hour in November 2011.

We propose further research to evaluate the impacts on revenue of both the introduction of the free two-hour transfer in October 2007, and the reduction to one hour in November 2011. There are reasons for thinking that the net effect of either of these changes could be positive or negative:

- On one hand, a free transfer causes the Waikato Regional Council to lose return fares that some patrons might have been willing to pay.
- On the other hand, a free transfer could act as a crude form of price discrimination, maximising potential revenue by charging full price for commuting and long-duration trips and half-price for short-duration trips.[24]

The findings from further research would be of interest to other transport operators that are either contemplating the introduction of a free transfer or making decisions regarding the length of time that should be provided as part of their free transfer schemes.

[24] We also note that these types of price discrimination can potentially encourage better utilisation of spare capacity in a public transport network because they encourage offpeak use. The marginal cost of additional offpeak patrons is often relatively low because buses are rarely full during these times.

9 Analysis of growth on the Tauranga bus system

This chapter presents our analyses of patronage growth on the Tauranga bus system:

9.1 Context

The Tauranga bus system is of a modest size and consists of a small number of routes that serve the suburbs of Tauranga city.

The Tauranga bus system is an exciting case study because there were a number of notable and interesting service improvements. In particular, there were a number of bus routes where frequency was doubled from an hourly service to a service with a 30-minute headway. There were also a number of bus routes in which the hours of operation were extended. Our estimates for the impact of those service improvements showed remarkable consistency.

9.2 Analytical issues

Patronage and service data for the Tauranga bus system was provided to us by the Bay of Plenty Regional Council (BOPRC) for the period from 2005–Q3 to 2009–Q2. We were advised that data beyond 2009–Q2 was not available at the time and, in any case, would not be comparable due to a number of significant changes to the bus network, including a change to the fare structure and the 'rejigging' of existing routes.

The patronage and service data was disaggregated into weekday and Saturday. Unfortunately, in the data provided to us, there is no further disaggregation (eg peak/interpeak/evening). Furthermore, there was no Sunday data because Sunday services were not provided until after 2009–Q2.

9.3 Analysis of historic growth[25]

Figures 9.1 and 9.2, respectively, show growth in weekday and Saturday patronage across all the routes in Tauranga city. Both figures show strong growth in patronage during the period analysed.

[25] In regard to graphical interpretation of the graphs provided, we advise the reader to note the distinction between permanent and temporary 'jumps' or 'falls' in patronage levels. A permanent change shows up on a graph as four quarters of unusually high or negative growth. In contrast, a temporary change shows up as a one-off spurt or loss of patronage and is reversed four quarters later.

Figure 9.1 Patronage growth on weekday services

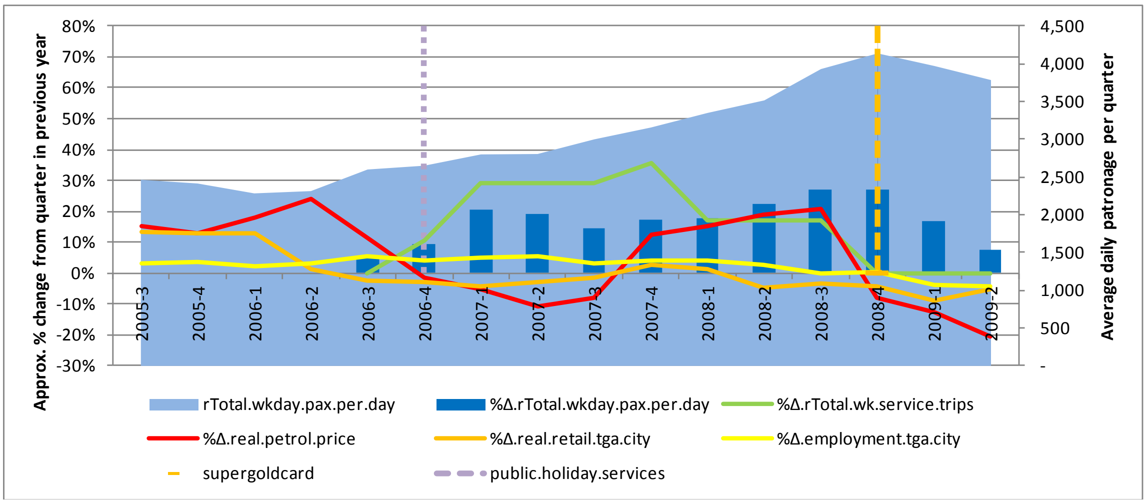

Figure 9.1 shows that weekday patronage has exhibited consistently high growth since early 2007. We attribute this to a combination of the following:

- service timetable improvements in October 2006 and December 2007, including a doubling of service frequency on some routes and an extension of hours
- introduction of the SuperGold Card in October 2008
- introduction of a new Lakes (12) service in May 2008.

After controlling for the changes mentioned above, we found that growth in weekday patronage fell to a more plausible 2% per annum. Furthermore, some of this growth could be attributed to the impact of inflation; there were no fare increases during the period studied so, in real terms, fares actually declined making Tauranga's buses relatively more appealing.

Figure 9.2 Patronage growth on Saturday services

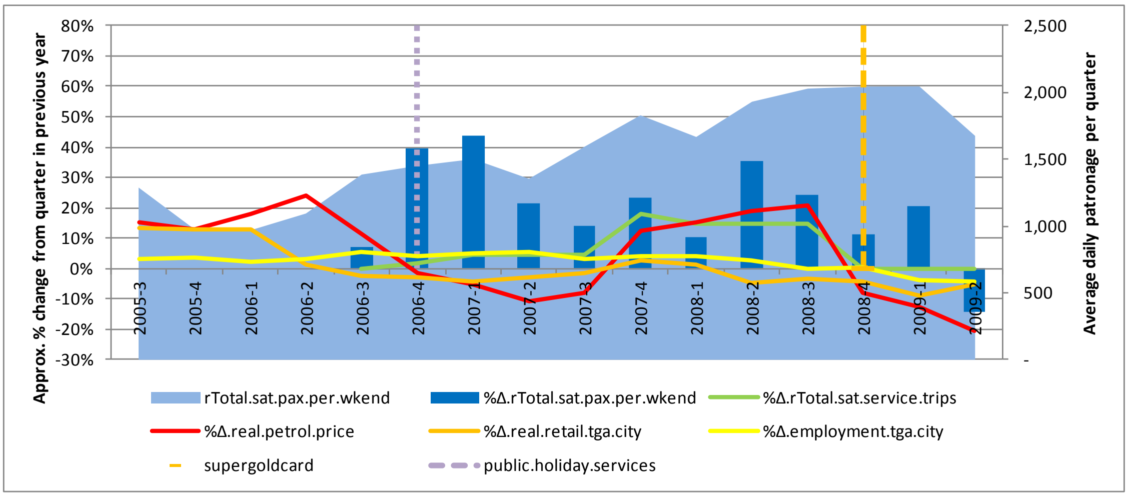

Figure 9.2 shows that Saturday patronage has exhibited high growth since early 2007, but the pattern of growth is more volatile; this volatility lowers our confidence in any inferences regarding growth of Saturday patronage.

There was a significant jump in Saturday patronage in 2006-Q4 and 2007-Q1. We conclude that this was due to the introduction of public holiday services in October 2006. Prior to October 2006, services did not operate on a Saturday if it fell on a public holiday. However, the ticketing system calculated 'patronage per Saturday' based upon all Saturdays rather than just Saturdays in which services operated.

There was a sharp shift in growth rates for Saturday patronage from positive in 2009–Q1 to negative in 2009–Q2. This was observed across most routes. The reasons for this are not clear but the BOPRC did suggest that this may have been caused by data errors associated with changes to electronic data collection from July 2009 onwards.

The other factors that had a discernible impact on Saturday patronage growth are:

- an extension of hours on a number of routes in December 2007
- the December 2007 transition of the Greerton (7) service into an 'orbiter-type' service was accompanied by an 125% increase in service frequency
- introduction of the SuperGold Card in October 2008
- introduction of a new Lakes (12) service in May 2008.

We also found some evidence, albeit not overwhelming, of a 'network effect'; the improvements to the weekday timetable October 2006 and December 2007 may have had a positive impact on Saturday patronage.

However, even after for the changes mentioned above, we still found unexplained growth in Saturday patronage over time of about 8% per annum. This suggests that there were other factors at play that may have been omitted from our model.

9.4 Summary of key findings

This section summarises some of the key findings from the econometric analysis of bus routes operated in Tauranga city. For more detail about these findings see appendix G.

Table 9.1 shows the impact of key economic variables on weekday and Saturday patronage.

Table 9.1 Elasticity estimates for key economic variables

Economic variables and events	Weekday	Saturday
Real petrol price cross-elasticity	0.25*	Removed due to implausible sign
$2.00 petrol price threshold dummy	8%	41%***
Real retail sales cross-elasticity	0.06	1.48‘
Employment cross-elasticity	1.22***	0.94
Introduction of SuperGold Card dummy	16%***	9%‘
Easter	Removed due to implausible sign	-8%**

Note for symbols of statistical significance: *** → 0.1%, ** → 1%, * → 5%, ‘ →10%

The key findings from table 9.1 are:

- The impact of petrol price movements on weekday patronage can be represented by a combination general petrol price cross-elasticity (+0.25) and a threshold associated with the crossing of the $2.00 nominal petrol price (+8%).
- The impact of petrol price movements on Saturday patronage appears to occur completely via the $2.00 nominal petrol price threshold, and also at a very high level (+41%); this seems implausible and may rather reflect the general volatility of the Saturday patronage data.

- We found that Saturday patronage was strongly associated with growth in retail sales, whereas weekday patronage was more strongly associated with employment growth; this is consistent with the idea that Saturday patronage is strongly driven by people who travel for the purposes of shopping, entertainment, etc while weekday patronage is dominated by commuters.
- The introduction of the SuperGold Card appears to have had an impact on both weekday and Saturday patronage.
- We note that Easter is negatively associated with Saturday patronage growth. This is a bemusing result: on one hand, we would expect people to go on holiday during Easter so this makes sense; on the other hand, the Tauranga Jazz Festival occurs during Easter and we had anticipated that this would have increased patronage. Perhaps this can be taken as evidence that more can be done to exploit potential bus patronage during the jazz festival.

Table 9.2 demonstrates how a panel data model can be used for a 'stocktake' of the effectiveness of past investments in public transport.

Table 9.2 Elasticity estimates for service improvements

Service elasticities	Weekday	Saturday
Doubling of frequency from hourly to 30min + extension of hours:		
Mount-Bayfair (1&2), Oct 07	0.46**	
Matua-Brookfield (4&5), Oct 07	0.32'	
Doubling of frequency from hourly to 30min:		
Matua-Brookfield (4&5), Dec 06	0.17	
Windermere Ohauiti (8), Dec 06	0.51***	
Welcome Bay (9), Dec 06	0.46***	
Bethlehem Brookfield (10), Oct 07	0.41***	
Extension of hours:		
Matua-Brookfield (4&5), Dec 06		0.69
Windermere Ohauiti (8), Dec 06		1.55*
Welcome Bay (9), Oct 07, Dec 06	1.65***	0.75
Introduction of express service:		
Papamoa (6), Dec 06, immediate impact (0–4 qtrs)	0.25*	
subsequent impact (5–8 qtrs)	0.14	
cumulative impact (0–8 qtrs)	0.39	
Transition to orbiter-type service:		
Greerton (7), Oct-07	-0.37	0.35*
'Network effects' of weekday timetable service improvements on Saturday patronage		0.12
Key weighted averages:		
Service changes involving doubling of frequency	**0.4**	
Service changes involving an extension of hours	**1.2**	
Service changes involving an express service	**0.4**	

Note for symbols of statistical significance: *** → 0.1%, ** → 1%, * → 5%, ' →10%

The key findings from table 9.2 are:

- The doubling of frequency from hourly to half-hourly had an average service elasticity of +0.4; this means that doubling frequency caused patronage to increase by about 40%. This was a reasonably consistent finding across all routes.
- The introduction of express services had both an immediate impact (+0.25) and a delayed impact (+0.14) and these added up to +0.4.
- The service elasticity for extension of hours was surprisingly high (+1.2). These extensions of hours involved relatively modest changes to the timetable[26] yet have a strong patronage benefit. For example, suppose that an extension of hours increases total service trips by 10%; the estimates in table 9.2 imply this would increase patronage by about 12%.
- The estimate for 'network effects' produces a service elasticity of +0.12. This implies that a doubling of weekday frequency causes a 12% increase in Saturday patronage. However, the service elasticity is not statistically significant so this can only be taken as modest evidence of network effects.

Table 9.3 shows how we estimated a 'service elasticity' for the new Lakes (12) route, hence demonstrating how econometric tools can be used to assist transport planners in comparing the benefits of new routes against improving existing routes:

Table 9.3 Calculation of net 'service elasticity' for the introduction of the Lakes (12) route

Calculation steps	Weekday	Saturday
% increase in trips across city	8%	6%
% increase in patronage in city that was directly associated with the new Lakes (12) service	4%	2%
Gross 'service elasticity'	0.49***	0.29***
Less patronage 'cannibalised' from Pyes Pa (11)	-11%'	Dropped
Net 'service elasticity'	**0.44**	**0.29**

Note for symbols of statistical significance: *** → 0.1%, ** → 1%, * → 5%, ' →10%

A simple regression model was used to estimate the gross 'service elasticity' shown in table 9.3. The panel data model used to produce the findings in tables 9.1 and 9.2 was used to estimate the patronage that the new Lakes (12) appears to have 'cannibalised' from the neighbouring Pyes Pa (11) service. This enabled us to calculate a net 'service elasticity'.

9.5 Confidence in findings

We have strong confidence in the service elasticities presented in table 9.2 because they have very desirable statistical properties; these estimates are produced by comparing the patronage growth on a corridor with a service change against 'control routes' (corridors without such service changes) – this approach produces unbiased estimates.

[26] The extensions for Saturday services involved additional departures before 8.00am and after 5.15pm and had an increase in total Saturday service trips of +12% to +19%. The extension for weekday services on route 9 involved additional departures at 6.05am, 6.40am and 7.15pm and an increase in total weekday service trips of +9%.

We have particularly strong confidence in the findings for both doubling of frequency (around +0.4) and extension of hours (around +1.2) because we studied a number of instances of these types of improvements and the subsequent estimates were remarkably consistent.

We have less confidence in the estimates for key economic variables, as shown in table 9.1, because of the short period involved (only about four years). This means that there is a risk that the model incorrectly associates patronage trends with coincidental movements in the economic variables. This risk is lowest with the weekday petrol price cross elasticity (ie +0.25) due to considerable volatility in real petrol prices but highest with variables that change very slowly, most notably employment.

In general, we have more confidence in the weekday findings than we do in the Saturday findings. Our lower confidence in the Saturday findings is due to the following:

- The data for Saturday patronage exhibits a lot of volatility.
- The data provided calculates average Saturday patronage without regard to the number of holidays and this can contribute to misleading jumps and dips in the data.
- There was a sharp shift in Saturday patronage growth from positive in 2009–Q1 to 2009–Q2 (see section 9.4) and, although we have possible explanations, the reasons for this are not known.
- There are patterns in the residuals from the Saturday patronage model that suggest the model is not adequately explaining growth rates in Saturday patronage; this is most likely due to a combination of the factors mentioned in the three bullet points above.

9.6 Recommendations and policy implications

Our main recommendation is that a service elasticity of +0.4 be used as a general rule of thumb for most service improvements, especially those that involve doubling frequency.

However, we recommend that consideration should be given to extending hours of operation on a number of routes and monitoring the results. The average service elasticity of +1.2 suggests that this could be a simple mechanism to increase patronage at a low cost; it is even conceivable that these types of service improvements could be net generators of revenue.

9.7 Opportunities for further research

9.7.1 Introduction

Section 11.4 provides a comprehensive description of all of the possible avenues for further research, taking into account the findings across all cities and modes.

The following section discusses further research as it applies specifically to the Tauranga bus system.

9.7.2 Incorporation of cost–benefit analysis into post-evaluation

The ‘post evaluation’ findings presented for Tauranga provide some insight into the effectiveness of various service improvements.

However, we can see there is even more to be gained if the estimated service elasticities are combined with information on the costs and benefits of service improvements. We can envisage a process in which cost data is used to calculate the average cost of each extra patron generated by a service improvement. That cost can then be assessed against the social and economic benefits arising from the extra patronage.

Tauranga could be a good test case for attempting this process of incorporating cost benefit analysis (CBA) into ‘post-evaluation’ because it is relatively ‘simple’ and straightforward. If the process can be done well here then it could be expanded to the larger, more complex public transport networks in Auckland, Christchurch and Wellington.

10 Methodology for econometric forecasting

10.1 Objectives of forecasting methodology

We engaged in discussion with stakeholders regarding their preferences in a forecasting model. The following attributes were most commonly identified as ideals:

- The forecasting model should enable transport planners to test the impact of different scenarios involving explanatory variables (fare increases, petrol price fluctuations, economic growth, etc).
- The forecasting model should be able to produce forecasts at a route or corridor level.
- The forecasting model should be designed to incorporate population and demographic projections. This will enable transport planners to not only test the impact of scenarios involving aging populations or falling birth-rates, but also to predict growth for variables of particular interest such as SuperGold Card patrons.

10.2 Overall forecasting approach

Broadly speaking, there are two contrasting philosophical approaches to forecasting:

- The explanatory approach involves building causal regression models that attempt to explain patronage growth in terms of explanatory variables like petrol prices, fare changes, etc. The main advantage of an explanatory approach is that it allows us to test and estimate the impact of changes in key explanatory variables and new scenarios (eg peak oil).
- The autoregressive approach involves building 'ad hoc' models that attempt to predict patronage growth drawing entirely on past patronage growth patterns and extrapolating those patterns into the future. The main advantage of an autoregressive approach is that it draws on a conventional wisdom in forecasting, which is that the best predictor of future growth is often past growth.

We experimented with the autoregressive approach but ultimately concluded that it would only provide forecasts for very short-term periods (ie from a single quarter to a year at most). Furthermore, incorporating the impact of explanatory variables like petrol prices into the autoregressive approach was problematic because the impacts of these variables do not seem statistically discernible within short-term periods.

We favoured the explanatory approach because, in addition to accommodating explanatory variables, it can also produce long-term forecasts. It can also be adapted to incorporate population and demographic projections.

10.3 Structure of forecasting methodology

The forecasting methodology proposed by this research project can be broken down into the following stages:

1. Calculation of patronage levels
2. Identification of catchment areas
3. Estimation of market segment-based regression models
4. Development of forecasting tool.

10.3.1 Calculation of patronage levels

The first stage of the forecasting methodology involves collecting and calculating patronage levels on each route, segregated by market segments (child, adult, tertiary, senior). The segregation into market segments is designed to enable us to incorporate other forecasts and projections that can now serve as an input into the forecasting process:

- projected birth rates and school enrolment levels
- projected employment demand
- projected tertiary enrolment
- projected aging populations.

10.3.2 Identification of catchment areas

The next stage of the forecasting methodology involves using maps to identify the catchment areas – the suburbs serviced by each route – and relating these suburbs to the corresponding area unit classifications employed by Statistics NZ in their analysis of geography-based data.

This stage involves aggregating the Statistics NZ demographic and population projections by area unit together to produce projections for the catchment areas for each of the routes. This step in the methodology ensures that we use population and demographic projections as an input into the route-based forecasts. For example if a particular route goes through catchment areas that have a high level of seniors then we would expect patronage on that route to grow disproportionately due to the anticipated aging population. The forecasting methodology is designed to take this into account.

10.3.3 Estimation of market segment-based regression models

The next stage of the analysis involves estimation of regression models for the patronage levels, similar to those presented in appendices B to G, but the patronage levels are disaggregated by market segments of interest. This process of disaggregation improves the accuracy of the forecasting process:

- The process of disaggregating and analysing by market segment encourages the researchers to identify all of the explanatory variables that might influence that market segment; this improves the accuracy of forecasting because some of those explanatory variables that are identified may remain relevant in the future.
- The production of market-segment-specific regression models for each market segment means that we can more accurately estimate the impact of variables that are market-segment specific, such as the introduction of the SuperGold Card.
- The process of market-segment-specific regressions produces fare elasticities and petrol price elasticities that are specific to the particular market segment – this improves our understanding of the impact of changes in these explanatory variables on both the levels and compositions of future patronage.

10.3.4 Development of forecasting tool

In the final stage of analysis we propose building a spreadsheet model that takes the most recent patronage levels on each route and extrapolates growth for them based on projected growth within the relevant catchment area. Those extrapolations are then modified to take into account scenarios involving the explanatory variables like petrol prices, fares, service frequency and economic variables.

Such a spreadsheet model can produce forecasts for each route. These forecasts can be used to predict not only future patronage, but also revenue and loading levels.

Therefore, spreadsheet models like these can be used to identify routes where loading levels might reach unacceptable levels at some point in the future.

11 Conclusions

11.1 Explaining historic patronage growth

The primary objective of the research was to examine historical trends in patronage growth and to build models to explain those trends in terms of a range of explanatory variables and factors. Our conclusions from examining and explaining historical trends in patronage growth are as follows:

- For Auckland rail patronage growth from 1992 to 2010, the completion of Britomart generated a sustained period of high growth from 2003 through to recent years. Britomart was accompanied by more train services and an improved service timetable and this clearly contributed to observed growth. But the more significant driver appears to have been due to some combination of the less tangible improvements associated with Britomart (ie greater convenience for commuters, publicity and general enhancement of facilities).
- For Auckland bus patronage from 2001 to 2010, enhancements to the Auckland train lines detracted patronage from Auckland bus corridors. We also found evidence that the labour strikes might have caused a permanent shift in patronage from bus to rail.
- For Wellington rail patronage from 2005 to 2009, petrol price changes, especially around the $2.00 mark, may have had an unusually strong impact on Wellington rail patronage. However, the limitations of the Wellington rail patronage data are noted.
- For Wellington bus patronage from 2005 to 2010, fare increases in 2006 and 2008 had a significant impact on patronage growth. But we also note that each of these fare increases had differing impacts on patronage (especially when patronage is broken down into peak weekday, offpeak weekday and weekend).
- For Hamilton bus patronage from 2004 to 2010, the massive growth in patronage over this time can be attributed to a range of service network improvements, including new routes, route changes, direct services and the introduction of Sunday services. There is also evidence that the introduction of a free two-hour transfer in 2007 may also have played a significant role by encouraging higher levels of offpeak patronage.
- For Tauranga bus patronage from 2005 to 2009, the high levels of growth over that period can be attributed to a combination of some quite notable service timetable improvements, along with the introduction of the SuperGold Card.

The models used to produce the conclusions above were also used to produce up-to-date public transport elasticities for the cities studied. These elasticities are summarised in chapter 3.

- Bus fare elasticities seemed to be around -0.3, on average, in Auckland. Bus fare elasticities for Wellington were variable and appeared to have been distorted by the introduction of the SuperGold Card. But bus fare increases had no discernible impact on patronage in Hamilton. (We note that a fare elasticity of -0.3 means that a 10% increase in fares triggers a 3% fall in patronage.)
- Rail fare elasticities were relatively high during the peak; around -0.7 in Wellington and as high as -0.9 in Auckland, suggesting that the scope for further revenue recovery may be constrained. (Similarly as above, we note that a fare elasticity of -0.9 means that a 10% increase in fares triggers a 9% fall in patronage and hence only about 1% extra revenue.)

- There was strong evidence of complex and non-linear responses to petrol prices, ie the crossing of the $2.00 nominal petrol price in 2008 was associated with a 'jump' in patronage.
  - After controlling for the 'threshold effects', petrol price cross-elasticities in Auckland and Wellington were relatively low – generally in the range of 0.0 to +0.2.
  - However, the petrol price cross-elasticities in the smaller cities of Hamilton and Tauranga were about +0.2 to +0.3, suggesting a greater responsiveness to petrol price changes.

  We note that the petrol price cross-elasticities are positive because petrol price increases induce a mode-shift from car transport to public transport. A petrol price cross-elasticity of +0.1 implies that a 10% increase in real petrol prices induces 1% increase in public transport patronage; but a petrol price cross elasticity of +0.3 implies a (much larger) 3% increase in public transport patronage.
- There were a number of findings regarding service elasticities:
  - For peak-time rail services, service elasticities were difficult to calculate due to insufficient data on crowding levels and challenges in determining the direction of causation between service levels and patronage.
  - For peak-time bus services, a service elasticity of about +0.3 seemed plausible.
  - For interpeak bus service frequency improvements, a service elasticity of around +0.4 to +0.5 seemed plausible for most frequency improvements.
  - For interpeak train service frequency improvements, a service elasticity of +0.3 to +0.4 seemed appropriate.
  - For weekend service improvements, there was a wide range of service elasticities depending on the nature and location of the improvement.

There were, in some cases, high service elasticities associated with more regular timetables and extension of hours; however, there was also evidence of diminishing returns and some situations in which these elasticities did not produce benefits

11.2 Forecasting methodology

The secondary objective of the research was to identify econometric structures and tools for forecasting public transport patronage. During the course of the research project, more priority was given to examining and explaining historic growth (see section 11.1) because econometric models will be of limited use as forecasting tools unless they can explain historic growth adequately.

However, we did develop a methodology to show how econometric models could be modified and transformed into public transport forecasting models. This methodology consists of the following basic steps:

1. Calculate patronage for each public transport corridor (route, route group, train line, etc) and segregate by demographic attributes (child, adult, senior, tertiary).
2. Estimate population growth for the catchment populations for each public transport corridor; again, these population growth rates are segregated by demographic attributes (child, adult, senior, tertiary).
3. Use market segment based regression models to estimate elasticities for each of the demographic segments (child, adult, senior, tertiary).
4. Combine data together to create a forecasting tool that combines demographic/population projections and scenarios regarding economic factors like petrol prices and fare increases.

12 Recommendations and opportunities for further research

12.1 Recommendations regarding 'post-evaluation'

The current practice in regard to public transport planning puts disproportionate emphasis on 'pre-evaluation': research and modelling of the theoretical patronage gains from proposed public transport investments. But there is less emphasis on 'post-evaluating' how effective those investments actually were and using that feedback to guide future investment.

One of the ambitions of the research project was to demonstrate that econometric methods can be used to 'post-evaluate' the effectiveness of past public transport investments and to bring more scientific rigour to the transport planning process. We consider that the findings presented in this report, especially those for the Tauranga bus network (see table 9.2) and the Hamilton bus network (see tables 8.2 and 8.3) validate our original vision.

We recommend that greater priority and attention and more resources be given to 'post-evaluation' of recent and future changes to public transport networks and service timetables.

12.2 Recommendations regarding data and documentation

We also recommend that processes be introduced to ensure that the details of any network changes (or other notable events) are recorded and documented in a manner that is amenable to future econometric analysis. Our experience during this research project has been that such information is difficult to obtain and/or provided in a form that is difficult to incorporate.

We also support initiatives to improve data collection. Ideally, we will reach a point in which all public transport operators collect accurate and disaggregated data on patronage, service levels, reliability and crowding levels.

12.3 Recommendations regarding fare recovery and investment in public transport

We note that fare elasticity estimates were generally higher for rail passengers than bus passengers, at least during the peak-times. This will have implications for future fare recovery and we recommend that transport planners take this into account in their planning processes.

We also recommend that any future fare increases be monitored carefully to ascertain whether the observed patterns represent a consistent trend.

There is evidence from our research of considerable 'network effects' arising from improvements to both the Tauranga and Hamilton public transport networks. We therefore recommend that transport planners take a holistic view of the needs of public transport users and the manner in which they perceive the public transport network.

There is also evidence from our research that a number of relatively minor initiatives (a two-hour free transfer, a free ticket promotion, minor extensions of hours, more regular timetables) had a profound impact on patronage. We recommend that these initiatives be given consideration by other regional councils.

12.4 Opportunities for further research

The econometric methods demonstrated by this research project have produced interesting and useful insights and findings. However, as discussed in sections 11.3.1 to 11.3.6, there are opportunities to extend the research in a number of directions:

- further post-evaluation of service improvements
- incorporation of cost–benefit analysis into post-evaluation
- estimation of zone-based fare elasticities
- market segment analysis
- further investigation of petrol price impacts
- extension of research to Christchurch and Dunedin
- research into the impact of free transfers on revenue.

12.4.1 Further post-evaluation of service improvements

Further 'post-evaluation' research should be considered for any cities that have recently engaged in public transport investment and/or anticipate public transport investment in the future. For example, a number of major changes to the network and service levels have recently been announced by Greater Wellington and will be carried out, in a staggered basis, over a number of years. This presents an exciting opportunity to apply the econometric methods innovated by this research project to 'post-evaluate' the effectiveness of those network changes *as they are being implemented.*

12.4.2 Incorporation of cost–benefit analysis into post-evaluation

The insights from 'post-evaluation' will provide even more insight and feedback if the estimated service elasticities are combined with information on the costs and benefits of service improvements. We can envisage a process in which cost data is used to calculate the average cost of each extra patron generated by a service improvement. That cost can then be assessed against the social and economic benefits arising from the extra patronage.

12.4.3 Estimation of zone-based fare elasticities

This report presents fare elasticities broken down by time period, where possible (ie weekday, peak, weekday offpeak, weekend). Based on our assessment of the data, we consider that these fare elasticities could feasibly be broken down even further by the number of zones travelled, at least in Auckland and Wellington, and perhaps in other cities.

Zone-based fare elasticities would create options for improved fare recovery because they would allow transport planners to price discriminate more effectively; for example, if patrons travelling four zones are shown to lower fare elasticities than those travelling shorter distances then an argument could be made to increase their fares disproportionately, to minimise the detrimental effect on patronage and to maximise revenue gains.

12.4.4 Market segment analysis

This report presents analysis of patronage growth for all patronage within certain periods. However, we consider that more sophisticated analysis could be done that separates patronage into certain market segments (eg child, adult, senior, tertiary).

The main advantage of this more sophisticated approach is that it allows us to then control for market-specific explanatory variables (eg tertiary enrolments) and events (eg introduction of the SuperGold Card). This approach also provides transport planners and operators with more in-depth insight into the causes and sources of patronage growth.

12.4.5 Further investigation of petrol price impacts

There is strong evidence of complex and non-linear responses to petrol prices, ie the temporary crossing of the $2.00 nominal petrol price in 2008 was associated with a 'jump' in patronage.

As noted elsewhere, this event should be interpreted as a proxy variable that encompasses a wide range of factors and events occurring around this time and should not be assumed to represent a predictable response to future crossings of these thresholds. However, it would be interesting to update this research in the near future, using patronage data since early 2010, and to examine the impacts of petrol price changes since then (which includes a permanent crossing of the $2.00 nominal petrol price threshold).

12.4.6 Extension of research to Christchurch and Dunedin

Due to the time-consuming and data intensive nature of the econometric methods employed, we did not have the resources to include Christchurch or Dunedin. However, we recommend that these cities be included in future extensions of this research.

Christchurch and Dunedin would represent particularly interesting case studies because there are patronage datasets available for both cities that go back quite far. The Christchurch dataset covers a 20-year period from 1992 to 2012 while the Dunedin dataset covers a 16-year period from 1991 to 2007 (and perhaps later). The long length of these datasets the following key advantages:

- There are numerous examples of service improvements and network changes that occurred during the histories of these public transport systems, and further research could provide a 'post-evaluation' of their effectiveness.
- The research findings presented in this report used econometric methods that produced short-run elasticities because we were limited by the short-time frames of most of the datasets employed. However, since the datasets for Christchurch and Dunedin are much longer, we could experiment with econometric methods that allow us to delve into long-run elasticities and the intermediate dynamics.

12.4.7 Research into the impact of free transfers on revenue

From what we can ascertain, a two-hour free transfer was introduced for the Hamilton bus network in October 2007, and this seemed to have contributed to a 6% jump in off-peak weekday patronage and a 16% jump in weekend patronage.

In November 2011, the Waikato Regional Council reduced the two-hour free transfer to one hour with the intention of increasing fare revenue.

We propose further research to evaluate the impacts on revenue of both 1) the introduction of the free two-hour transfer in October 2007 and 2) the reduction to one hour in November 2011. There are reasons for thinking that the net effect of either of these changes could be positive or negative.

The findings from that further research would be of interest to other transport operators that are either contemplating the introduction of a free transfer or making decisions regarding the number of hours to allow as part of their free transfer scheme.

13 Bibliography

Booz Allen Hamilton (2005) *Appraisal of Stagecoach Auckland bus patronage trends*. Report to Stagecoach NZ/Auckland Regional Transport Authority (ARTA).

Bresson, G, J Dargay, J-L Madre and A Pirotte (2004) Economic and structural determinants of the demand for public transport: an analysis on a panel of French urban areas using shrinkage estimators. *Transportation Research Part A: Policy and Practice 38*, no.4: 269–285.

Colman, A (2009) Comment: appraisal of factors influencing public transport patronage. Referee report from Andrew Coleman, Motu Economic and Public Policy Research.

Coto-Millan, P, J Banos-Pino and V Inglada (1997) Marshallian demands of intercity transport in Spain: 1982-1992. An economic analysis. *Transportation Research Part E: Logistics and Transportation Review 33*, no.2: 79–96.

Dargay, JM and M Hanly (1999) Bus fare elasticities. *Report to the Department of the Environment, Transport and the Regions*, London: University College London, ESRC Transport Studies Unit.

Dargay, JM and M Hanly (2002) The demand for local bus services in England, *Journal of Transport Economics and Policy 36,* no.1: 73–91.

Dougherty, C (2002) *Introduction to econometrics*. Second edition, Oxford: Oxford University Press. 409pp.

Douglas, N and G Karpouzis (2009) An explorative econometric model of Sydney metropolitan rail patronage, *Proceedings of the 32nd Australasian transport research forum (ATRF).*

Engel, RF and CW Granger (1987) Co-integration and error correction: representation, estimation, and testing. *Econometrica 55*: 251–76.

Granger, CWJ and P Newbold (1974) Spurious regressions in econometrics. *Journal of Econometrics 2*, no.2: 111–120.

Gujarati, DN (1995) *Basic econometrics.* Third edition. Singapore: McGraw-Hill Inc, McGraw-Hill International Editions Economic Series. 838pp.

Jevons, D, A Meaney, N Robins, J Dargay, J Preseton, P Goodwin and M Wardman (2005) How do rail passengers respond to change. Working paper no.1014. Oxford: Oxford University Centre for the Environment, Transport Studies Unit.

Kennedy, D and I Wallis (2007) Impacts of fuel price changes on New Zealand transport. *Land Transport NZ research report 331*. 138pp.

NERA (2003) *Research on long term fare elasticities, a final report for the Stategic Rail Authority, London*. 97pp.

Nerlove, M (1956) Estimates of the elasticities of supply of selected agricultural commodities. *Journal of Farm Economics 38*: 496–509.

Owen, AD and GDA Phillips (1987) The characteristics of railway passenger demand. An econometric investigation. *Journal of Transport Economics and Policy 21*, no.3: 231–253.

Verbeek, M (2000) *A Guide to modern econometrics*. UK: John Wiley & Sons. 386pp.

Wallis, I and D Kennedy (2008) '*Go Wellington' patronage analysis*. Ian Wallis Associates, Report to NZ Bus Limited. 31pp.

Wallis, I and P Yates (1990) Public transport patronage trends in New Zealand. Where are all the passengers going? *Proceedings of the 15th Australasian Transport Research Forum (ATRF)* (19pp. unpaged).

Wang, J (2011) Appraisal of factors influencing public transport patronage. *NZ Transport Agency research report 434.* 176pp.

Wardman, M, and J Shires (2003) Review of fares elasticities in Great Britain. *Institute of Transport Studies University of Leeds working paper 573*.

Wijeweera, A and MB Charles (2012) Passenger rail demand in Perth: a time series analysis. *Proceedings of the 41st Australian Conference of Economists*, Melbourne, Australia.

Zhang, D, X Yang, J Teng, J Ann, G Chen and R Cai (2012) Socioeconomic development and urban public transit, ridership in China: panel data model based empirical analysis. *TRB 2012 Annual Meeting*, 28pp.

Appendix A: Literature review of econometric modelling options

A1 Introduction

A key stage in this research project was a literature review of econometric models adopted by other researchers in their analysis of public transport patronage. The 'pros' and 'cons' of each of those econometric models were assessed. That assessment then fed into the development of our preferred econometric methodology.

- Section A2 discusses and assesses the 'static' regression model.
- Section A3 discusses and assesses the partial adjustment model.
- Section A4 discusses and assesses the cointegration and error correction models.
- Section A5 discusses and assesses the annual difference model.
- Section A6 discusses and assesses the seasonal difference model.
- In section A7 we present our conclusions regarding the models presented in sections A2 to A6 and explain why we favoured the seasonal difference model.
- In section A8 we discuss the panel data approach, and show how the seasonal difference model can be modified to accommodate corridor-level data (ie by bus route, bus corridor, train line). We note that while the panel data approach appears to have been used in a number of recent public transport studies, the approach and ideas envisaged by this research project do not appear to have been implemented elsewhere.

A2 'Static' regression model

A2.1 Structure of the 'static' regression model

The 'static' regression model involves regressing dependent variables directly on explanatory variables without any additional testing. Here is an example of a 'static' regression model that has been adapted for use in public transport patronage analysis:

$$P_t = \propto + \beta X_t + e_t \quad \text{(Equation A.1)}$$

where: P_t= patronage levels (log-transformed)

X_t = explanatory variable levels (log-transformed)

e_t = error term

A2.2 Assessment of the 'static' regression model

Up until 1987, most econometric studies of public transport patronage fitted 'static' regression models. These models – sometimes referred to in transport economics literature as 'static' models[27] – have since fallen out of favour primarily because they do not distinguish between short-run and long-run elasticities.

However, the more serious problem with 'static' regression models is that the variables analysed (patronage levels, petrol prices, fares, income, etc) usually lack a desirable statistical quality known as 'stationarity' (ie a tendency to revert to a mean value). Econometric theory implies that, as a rule, regression models of variables through time will only provide trustworthy estimates if the variables are 'stationary'.

Kennedy and Wallis (2007) drew attention to the issue of 'nonstationarity' in transport economics research. They noted that regressions with nonstationarity data were commonly carried out in the transport economics literature and acknowledged that these regressions often produced plausible estimates. But they also noted the risk that the resulting estimates were 'spurious' or invalid.

A2.3 Application of the 'static' regression model in the transport economics literature

The 'static' regression model has fallen in popularity and is not employed in the transport literature as commonly as partial adjustment models, so we do not review its use here.

A3 Partial adjustment model

A3.1 Structure of the partial adjustment model

The partial adjustment model was originally developed by Nerlove (1956) to explain the lagged response of capital stocks to agricultural prices.

In theory, the partial adjustment model (PAM) can be been applied to analysis of public transport patronage. When applying the PAM, the researchers (explicitly or implicitly) assume there is an equilibrium or long-run level of patronage associated with certain fares, petrol prices, service levels, etc:

$$P_t^* = \propto + \beta X_t + e_t \qquad \text{(Equation A.2)}$$

where: P_t^*= long-run level of patronage (log-transformed)

X_t= explanatory variable levels (log-transformed)

e_t= error term

Then one assumes that the equilibrium or long-run level of patronage cannot be reached immediately (for reasons referred to in the literature as 'habits' or 'inertia') but the difference between actual and the long-run is closed by a partial adjustment each period:

$$P_t - P_{t-1} = \delta(P_t^* - P_{t-1}) \qquad \text{(Equation A.3)}$$

where: P_t^*= long-run level of patronage (log-transformed)

P_t= actual level of patronage (log-transformed)

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[27] These models are often referred to as 'static' models in transport economics literature, presumably because they are said to lack the 'dynamic' qualities of methods like partial adjustment models that produce 'short-run' and 'long-run' elasticities. However, we do question whether the term 'static' is appropriate. If a cointegrating relationship can be established then the estimates from a 'static' regression should, in theory, represent 'long-run' impacts.

One can then show (via manipulation and substitution) that the assumptions above will lead to the following model, which can then be estimated via normal regression methods:

$$P_t = \delta\alpha + \delta\beta X_t + (1-\delta)P_{t-1} + \delta e_t \qquad \text{(Equation A.4)}$$

Furthermore, with those assumptions, one can show that the short-run elasticity for the impact of X_t is δβ while the long-run elasticity for the impact of X_t can be derived from equation A.4 by calculating the following:

$$Long\ run\ elasticity\ for\ \mathrm{X_t} = \frac{\delta\beta}{1-(1-\delta)} \qquad \text{(Equation A.5)}$$

A3.2 Assessment of the partial adjustment model

The PAM is commonly employed in transport economics and especially in econometric analysis of public transport patronage. This popularity can be attributed to the fact that, unlike the ‘static’ regression model, it produces ‘dynamic’ elasticities (ie both short-run and long-run elasticities).

Unfortunately, like the ‘static’ regression model, the variables analysed within a PAM are often nonstationary so there remains a risk that the resulting estimates are ‘spurious’ or meaningless.

However, we note that there are also a number of further risks and statistical issues that arise due to the unique structure of PAM:

- The PAM has a lagged dependent variable in it (ie P_{t-1} is used to predict P_t). Gujarati (1995) noted that the presence of a lagged dependent variable exacerbates problems associated with autocorrelation; in the presence of any autocorrelation, a lagged dependent variable will produce biased and inconsistent estimates.
- The validity of the estimates produced by a PAM hinge on a number of quite specific assumptions, as described in section A3.1. In particular, the model assumes there is a difference between actual patronage and ‘long-run’ patronage and that the difference is closed by a certain proportion each period. If this assumption is not correct then the accuracy of the subsequent estimates is cast into doubt. In addition, the model implicitly assumes the ratio of ‘long-run’ to ‘short-run’ elasticities is the same for all explanatory variables; we question whether this assumption is appropriate.

A3.3 Application of the partial adjustment model in the transport economics literature

Owen and Phillips (1987) were the first to apply the PAM to public transport patronage analysis, and it has grown in popularity since then. Since then, the use of the PAM has became widespread and is the most commonly employed model. We see no reason for in-depth discussion of this type of model since it has been reviewed thoroughly in a number of comprehensive literature reviews such as Wardman and Shires (2003).

However, we do wish to draw attention to one particular anomaly in the literature because it reinforces our doubts regarding the statistical validity of findings produced using PAM. Jevons et al (2005) note that PAMs using annual rail patronage data imply that it takes around two to five years to reach the ‘long-run’[28] In contrast, PAMs fitted using more frequent four-weekly rail patronage data imply that it takes 0.1 to 0.23 years to reach the long-run. Jevons et al (2005) note there is no logical reason why a more frequent

[28] The ‘long-run’ is assumed to be the point at which 95% of the effect of the change to an explanatory variable has worked through.

dataset would produce markedly different findings in regard to the length of the long-run, and identify this as an econometric issue that needs to be resolved.

We consider that this anomaly could be due to a spurious statistical relationship in the partial adjustment model between P_t and its lag, P_{t-1}. As shown in section A3.1, this relationship is estimated by $(1-\delta)$ and is assumed to reflect the 'speed of adjustment' for patronage behaviour. The speed of adjustment should therefore be much lower with the more-frequent four-weekly data. However, in our opinion, the high correlation between P_t and P_{t-1} may simply reflect the fact that patronage is nonstationary and therefore a similar coefficient for $(1-\delta)$ is estimated regardless of whether the data is four-weekly or annual.

A4 Cointegration and error correction model

A4.1 Structure of the cointegration and error correction model

In section A2.2, we noted that, as a rule, regression models of variables through time will only provide trustworthy estimates if the variables are 'stationary'.

There is one exception to that rule. Engle and Granger (1987) showed that regressions involving nonstationary data could actually produce highly accurate long-run elasticities, but *only* if one can establish that there is a cointegrating relationship between the dependent variable and the explanatory variables. A cointegrating relationship means the dependent variable may deviate from equilibrium but only temporarily; if this occurs then the residuals of the model represent temporary deviations from equilibrium, hence the residuals should be stationary.

Engle and Granger went on to show that one can use error correction model to estimate short-run elasticities by modifying difference models to control for adjustment to equilibrium.

Engle and Granger combined these ideas together to create the cointegration and error correction approach to time serious analysis. A cointegration model is an excellent tool for estimating long-run relationships (assuming such relationships exist) as well as short-run relationships. These models guard against spurious regression and will produce robust long-run estimates providing there is a sufficiently long-enough dataset.

The particular method developed by Engle and Granger consists of two steps and, when their method is applied to patronage analysis, proceeds as follows:

1 First, the researcher fits the 'static' model discussed in section A2, but tests for a cointegrating relationship between P_t and X_t by looking for stationarity in the residuals.

$$P_t = \propto + \beta^{LR} X_t + e_t \quad \text{(Equation A.6)}$$

where: P_t= patronage levels (log-transformed)

X_t=explanatory variable levels (log-transformed)

e_t=error term

If such a relationship can be established then you will have an accurate estimate of long-run elasticities, as long as one can show there is a cointegrating relationship.

2 If step 1 is successful, the researcher will estimate a short-run elasticity. Engle and Granger (1987) showed that the short-run elasticity can be calculated by the following equation:

$$\Delta P_t = \propto + \beta^{SR} \Delta X_t + \gamma e_t + u_t \quad \text{(Equation A.7)}$$

where: $\Delta P_t = P_t - P_{t-1}$ = change in (log-transformed) patronage between time t-1 and t

$\Delta X_t = X_t - X_{t-1}$ = change in (log-transformed) explanatory variable/s between time t and t-1

e_t = error term from LR cointegrating equation

u_t = error term

A4.2 Assessment of the cointegration and error correction model

Cointegration models have the advantage that if the dataset is sufficiently long enough and if a cointegrating relationship can be established then they produce highly accurate elasticity estimates.

Cointegration models also have the appealing feature that, like PAMs, they produce both short-run and long-run elasticity estimates.

The main disadvantage of cointegration models is that they require a long dataset in order to identify the 'long-run' cointegrating relationship. They also require a constant relationship over time between the dependent and explanatory variables that can be 'discovered' by the cointegrating model.

A4.3 Application of the cointegration and error correction model in the transport economics literature

As noted in section A3.3 the partial adjustment model has been the most commonly employed model in the transport economics literature over the past few decades.

However, more recently, there has been increased acknowledgement of the risks associated with the nonstationarity data in the PAM. This has prompted a number of authors to investigate and test cointegration models, with some success:

- Dargay and Hanly (1999) attempted to fit a cointegration model for annual Great Britain patronage from 1970 to 1996. They were able to establish that there wass a long-run relationship between bus patronage and the explanatory variables (bus fares and income per capita). They then used an error correction model to estimate the short-run dynamics. Their model generally found that the speed of adjustment was low; less than 50% of disequilibrium was corrected within a year. Subsequently, long-run fare elasticities were approximately twice short-run fare elasticities.
- Coto-Milan et al (1997) attempted to fit a cointegration model for quarterly rail passenger transport in Spain from 1980 to 1992. They were able to establish a long-run relationship between patronage and the explanatory variable (rail fares, fuel price and GDP). They then used an error correction model to estimate the short-run dynamics. However, unlike Dargay and Hanly (1999), they found that the speed of adjustment was very quick; they estimated that 92% of disequilibrium was corrected within a quarter.
- Wijeweera and Charles (2012) attempted to fit a cointegration model for annual rail passenger boardings in Perth from 1988 to 2008. They were able to establish a long-run relationship between rail patronage boardings and the explanatory variables (rail fares, income per capita, fuel prices, service levels (ie vehicle kilometres), rail safety perception (ie rail fatality rates) and population). Like Coto-Milan et al, they found that the speed of adjustment was very quick; they estimated that 100% of disequilibrium was corrected within a year. In general they found that short-run elasticities were similar in size to the long-run elasticities.

We would expect that cointegration and error correction models would provide insights into the differences between short-run and long-run elasticities. It is therefore noteworthy that two of the cointegration studies above produce findings that imply that the impact of changes to explanatory variables feeds through quite quickly; the long-run is reached within a year or so. This contradicts the findings of research using PAMs which have often found that the long-run is in the range of two to five years.

A5 The annual difference model

A5.1 Structure of the annual difference model

When Granger and Newbold (1974) first drew attention to the risks associated with taking regressions of nonstationary data, they recommended a difference model as a means of minimising the risk of 'spurious' or invalid estimates.

In a difference model, both the dependent and explanatory variables are 'differenced'. If the data being analysed is annual then this means that, instead of regressing log-transformed patronage on log-transformed explanatory variables, we are regressing the annual change in patronage on the annual change in explanatory variables:

$$\Delta P_t = \propto + \beta \Delta X_t + e_t \qquad \text{(Equation A.8)}$$

where: $\Delta P_t = P_t - P_{t-1}$ = change in (log-transformed) patronage between year t-1 and t

$\Delta X_t = X_t - X_{t-1}$ = change in (log-transformed) explanatory variable/s between year t and t-1

e_t = error term

A5.2 Assessment of the annual difference model

The main advantage of difference models generally is that the process of 'differencing' generally makes the variables of interest stationary (ie the variables show a tendency to revert to a mean). This stationarity reduces the risk of 'spurious' or invalid findings.

Econometric theorists such as Dougherty (2002) note that the main disadvantage of difference models is they only reflect the short-run impact of explanatory variables on the dependent variable.

The other disadvantage of annual difference models is they only employ annual data, and hence fail to exploit some of the extra information that would be available in quarterly or monthly data. In public transport patronage most changes to fares or services present themselves as sudden 'jumps' partway through the year; and quarterly or monthly data show these 'jumps' and their impact on patronage quite clearly. These changes and their subsequent impact on patronage are often 'muffled' if the researcher only analyses the data at an annual level.

This limitation of the annual differences model prompted Kennedy and Wallis (2007) to adopt the seasonal difference approach discussed in section A6.

A5.3 Application of the annual difference model in the transport economics literature

There are a small number of difference models in the transport economics literature, which is surprising given that difference models were recommended by Newbold and Granger (1974), some time ago, as a straightforward means of minimising the risk of spurious regression. A few examples of difference models relating to the Australasian region are noted below:

- Wallis and Yates (1990) carried out an econometric analysis of annual data from 1974/75 – 1988/89 for municipal bus operators in Auckland, Wellington, Christchurch, Dunedin, Invercargill, Timaru and New Plymouth. They estimated a conventional 'static' regression using nonstationary data, but also included a ‘delta model’ which regressed % changes in patronage on % changes in the explanatory variables[29]. The results of both approaches were very similar, suggesting that there were few differences between the short-run impact within a year and the long-run impact that was potentially being estimated by the static regression.

- Douglas and Karpouzis (2009) carried out an econometric analysis of annual data for Sydney metropolitan rail patronage from 1969 to 2008. The dependent variable was the annual change in (log-transformed) patronage per capita, and the explanatory variables were transformed in a similar manner. Their model produced plausible elasticities.

A6 The seasonal difference model

A6.1 Structure of the seasonal difference model

In the seasonal difference model approach, the variables of interest are ‘seasonally differenced’. If the data being analysed is quarterly, then this means that the dependent variable is the change in patronage between one quarter (eg 2007–Q1) and the same quarter in the previous year (eg 2006–Q1). The explanatory variables are produced via the same transformation:

$$\Delta_{SD}P_t = \propto + \beta\Delta_{SD}X_t + e_t \qquad \text{(Equation A.9)}$$

where: $\propto$ = time trend

$\Delta_{SD}P_t = P_t - P_{t-4}$ = change in (log-transformed) patronage between quarter t and quarter t-4

$\Delta_{SD}X_t = X_t - X_{t-4}$ = change in (log-transformed) explanatory variable/s between quarter t and quarter t-4

e_t = error term.

A6.2 Assessment of the seasonal difference model

The main advantage of the seasonal difference model is that, as with the annual difference model (see section A5) the process of ‘differencing’ generally makes the variables of interest stationary. This stationarity reduces the risk of ‘spurious’ or invalid findings.

However, in our judgement, seasonal difference models are preferable to annual difference models because they allow us to exploit the richness of information that is available in quarterly data.

One disadvantage of seasonal difference models is that the process of seasonal differencing inevitably induces autocorrelation in the model. For example, take the observation representing the change in patronage from 2006–Q1 to 2007–Q1; this is followed by another observation representing the change in patronage from 2006–Q2 to 2007–Q2. Some correlation between these observations would be expected because they have three quarters in common. However, we find that this autocorrelation can generally be satisfactorily addressed using generalised least squares techniques.

The main disadvantage of seasonal difference models is that, like annual difference models, they only reflect the short-run impact of explanatory variables on the dependent variable.

[29] This transformation would most likely achieve stationarity and is approximately the same as the approach described in section A5.1

A6.3 Application of the seasonal difference model in the transport economics literature

Kennedy and Wallis (2007) researched the impact of petrol price changes on petrol consumption and traffic in New Zealand. They identified a number of econometric models that could be employed for the research and expressed a preference for a seasonal difference model. They noted at the time that the concept of seasonal differencing, although common in other fields like macroeconomics, did not appear to have been applied in the transport economics field.

Wallis and Kennedy (2008) investigated the impact of fare increases on Wellington city bus patronage and demonstrated that the seasonal difference model could be successfully applied to analysis of bus patronage.

A7 Conclusions regarding models

A7.1 Conclusions regarding 'static' regression models

We decided against using 'static' regression models because such a model (with nonstationary data) is not statistically reliable unless the researcher can show that a cointegrating relationship exists. If this can be shown, then we are for all intents and purposes actually fitting a cointegration model.

A7.2 Conclusions regarding partial adjustment models

We recognise that partial adjustment models are widely employed in the transport economics literature but have doubts about their statistical robustness and about the validity of the strict assumptions underlying these models.

Even if we put those doubts aside, we still question the appropriateness of a partial adjustment model for this research project due to the short periods covered by the data provided to us. Table A.1 shows the length of the datasets ranged from about four to nine years.

Table A.1 Periods for patronage datasets

City	Mode	Period	Number of years	Number of quarters	Number of quarters after seasonal differencing
Auckland	Rail	2001-Q3 to 2010-Q1[30]	8.5	34	30
Auckland	Bus	2002-Q2 to 2010-Q1[31]	7.75	31	27
Wellington	Rail	2005-Q3 to 2009-Q4	4.25	17	13
Wellington	Bus	2005-Q2 to 2009-Q4	4.5	18	14
Hamilton	Bus	2004-Q3 to 2010-Q1	5.5	22	18
Tauranga	Bus	2005-Q3 to 2009-Q2	3.75	15	11

If we were to fit a partial adjustment model to these datasets then we have no doubt that it would produce a 'long-term elasticity' (even for the Tauranga dataset with only 3.75 years). Indeed, we have observed

[30] The data for Auckland rail actually goes back to 1992-Q2. However, the period shown for Auckland rail data represents the period for which data was available that was disaggregated by weekday peak, weekday interpeak, weekday evening and weekend. Our econometric modelling focused on this later period.

[31] The data for Auckland bus actually goes back until 2001-Q2. But the first four quarters of data were regarded as unreliable and therefore omitted from econometric modelling.

studies that apply a PAM to datasets of such lengths. However, it is questionable whether this 'long-term elasticity' really means anything given that the datasets do not appear long enough to actually tell us anything about long-term relationships.

A7.3 Conclusions regarding cointegration and error correction models

We do support recent attempts in the transport economics literature to fit cointegration and error correction models (ECMs) to public transport patronage. We regard these models as being more statistically valid than PAMs and less restrictive in regard to the assumptions they make about dynamics.

However, there are two main reasons why we have chosen not to use cointegration and ECMs, at least for the purposes of this research project:

- The first reason is that the time periods for the datasets available to us, as shown in table A.1, are generally quite short. A cointegration model, by definition, seeks to identify an overriding long-term relationship in the data. We question whether a dataset of four to nine years is sufficiently long enough to identify such a relationship.
- The second reason is that there is an assumption underlying cointegration models that there is a *constant* long-term relationship between patronage and the explanatory variables. Prior to this research project, it was not clear to us whether this assumption was plausible. The findings from the research project cast further doubt on the plausibility of this assumption: the findings from our research were that fare elasticities changed over time, petrol price responses were complex and nonlinear, and the impact of service improvements differed considerably by time and situation.

We emphasise that, although we decided against cointegration and ECMs for this research project, we do see merit in their investigation further in the future. We anticipate that, in conjunction with other modelling approaches, they could provide insights into patronage networks with much longer datasets: examples of such networks include the Christchurch bus system (18+ years of data) and the Dunedin bus system (16 years of data).

A7.4 Conclusions regarding annual difference models

We consider that annual difference models are inferior to seasonal difference models, because they are unable to exploit the information provided by quarterly data. This is particularly relevant in public transport analysis because a number of key variables (notably fare changes and service changes) exhibit themselves as distinct 'jumps' in the data; these 'jumps' and their impacts on patronage do not show up as clearly in annual data as they do in quarterly data.

A7.5 Conclusion regarding seasonal difference models

We decided in favour of seasonal difference models because, compared with 'static' regression models or partial adjustment models, they have a much lower risk of producing 'spurious' or invalid results.

Furthermore, unlike cointegration and ECMs, seasonal difference models can be applied with validity even where the datasets cover quite short periods.

Other advantages of seasonal difference models include the following:

- Seasonally differenced models simplify the analytical process because the process of calculating % change between, say, 2007–Q1 and 2006–Q1 filters away any seasonal patterns from the data in a clean and straightforward manner.

- Seasonal difference models are less likely to be affected by multicollinearity because, although explanatory variables may be highly correlated when expressed in levels, the differences (ie approximately % changes) in those variables are usually weakly correlated.

We acknowledge the main disadvantage of seasonal difference models is that they only produce short-run elasticities. However, we do not see this as much of a disadvantage given that the datasets available for this research range from four to nine years (see table A.1) so accurate long-run elasticities would have been infeasible regardless of the modelling approach adopted. In time, we hope to develop alternative modelling approaches to produce longer-run elasticities.

A8 The panel data approach

A8.1 Introduction

The panel data approach to econometric analysis involves building econometric models that exploit cross-sectional differences between individual units of observations (individuals, households, firms, countries) while also looking at the behaviour of those units through time.

The panel data approach is commonly employed in fields of economics that involve analysis of individuals or households, such as labour economics. For example, a labour economist might use a panel data approach to explore the impact of explanatory variables on employment status by looking at comparing individuals against each other, while also looking at how individuals change through time.

This research project envisaged an application of the panel data approach in which we analysed public transport patronage at a corridor-level (ie by bus route, bus corridor or train line). We believe that this approach has benefits because it allows researchers to more accurately control for and estimate the impact of service improvements or disruptions that are specific to the particular corridor. When the panel data model is applied in this manner, the units of observation are then the corridors.

A8.2 Panel data modification of seasonal differences model

The seasonal difference model was therefore modified to accommodate corridor-level panel data analysis. This modification is shown in equation A.10.

$$\Delta_{SD}P_{ti} = \propto_i + \beta\Delta_{SD}X_t + \gamma_i\Delta_{SD}Z_{ti} + e_{ti} \qquad \text{(Equation A.10)}$$

where: $\propto_i$ = time trend on each route/corridor/line i

$\Delta_{SD}P_{ti} = P_{ti} - P_{(t-4)i}$ = change in (log-transformed) patronage between quarter t and quarter t-4 for route/corridor/line i

$\Delta_{SD}X_t = X_t - X_{t-4}$ = change in (log-transformed) generic explanatory variable/s (petrol prices, retail sales, etc) between quarter t and quarter t-4

$\Delta_{SD}Z_{ti} = Z_{ti} - Z_{(t-4)i}$ = change in (log-transformed) route-specific explanatory variable/s (service improvements, line maintenance, etc) between quarter t and quarter t-4 for route/corridor/line i

e_{ti}= error term

The key advantages of the panel data approach described above is that it enabled us to isolate and estimate the impact of route-specific explanatory variables such as service improvements and line maintenance (ie Z_{ti} in the formulae above). In addition, by controlling for the impact of those variables, the panel data approach enables researchers to more accurately estimate the impact of explanatory variables that are common to all routes (ie X_t in the formulae above).

A8.3 Panel data applications in the transport economics literature

In our review of the international literature, we found a number of studies that adopted a panel data approach for econometric analysis of public transport analysis.

However, the panel data approach employed by most of these studies is fundamentally quite different from the approach envisaged by this research project. While our approach was designed to analyse corridor-level patronage and service data, most of these studies analysed data at the level of location (ie city, urban area or local county):

- Dargay and Hanly (2002) obtained annual time series patronage data from 1987/88 to 1996/97 for 46 local county bus services in England. Data on bus fares, service levels (bus vehicle kilometres), income and population/demographics was also collected at the county-level. A partial adjustment model was used to relate patronage per capita (in each local county) to the explanatory variables
- Similar analysis has been carried out in France, most recently by Bresson et al (2004). They implemented a panel data model using annual patronage data from 1975 to 1995 for 62 French urban areas including Paris. The patronage data reflected demand for a collection of bus services, a train service, metros, a light rail system and tramways. It appears that data on bus fares, service levels (bus vehicle kilometres, seating capacity, frequency and network density per capita), income and population/demographics was collected at the level of urban area. A partial adjustment model was used to relate patronage per capita (in each urban area) to the explanatory variables.
- Zhang et al (2011) submitted research with a panel data model using annual time series data from 1998 to 2008 for 30 Chinese capital cities.

The main benefits arising from these location-based panel data studies are that they exploit cross-sectional differences between these different geographical locations. For example, the pattern of fare increases through time may differ quite considerably between these locations; a panel data model can exploit these differences between locations and use them to make more informed inferences about fare elasticities.

We have found one line of research that employs a panel data approach more similar in spirit to that envisaged by this research project: a team of researchers have been implementing panel data analysis of long-distance travel in Great Britain. NERA (2003) obtained four-weekly data on ticket sales from April 1989 to March 2003 for each of 97 unique long distance rail 'flows' between major urban centres. Data on national GDP, unemployment, and vehicle kilometeres (as a proxy for congestion) was collected and interpolated so that it was also on a four-weekly basis. Petrol prices and service level variables were also collected.

However, there was still a key philosophical difference between the NERA (2003) research and our approach in regard to treatment of corridor-specific factors and events. NERA (2003) incorporated service quality across all journey 'flows' via a single measure called generalised journey time. In contrast, we see the panel data approach as an opportunity to control for these corridor-specific factors by creating unique variables for each service change and or event along for each corridor. To our knowledge, we are the first to take this approach in the transport literature.

A9 References

Bresson, G, J Dargay, J-L Madre and A Pirotte (2004) Economic and structural determinants of the demand for public transport: an analysis on a panel of French urban areas using shrinkage estimators. *Transportation Research Part A: Policy and Practice 38*, no.4: 269–285.

Coto-Millan, P, J Banos-Pino and V Inglada (1997) Marshallian demands of intercity transport in Spain: 1982–1992. An economic analysis. *Transportation Research Part E: Logistics and Transportation Review 33*, no.2: 79–96.

Dargay, JM and M Hanly (1999) Bus fare elasticities. *Report to the Department of the Environment, Transport and the Regions*, London: University College London, ESRC Transport Studies Unit.

Dargay, JM and M Hanly (2002) The demand for local bus services in England, *Journal of Transport Economics and Policy 36,* no.1: 73–91.

Dougherty, C (2002) *Introduction to econometrics.* Second edition, Oxford: Oxford University Press. 409pp.

Douglas, N and G Karpouzis (2009) An explorative econometric model of Sydney metropolitan rail patronage. *Proceedings of the 32nd Australasian transport research forum (ATRF).*

Engel, RF and CW Granger (1987) Co-integration and error correction: representation, estimation, and testing. *Econometrica 55*: 251–76.

Granger, CWJ and P Newbold (1974) Spurious regressions in econometrics. *Journal of Econometrics 2*, no.2: 111–120.

Gujarati, DN (1995) *Basic econometrics.* Third edition. Singapore: McGraw-Hill Inc, McGraw-Hill International Editions Economic Series. 838pp.

Jevons, D, A Meaney, N Robins, J Dargay, J Preseton, P Goodwin and M Wardman (2005) How do rail passengers respond to change. Working paper no.1014. Oxford: Oxford University Centre for the Environment, Transport Studies Unit.

Kennedy, D and I Wallis (2007) Impacts of fuel price changes on New Zealand transport. *Land Transport NZ research report 331*. 138pp.

NERA (2003) *Research on long term fare elasticities, a final report for the Stategic Rail Authority, London*. 97pp.

Nerlove, M (1956) Estimates of the elasticities of supply of selected agricultural commodities. *Journal of Farm Economics 38*: 496–509.

Owen, AD and GDA Phillips (1987) The characteristics of railway passenger demand. An econometric investigation. *Journal of Transport Economics and Policy 21*, no.3: 231–253.

Wallis, I and D Kennedy (2008) '*Go Wellington' patronage analysis*. Ian Wallis Associates, Report to NZ Bus Limited. 31pp.

Wallis, I and P Yates (1990) Public transport patronage trends in New Zealand. Where are all the passengers going? *Proceedings of the 15th Australasian Transport Research Forum (ATRF)* (19pp. unpaged).

Wardman, M, and J Shires (2003) Review of fares elasticities in Great Britain. *Institute of Transport Studies University of Leeds working paper 573*.

Wijeweera, A and MB Charles (2012) Passenger rail demand in Perth: a time series analysis. *Proceedings of the 41st Australian Conference of Economists*, Melbourne, Australia.

Zhang, D, X Yang, J Teng, J Ann, G Chen and R Cai (2012) Socioeconomic development and urban public transit, ridership in China: panel data model based empirical analysis. *TRB 2012 Annual Meeting*, 28pp.

Appendix B: Econometric analysis of patronage growth on the Auckland rail system

B1 Introduction

In section 4.4 of the main report we presented our conclusions regarding the contribution of explanatory variables to Auckland rail patronage growth over the 17-year period from 1992–Q2 to 2010–Q1 with an emphasis on understanding events over the last seven years of that period (ie 2002–Q3 to 2010–Q1). Then in section 4.5 we presented our findings in regard to elasticities and other estimates for those explanatory variables.

Those conclusions and findings are based on a thorough econometric methodology[32] that helps us understand as much as we can about what is driving patronage growth at a line level. We then bundle data from the two 'lines' together and use an econometric tool (called a panel data model) to estimate what is driving patronage across the whole Auckland train system, while controlling for any explanatory variables that are unique to particular lines such as maintenance disruptions or line-specific service improvements.

The following sections show how the econometric methodology was applied to analysis of Auckland rail patronage, and describe the analyses underlying our conclusions and findings.

- *B2 Data collection and data manipulation* – the analytical process begins with data collection. The data then has to be checked and manipulated into a form that is suitable for econometric analysis.
- *B3 Graphical analysis* – we believe it is important to look at the data and make sense of it intuitively before proceeding onto econometric analysis. In section B3 we look at patronage growth along each of the main train lines and seek to explain and understand any trends or anomalies in the data. The observations here feed into the models tested in sections B4 to B7.
- *B4 Data analysis* – there are a number of statistical problems that can potentially undermine the validity of the econometric analysis. (These problems are technically referred to as multicollinearity, spurious regression and endogeneity). In section B4 we show that we have examined the data for presence of these problems and have responded accordingly where there is evidence of a problem.
- *B5 Model building process* – the process of building models for patronage growth involves fitting general models and testing the contribution of the possible explanatory variables, removing those that look suspect or indeterminate, and whittling the model down to its core components. Section B5 describes the process by which each of the initial models was whittled down into preferred models.
- *B6 Diagnostic analysis* – the preferred model will still not be statistically valid unless the residuals of the model meet certain criteria. In section B6 we show our examination of the residuals of each individual line, in which we look for evidence of autocorrelation, non-normality or omitted variables
- *B7 Estimates and findings* – in section B7 we show the estimates produced using the preferred models.

[32] See chapter 2 of the main report for presentation and explanation of the econometric methodology.

B2 Data collection and data manipulation

B2.1 Patronage data

Auckland Transport provided datasets on patronage. This patronage data was split into the western line and the southern and eastern lines.

The southern and eastern lines have traditionally been reported together for the following reasons:

- They share a common line section south of Westfield where lines divert (one, the NIMT, via Glen Innes and the other via Newmarket) and join again at Quay Park in the vicinity of the old Auckland station.
- Between July 1994 and July 2003 the southern line operated as an 'alternating-loop' service with services departing Papakura and running via the southern line into Auckland then the eastern line back to Papakura with every second departure reversing this pattern. This meant that both lines were served by the same train service with Auckland being an intermediate station.
- Travellers waiting at stations south of Westfield who wish to travel to the Auckland CBD (Britomart) have a choice of either route with no material travel time difference.
- When the timetable changed following the opening of Britomart the base train operating pattern remained the same even though trains now terminated in the CBD.
- Timetable changes over time have varied the route of the equivalent departure from the origin to best fit within constraints.

Auckland Transport provided us with two key datasets.

- The first dataset shows total patronage from July 1992 to March 2010. Unfortunately, patronage for this dataset was not segregated into time period.
- The second dataset shows patronage for each service trip from July 2001 to March 2010. We were able to disaggregate this dataset into the following time periods:
  - weekday peak (5am to 9am, 3pm to 6pm)
  - weekday interpeak (9am to 3pm)
  - weekday evening: (6pm to early morning)
  - Saturday
  - Sunday.

These time periods were selected to maximise consistency with the time periods adopted by public transport databases in other cities throughout New Zealand.

Section 2.2.1 of the main report describes the general approach used to manipulate patronage data into a form adequate for econometric modelling. For the second dataset, we followed this approach and were able to produce average weekday patronage per quarter (by peak, interpeak and evening) and average-weekend patronage per 'weekend equivalent' to use as dependent variables in the econometric modelling.

For the first dataset, since patronage was not segregated by time period, we simply employed total patronage per quarter as the dependent variable.

B2.2 Service change data

The first dataset also shows the total number of services (displayed as available to the public in the published timetable) from July 1992 to March 2010.

The second dataset provided electronic timetables from July 2001 to March 2010 so we were able to identify the number of trips within specific time periods. We were then able to identify key service changes by specific time period, as shown in table B.1.

We concluded that the second dataset provided more accurate estimates because it allowed us to create unique elasticities for each time period (peak, interpeak, evening, weekend) rather than assume that the impact was the same regardless of the time period.

The second dataset, by enabling us to segregate by time period, also allowed us to get around the problem that there were almost continuous service improvements since the completion of Britomart in July 2003. This issue is discussed in more detail in section B3.

Table B.1 Key service changes on the Auckland rail system since July 2001

Line	Period	Date	Trips before	Trips after	% Change	Notes
Southern and eastern	Peak wkday	Jun 03	49	57	16%	Additional services mainly in morning
Southern and eastern	Peak wkday	Feb 08	59	70	19%	Additional services in morning only
Southern and eastern	Peak wkday	Oct 05	70	78	11%	Additional services in morning only
Southern and eastern	Peak wkday	Jul 09	83	88	6%	Additional services in morning and afternoon
Southern and eastern	Interpeak wkday	Dec 06	28	48	71%	
Southern and eastern	Evening wkday	Jun 03	10	15	50%	
Southern and eastern	Evening wkday	Oct 05	15	32	113%	
Southern and eastern	Saturday	Jun 03	27	30	11%	
Southern and eastern	Saturday	Apr 04	30	60	100%	
Southern and eastern	Saturday	Oct 05	60	63	5%	
Southern and eastern	Saturday	Jan 06	63	72	14%	
Southern and eastern	Saturday	Jul 07	72	98	36%	
Southern and eastern	Sunday	Oct 05	0	60		Sunday services introduced
Western	Peak wkday	Feb 05	24	38	58%	Additional services in morning and afternoon
Western	Peak wkday	Jul 08	41	48	17%	Additional services mainly in morning
Western	Interpeak wkday	Nov 05	13	20	54%	
Western	Interpeak wkday	Jul 08	20	25	25%	
Western	Evening wkday	Jun 03	4	8	100%	
Western	Evening wkday	Oct 05	8	18	125%	
Western	Evening wkday	Jul 08	19	24	26%	
Western	Saturday	Jun 03	25	28	12%	
Western	Sunday	Oct 05	0	27		Sunday services introduced

B2.3 Other data

We collected and incorporated data on a number of explanatory variables: fares, petrol prices, retail sales and employment. Where applicable, these variables were then adjusted for inflation and hence the rest of the report refers to them as real fares, real petrol prices and real retail sales.

Retail sales and employment were available for a number of territorial authorities in the Auckland region (notably, Auckland city, Waitakere city, Manukau city and Papakura district). For the sake of simplicity, we chose to focus on retail sales and employment in the 'Auckland city' territorial authority because we consider that most of the travel on the Auckland rail relates to employment, shopping and other activities in the Auckland CBD. Our research shows, for example, that over 60% of employment arises in Auckland city. Furthermore, the correlations between all these authorities are very high anyway, so the growth rates in Auckland city act as a good proxy for the wider region.

We also collected data on cars licensed by territorial authority but, after examination we found evidence of substantial corruption in the data so it was discarded.

Auckland Transport provided us with data on reliability by line. This reliability data was examined during the graphical analysis shown in section B3. But we found that the reliability data did not exhibit any obvious relationships with rail patronage so it was not integrated into the formal econometric modelling.

In section 2.2.2 of the main report, we explain why we decided against incorporating population statistics into the econometric analyses. In general, we have doubts about the statistical robustness of findings produced using population statistics because they are low frequency (ie data is only annual), low accuracy (ie data is only an estimate), exhibit low variance (ie populations exhibit steady growth rates over time) and could only be obtained for broad geographical regions (ie territorial authorities).

That said, the Auckland rail system has exhibited rapid passenger growth since about 2002, and population growth could have played a role. Therefore, we see merit in more detailed analysis of population and demographic factors in further extensions of this research. This more detailed analysis would involve identifying population growth rates and demographic changes for the catchment areas along each train line. It could then be integrated with research that disaggregates rail patronage into demographic-based market segments (eg child, adult, senior) as proposed in section 4.8.2 of the main report.

With the help of Auckland Transport and NZ Bus Ltd, we were able to identify a number of key miscellaneous events and to explain various anomalies in the data. Table B.2 provides information on key miscellaneous events that we considered and incorporated into the analyses.

Table B.2 Miscellaneous events

Event	Months affected	Quarters affected	Notes relating to event
Diesel multiple units (DMUs) introduced	Jul 93	1993-Q3	In July 1993, new DMUs were introduced and replaced the pre-existing carriage trains.
Auckland CBD power crisis	Feb 98, Mar 98	1998-Q1	In February 1998, the Auckland CBD power crisis caused the southern line to be closed for five weeks
Fare increases	Oct 00, Feb 06, Jan 07, Feb 10	2000-Q4, 2006-Q1, 2007-Q1, 2010-Q1	There was a fare increase in 2000 followed by an absence of any fare increases between 2000 and 2006. However, since 2006 there have been a number of fare increases.

Event	Months affected	Quarters affected	Notes relating to event
Completion of Britomart	Jul 03	2003–Q3	The Britomart development was completed in July 2003, enabling train lines to provide commuters with direct access to the Auckland CBD. This appears to have had a dramatic impact on patronage growth on both lines, most notably during the offpeak.
Project Boston	Apr 04	2004–Q2 through 2005–Q1	In 9 April 2004 the first stage of western line track duplication (aka 'Project Boston' commenced. This unfortunately limited train usage of the western line and appeared to have a discernible negative impact on patronage growth on this line. 'Project Boston' was completed on 1 February 2005, hence enabling double tracking on the western line (see below).
Changeover anomaly	Jul 04	2004–Q3, 2004–Q4	There were anomalies in the second dataset (which was based on ticket sales) arising from the 'changeover' from Tranz Metro to Connex on 22 August 2004. There was a 'wash-up' whereby all outstanding sales up to the last day of Tranz Metro operations were accounted for as sales in August 2004. This caused a higher than expected patronage in 2004–Q3 and lower than expected patronage in 2004–Q4.
Negative publicity affecting numbers of foreign students	Mid 2004	2004–Q3 through 2005–Q2	From 2004–Q3, there was a decline in tertiary patronage. We have been informed that there was negative publicity for New Zealand around this time and there was, subsequently, a large reduction in foreign students
Partial completion of double-tracking on the western train line	Feb 05	2005–Q1	In February 2005, double-tracking between Mount Eden and Morningside was completed and an improved timetable was introduced.
Stagecoach bus labour strike for six days	May 05	2005–Q2	From 5 May 2005, there was a six-day labour strike by staff at Stagecoach (pre-NZ Bus). This appears to have had a permanent negative impact on Auckland bus patronage, most notably on bus corridors that 'compete' with rail lines; we see evidence (see section C3.3 and table C.5) that this event may have encouraged a permanent mode-shift from bus to rail.
Network signalling problem	c. Apr 07	2007–Q2	During the months of February/March 2007 there was a major construction programme that caused an instability in the signalling system. This caused many services to be delayed and cancelled and appears to have had a negative impact on patronage during subsequent months.
Student discount increased	Feb 08	2008–Q2	In February 2008, the student discount was increased to 40% (from 20%)
Crossing of the \$2.00 nominal petrol price threshold	May 08 through Aug 08	2008–Q3	During the period from 22 May 2008 through to 13 August 2008 the nominal price of regular petrol crossed the \$2.00 threshold. There is reason to believe that the crossing of this threshold may have been a key trigger for behavioural change. (However, it is important to note that the impact of thresholds like the \$2.00 mark is not concrete – it may reflect a number of other issues around the same time (eg media attention on 'peak oil') and may very well have changed as people have become accustomed to higher petrol prices.)
Introduction of SuperGold Card	Oct 08	2008–Q3	The SuperGold Card was introduced in October 2008, providing free off-peak and weekend travel for persons over 65.

Event	Months affected	Quarters affected	Notes relating to event
Line maintenance	Dec 08, Jan 10	2008–Q4, 2010–Q1	There is evidence of significant line maintenance on both lines during these dates, causing a number of buses to be employed as a replacement for the trains. These disruptions could potentially have had an impact on patronage.
Station upgrades	Various dates	Various dates	There have been a number of station upgrades since 2004, and these have occurred on a regular basis. Estimating the impact of isolated station upgrades is not statistically feasible until patronage data is available on an origin-to-destination basis. However, it should be noted that these upgrades do improve the quality of train travel, and most likely did contribute to the upward trend in Auckland rail patronage observed since 2002/2003.
Additional carriages	Various dates	Various dates	There have been various situations in which the transport operator added capacity to the train system via additional carriages. This additional capacity would have reduced crowding and potentially encouraged additional patronage growth. Unfortunately, the only data available focuses on the number of trains (rather than vehicles) so we were not able to ascertain the impact that these additional carriages had.
Easter holidays	March or April depending on calendar	Q1 or Q2 depending on calendar	The Easter holidays occurred sometimes in March and sometimes in April. This can affect patronage because the timetables are more limited and because patrons are on holiday and hence less likely to use public transport.

Table B.2 notes that negative publicity affecting numbers of foreign students may have had a negative impact on public transport patronage in Auckland (on both rail and bus). In the case of the Auckland bus network, we were able to adjust for this distortion by excluding tertiary students from the total (see section C2.3 of appendix C for discussion of this issue).

In the case of the Auckland rail network we were not able to do this because the dataset provided did not distinguish by ticket type. That said, there is an opportunity to do further research by incorporating a third dataset that does distinguish by ticket type. See section 4.8.2 of the main report for more discussion of this opportunity.

B3 Graphical analysis of individual lines

B3.1 Graphical analysis of total data (all periods)

This section shows graphical analysis of the first dataset, which consists of total patronage across all periods back until 1992.

The dataset has been split into the southern and eastern lines and the western line, but figures B.1 and B.2 show similar themes across all lines.

- There was an initial growth spurt in 1994 through to 1996. This appears to represent a response (albeit somewhat delayed) to the considerable increase in service trips at the end of 1994. We note, however, that the replacement of pre-existing carriages with the new DMUs may also have played a role in this growth period.

- There was a second growth spurt starting in 2003-Q3, which coincided with the completion of the Britomart development. However, figures B.1 and B.2 also show this date also coincided with a period of continuous increases in the number of service trips. This period of continuous increases in service trips made the task of disentangling the effects of the increased service trips from the impact of Britomart somewhat challenging.
- Figures B.1 and B.2 also suggest that fare increases (in 2000-Q4, 2006-Q2, and 2007-Q1) have had quite a pronounced negative impact on patronage growth.
- Graphical analysis also shows that Project Boston had a negative impact on patronage on the western line. Figure B.2 shows a fall in patronage growth during the period associated with Project Boston (2004-Q2 through to 2005-Q1).

Figure B.1 Southern and eastern lines – analysis of total patronage growth (all time periods)

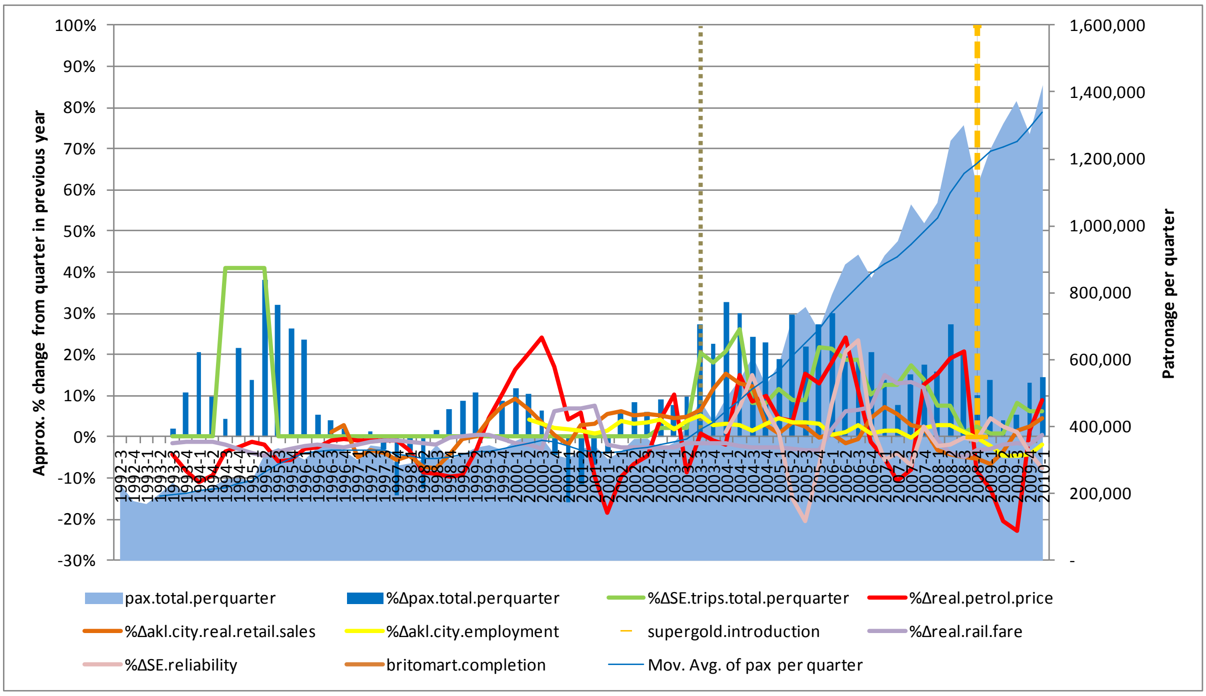
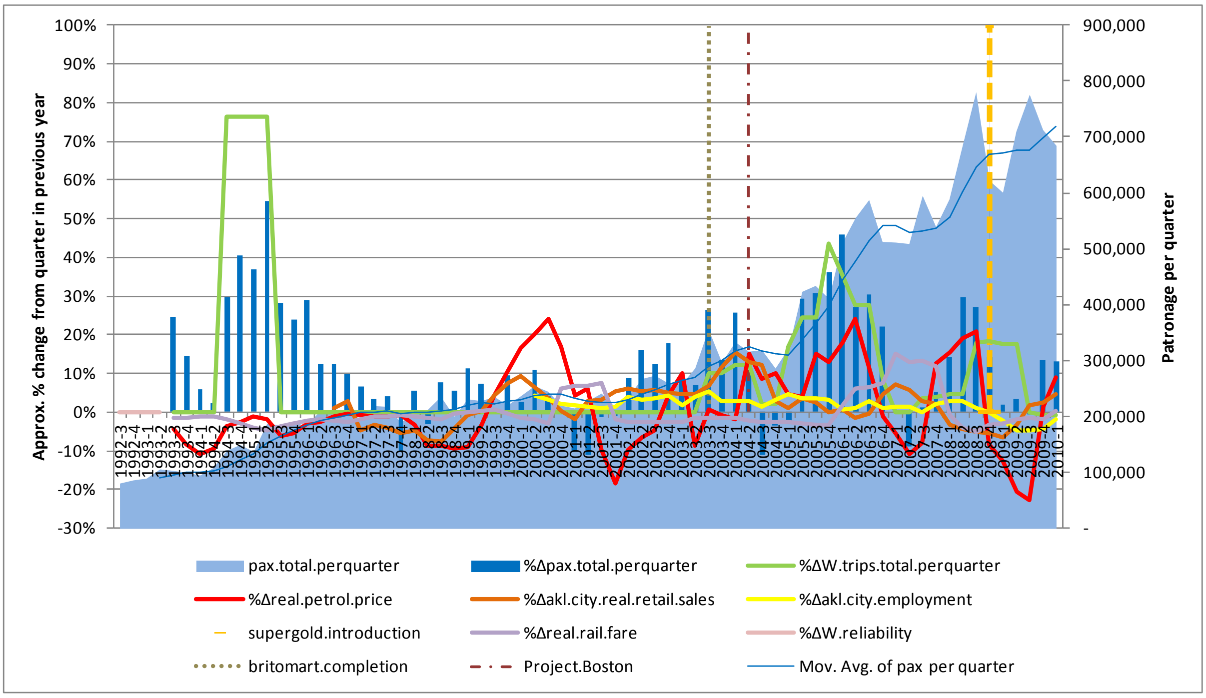


Figure B.2 Western line – analysis of total patronage growth (all time periods)



B3.2 Graphical analysis of peak data

This section shows analysis of peak (5am–9am, 3pm–6pm) data from the second dataset.

This section, along with sections B3.3, B3.4 and B3.5, illustrate one of the key advantages of disaggregating the data by time period. If we look at data within specific time periods then changes in service trip numbers look 'lumpier' and there is more contrast between the two parts of the rail system.

- The southern and eastern lines exhibit a continuous increase in the number of peak service trips provided from 2002-Q4 up until about 2006-Q3. From 2006-Q3 there were no notable increases in peak services until mid-2009, while:
  - the western line exhibits distinctive 'jumps' in peak trips in 2005-Q1 and 2008-Q3
  - there is some evidence that Project Boston contributed to lower growth rates between 2004-Q2 and the completion of double tracking on the western line in 2005-Q1.

Figure B.3 Southern and eastern lines – analysis of peak patronage growth

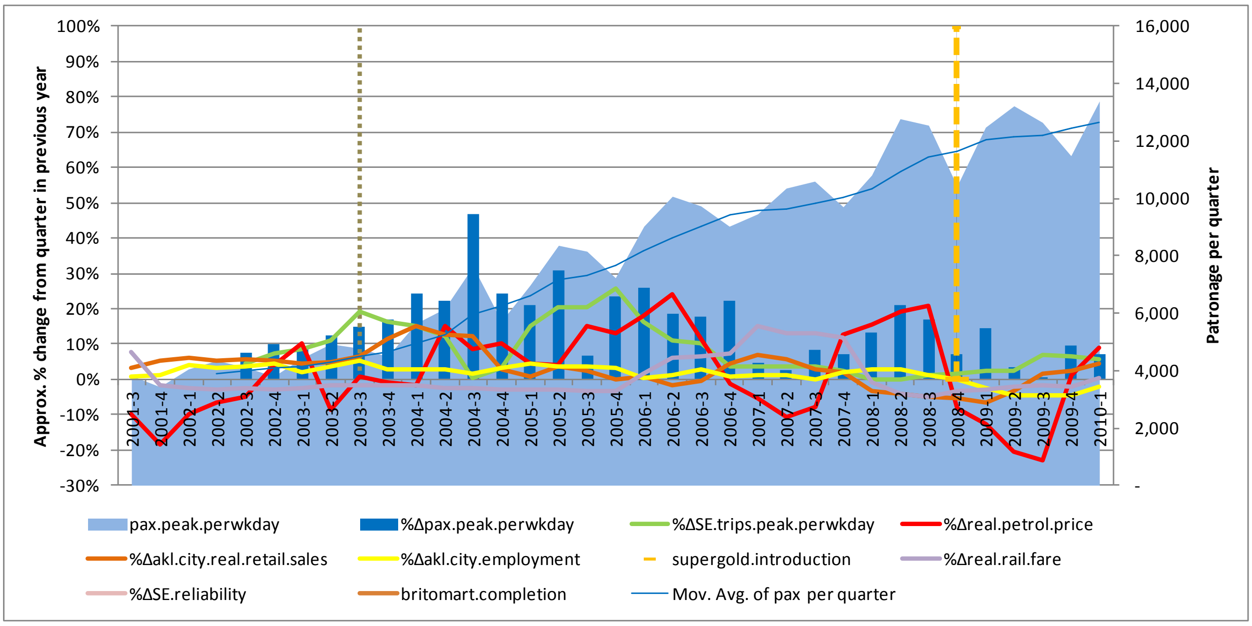
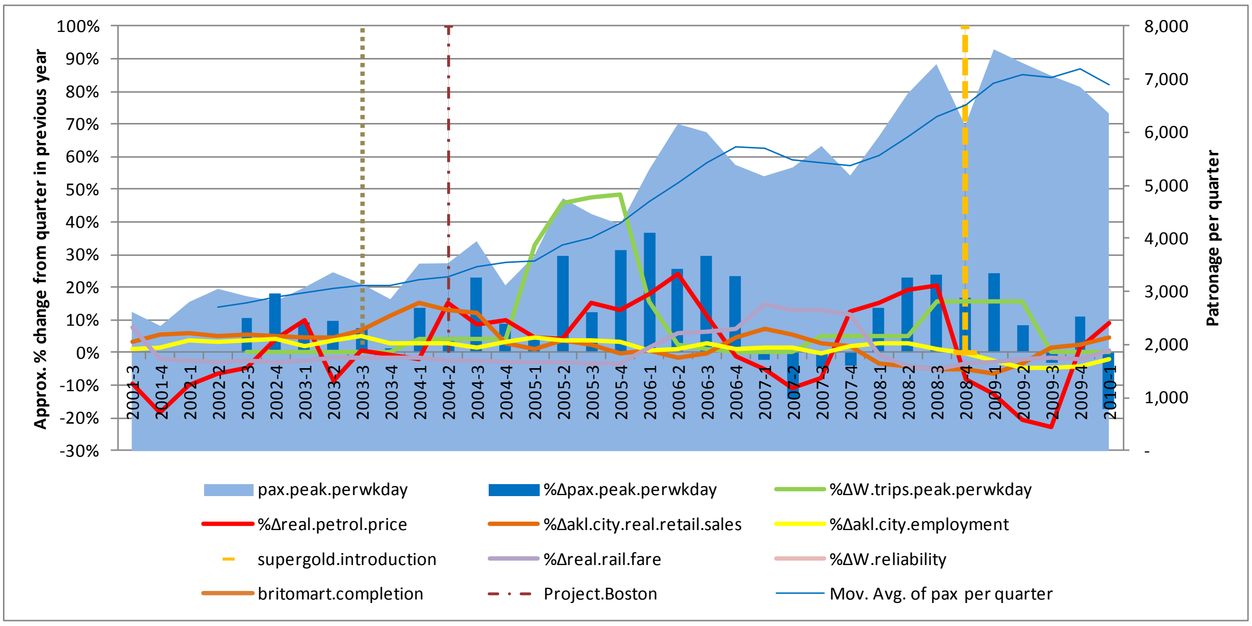


Figure B.4 Western line – analysis of peak patronage growth



B3.3 Graphical analysis of interpeak data

This section shows analysis of interpeak (9am–3pm) data from the second dataset.

Figures B.5 and B.6 show that, since the completion of Britomart, there has been dramatic growth in interpeak patronage. This is despite the fact that there were no changes to the level of interpeak service trips until much later, suggesting that Britomart played a key role on its own.

That said, the eventual increases in interpeak service frequency do appear to have also played a role in the growth on interpeak patronage: there were service improvements on the southern and eastern lines in

2007-Q4 and on the western line in 2006-Q4 and 2009-Q3. All these were accompanied by discernible patronage responses.

Figure B.6 shows that Project Boston (2004-Q2 through to 2005-Q1) had a discernible negative impact on interpeak patronage on the western line.

Figure B.5 Southern and eastern lines – analysis of interpeak patronage growth

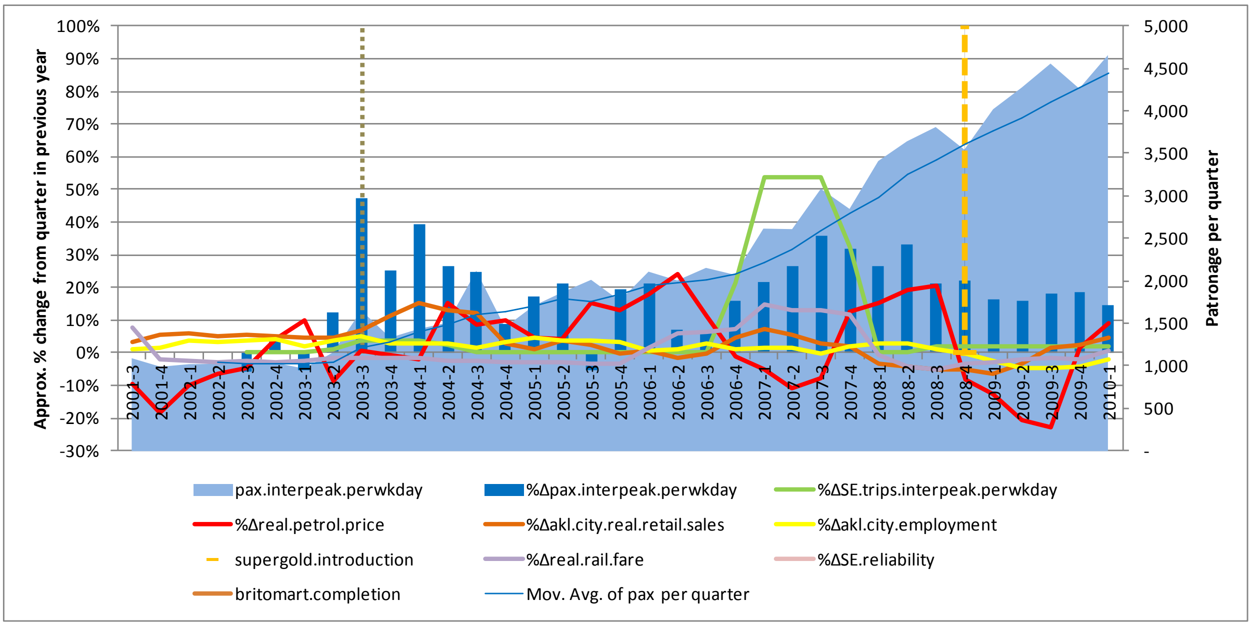
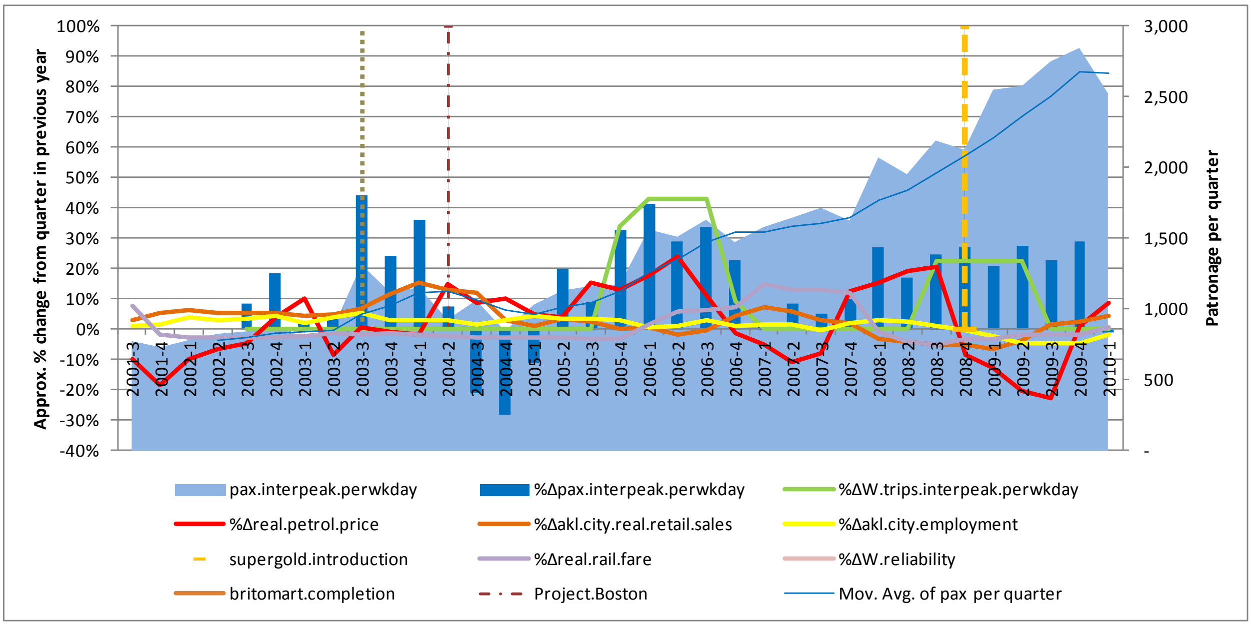


Figure B.6 Western line – analysis of interpeak patronage growth



B3.4 Graphical analysis of evening data

This section shows analysis of evening (6pm onwards) data from the second dataset.

Figures B.7 and B.8 show that the improvements to evening services have had quite a pronounced impact on evening patronage growth. However, even after taking that into account, it appears that Britomart has also had an impact on evening patronage growth.

We note that evening patronage growth on the western line was surprisingly high prior to the introduction of Britomart, and the reasons for this are not clear.

As with interpeak patronage, figure B.8 shows that Project Boston (2004-Q2 through to 2005-Q1) had a discernible impact on evening patronage on the western line.

Figure B.7 Southern and eastern lines – analysis of evening patronage growth

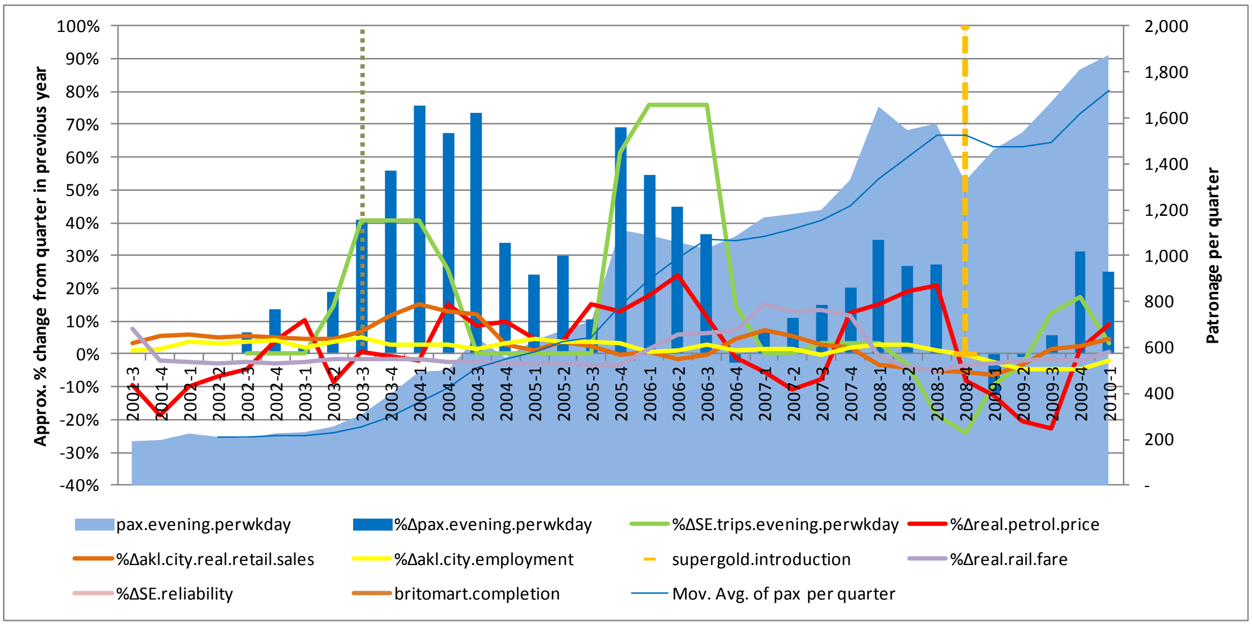
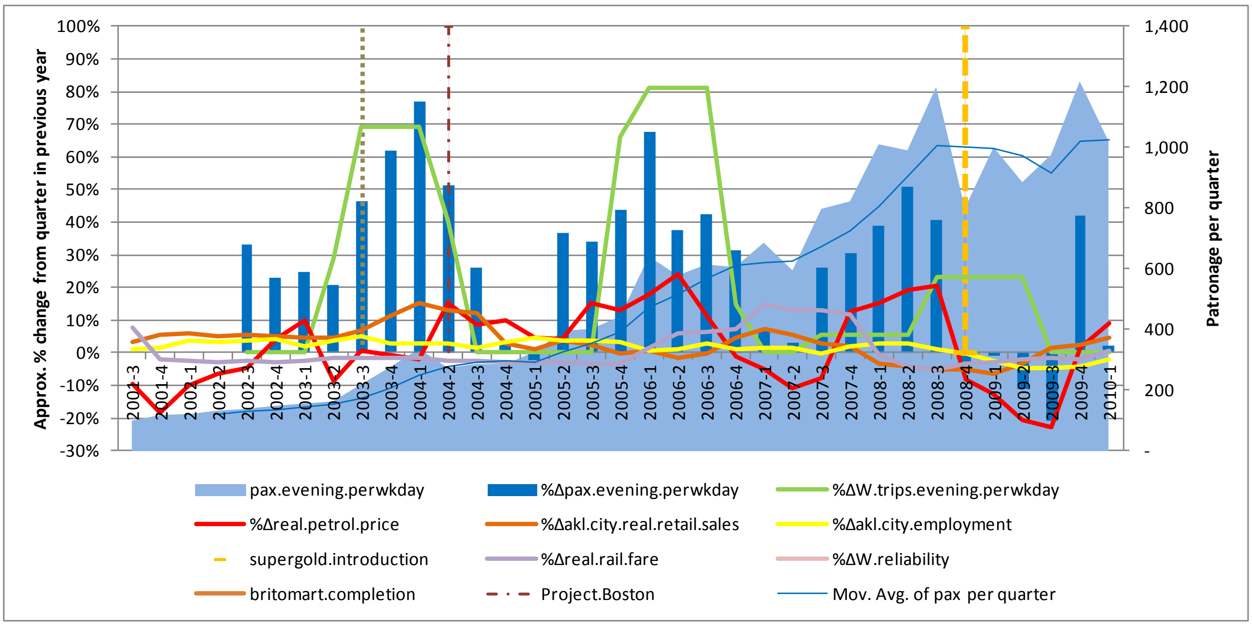


Figure B.8 Western line – analysis of evening patronage growth



B3.5 Graphical analysis of weekend data

This section shows analysis of weekend data from the second dataset.

There are a number of key observations from figures B.9 and B.10:

- As with interpeak (B3.3) and evening (B3.4) data, the completion of Britomart in 2003-Q3 appears to have a pronounced impact on patronage. However, the impact on weekend patronage was especially notable in the first quarter – a lot of this can be attributed to a surge in patronage in the weeks following the commencement of operations from Britomart, much of which can be attributed to the novelty factor, media attention and its relevance to the Auckland public as a political issue. The impact on travel demand was experienced with family groups travelling mainly in the weekends following the operational opening date (7 July 2003), and in particular on Saturday 26 July which was the official opening ceremony.
- The increases in Saturday service trips on the southern and eastern lines (in 2004-Q2 and 2007-Q3) have had a discernable impact on weekend patronage growth.
- Sunday services were introduced in October 2005 (ie 2005-Q4) and appear to have had a discernable impact on weekend patronage growth.
- There was unusual volatility in weekend patronage on the western line from 2008-Q1 onwards. Some of this may be due to the impact of sporting events on weekend patronage, especially given that the major sporting stadium (Eden Park) is adjacent to Kingsland station on the western line. The other possible explanation is line closures: the completion of Project Boston in 2005-Q2 was followed by Project DART. Project DART consisted of considerable substantial reconstruction work on sections along the western line. This required frequent partial or full line blocks in weekends and public holidays when buses were substituted for the trains.

As with interpeak and evening patronage, figure B.10 shows that Project Boston (2004-Q2 through to 2005-Q1) had a discernible impact on weekend patronage on the western line.

Figure B.9 Southern and eastern lines– analysis of weekend patronage growth

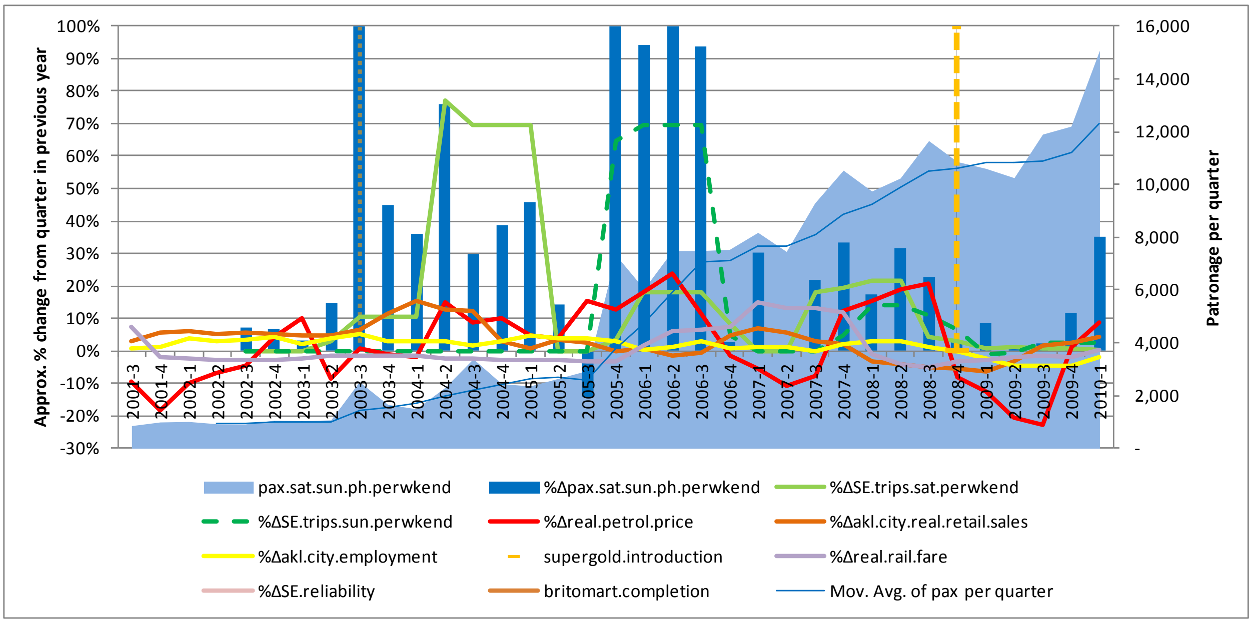
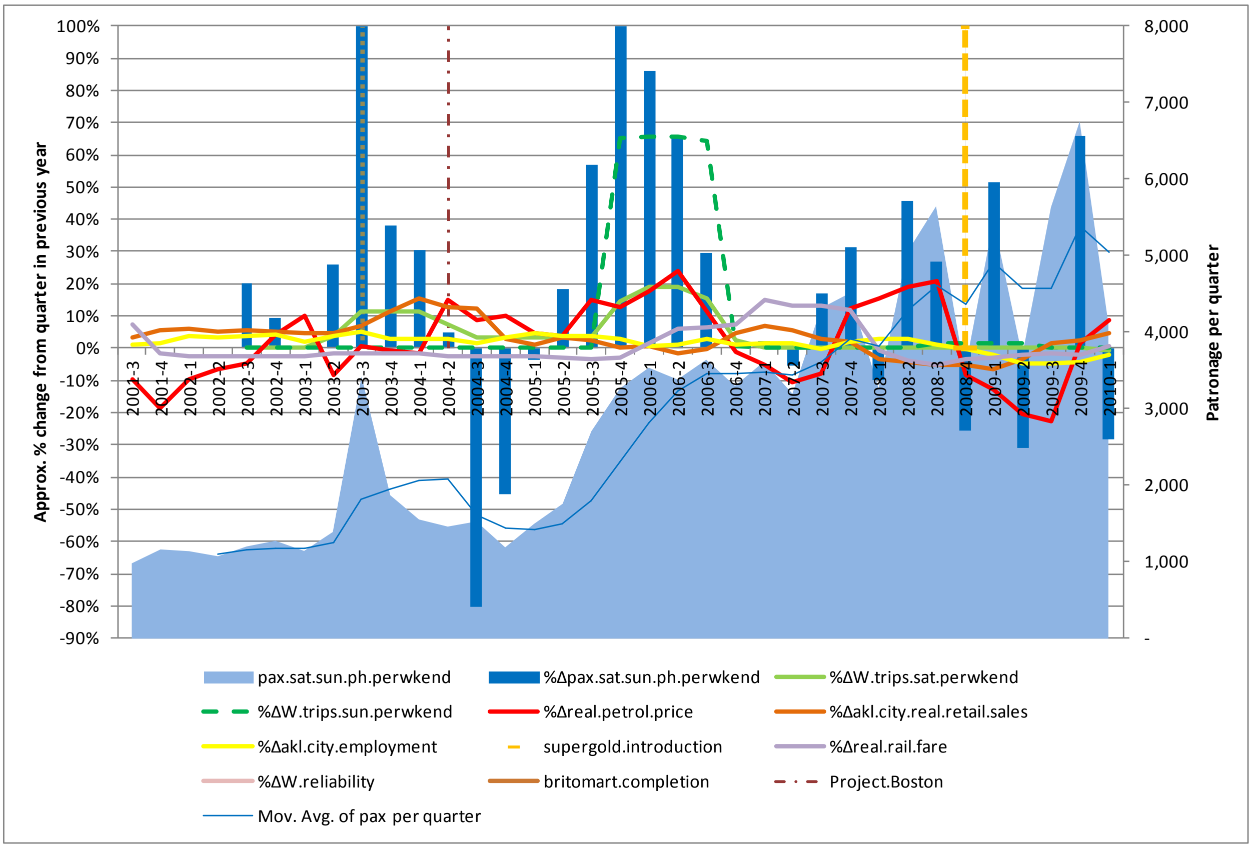


Figure B.10 Western line – analysis of weekend patronage growth



B4 Data analysis

B4.1 Multicollinearity analysis

As noted in section 2.4.1 of the main report, high correlations between explanatory variables can make econometric estimation difficult. This section uses correlation tables to examine the extent to which such correlations might be problematic.

Table B.3 shows correlations between the explanatory variables for the period corresponding to the first dataset (ie the entire period back until 1993). These correlations are generally low.

Table B.3 Correlations between explanatory variables for period from 1993-Q3 to 2010-Q1

	trips.total.perquarter	DMU.replace.dummy.Jul93	SE.CBD.power.crisis.dummy.Feb98	Britomart.commence.Jul03	Britomart.first.quarter.Jul03	W.Project.Boston.dummy.Apr04	W.double.tracking.Feb05	labour.strike.May05	network.signalling.problem.Apr07	student.discount.dummy.Feb08	line.maintenance.Dec08	line.maintenance.Jan10	station.development.complete.dummy.Jan10	real.rail.fare	real.petrol.price	petrol.price.threshold.dummy.2dollar	supergoldcard.dummy.Oct08	Easter.dummy
trips.total.perquarter	1.0																	
DMU.replace.dummy.Jul93	-0.1	1.0																
SE.CBD.power.crisis.dummy.Feb98	0.0	0.0	1.0															
Britomart.commence.Jul03	0.1	-0.1	0.0	1.0														
Britomart.first.quarter.Jul03	0.1	0.0	0.0	0.4	1.0													
W.Project.Boston.dummy.Apr04	-0.2	0.0	0.0	0.1	-0.2	1.0												
W.double.tracking.Feb05	0.2	0.0	0.0	0.0	0.0	-0.5	1.0											
labour.strike.May05	0.3	-0.1	0.0	-0.1	0.0	-0.5	0.6	1.0										
network.signalling.problem.Apr07	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.0									
student.discount.dummy.Feb08	0.0	-0.1	0.0	-0.1	0.0	0.0	-0.1	-0.1	-0.4	1.0								
line.maintenance.Dec08	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.5	1.0							
line.maintenance.Jan10	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.0						
station.development.complete.dummy.Jan10	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.0	1.0					
real.rail.fare	-0.1	-0.1	0.0	-0.1	0.0	0.0	-0.1	-0.1	0.3	-0.2	-0.1	0.0	0.0	1.0				
real.petrol.price	0.1	-0.2	0.0	0.1	-0.1	0.0	0.2	0.3	-0.2	0.2	-0.1	0.1	0.1	0.0	1.0			
petrol.price.threshold.dummy.2dollar	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	-0.3	0.5	0.0	0.0	0.0	-0.1	0.5	1.0		
supergoldcard.dummy.Oct08	0.0	-0.1	0.0	-0.1	0.0	0.0	0.0	-0.1	0.0	0.3	0.5	0.0	0.0	-0.1	-0.4	-0.5	1.0	
Easter.dummy	0.0	0.0	-0.1	0.0	0.0	0.2	-0.1	-0.2	0.2	-0.1	0.0	0.0	0.0	0.1	-0.1	-0.2	0.0	1.0

Table B.4 shows correlations of all the explanatory variables corresponding to the second dataset (ie from 2000-Q2 to 2010-Q1). The correlations are much higher due to the shorter time period covered.

Table B.4 shows a high correlation between real fares and the service trip variables. However, we note that the highest correlations are with (lagged) service trip variables that were not employed in the preferred econometric model (trips.evening.per.wkday.lag, trips.sat.sun.ph.per.wkend.lag).

Table B.4 also shows high correlations between the introduction of the SuperGold Card and various explanatory variable, most notably petrol prices, employment and retail sales. There is also a moderate correlation between the introduction of the student discount and real retail sales. These correlations suggest that some caution needs to be taken in interpreting the findings associate with these variables. We also note that these correlations could be mitigated in an extension of this research using demographic-based market segmentation approach, as recommended in section 4.8.1 of the main report.

Table B.4 Correlations between explanatory variables for the period from 2002-Q2 to 2010-Q1

	trips.peak.perwkday	trips.interpeak.perwkday	trips.evening.perwkday	trips.sat.sun.ph.perwkend	trips.wkday.perwkday.lag	trips.peak.perwkday.lag	trips.interpeak.perwkday.lag	trips.evening.perwkday.lag	trips.sat.sun.ph.perwkend.lag	Britomart.commence.Jul03	Britomart.first.quarter.Jul03	W.Project.Boston.dummy.Apr04	W.double.tracking.Feb05	labour.strike.May05	changeover.anomoly.Jul04	network.signalling.problem.Apr07	student.discount.dummy.Feb08	line.maintenance.Dec08	line.maintenance.Jan10	station.development.complete.dummy.Jan10	real.rail.fare	real.petrol.price	petrol.price.threshold.dummy.2dollar	supergoldcard.dummy.Oct08	Easter.dummy	real.retail.akl.city	employment.akl.city
trips.peak.perwkday	1.0																										
trips.interpeak.perwkday	0.0	1.0																									
trips.evening.perwkday	0.2	0.2	1.0																								
trips.sat.sun.ph.perwkend	0.2	0.2	0.6	1.0																							
trips.wkday.perwkday.lag	-0.3	0.3	0.0	0.2	1.0																						
trips.peak.perwkday.lag	-0.1	0.5	0.4	0.5	0.8	1.0																					
trips.interpeak.perwkday.lag	-0.3	-0.2	-0.4	-0.1	0.5	0.0	1.0																				
trips.evening.perwkday.lag	-0.1	0.2	-0.3	-0.1	0.7	0.2	0.2	1.0																			
trips.sat.sun.ph.perwkend.lag	0.0	0.3	-0.2	-0.1	0.5	0.2	0.2	0.6	1.0																		
Britomart.commence.Jul03	0.0	-0.2	0.4	0.0	-0.2	-0.1	-0.2	-0.2	-0.2	1.0																	
Britomart.first.quarter..Jul03	0.1	0.0	0.2	-0.1	-0.1	-0.1	0.0	-0.2	0.0	0.4	1.0																
W.Project.Boston.dummy.Apr04	-0.4	-0.2	-0.2	-0.2	0.0	-0.2	0.0	0.3	0.0	0.1	-0.2	1.0															
W.double.tracking.Feb05	0.8	0.1	0.0	0.1	-0.1	0.0	-0.1	0.0	-0.1	-0.1	0.0	-0.5	1.0														
labour.strike.May05	0.7	0.1	0.3	0.4	-0.1	0.1	-0.2	-0.2	0.2	-0.2	0.0	-0.5	0.6	1.0													
changeover.anomoly.Jul04	0.0	0.1	0.2	0.2	0.0	0.0	0.0	0.0	0.0	0.0	-0.4	0.0	0.0	0.0	1.0												
network.signalling.problem.Apr07	0.0	0.2	0.0	-0.1	0.2	0.1	0.0	0.3	0.3	0.0	0.0	0.0	0.0	0.0	0.0	1.0											
student.discount.dummy.Feb08	-0.1	0.0	-0.2	-0.1	-0.1	-0.2	0.4	-0.2	-0.2	-0.2	0.0	0.0	-0.1	-0.2	0.0	-0.4	1.0										
line.maintenance.Dec08	0.0	0.0	-0.1	-0.1	0.0	-0.1	0.1	-0.1	0.0	-0.1	0.0	0.0	-0.1	-0.1	0.0	0.0	0.5	1.0									
line.maintenance.Jan10	-0.1	-0.1	-0.1	-0.1	0.0	0.0	0.1	-0.1	-0.1	-0.1	0.0	0.0	-0.1	-0.1	0.0	0.0	-0.1	0.0	1.0								
station.development.complete.dummy.J	-0.1	-0.1	-0.1	-0.1	0.0	0.0	0.1	-0.1	-0.1	-0.1	0.0	0.0	-0.1	-0.1	0.0	0.0	-0.1	0.0	1.0	1.0							
real.rail.fare	-0.3	0.5	0.1	0.0	0.6	0.4	0.2	0.6	0.6	-0.2	0.0	0.0	-0.2	-0.1	0.0	0.4	-0.3	-0.1	0.0	0.0	1.0						
real.petrol.price	0.2	0.0	0.3	0.5	0.0	0.2	0.0	-0.2	-0.2	0.0	-0.1	0.0	0.2	0.4	0.0	-0.3	0.2	-0.2	0.1	0.1	-0.1	1.0					
petrol.price.threshold.dummy.2dollar	0.0	0.0	0.0	0.1	0.1	0.0	0.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	-0.3	0.6	0.0	0.0	0.0	-0.1	0.6	1.0				
supergoldcard.dummy.Oct08	0.0	0.0	-0.2	-0.2	-0.2	-0.1	0.0	-0.2	-0.1	-0.1	0.0	0.0	-0.1	-0.2	0.0	0.0	0.3	0.5	-0.1	-0.1	-0.2	-0.6	-0.5	1.0			
Easter.dummy	-0.1	0.0	0.1	0.1	0.0	0.1	0.0	0.0	-0.1	0.0	0.0	0.2	-0.1	-0.2	0.0	0.2	-0.1	0.0	0.0	0.0	0.1	-0.1	-0.3	0.0	1.0		
real.retail.akl.city	-0.1	-0.2	0.1	-0.1	0.0	0.0	-0.2	0.2	0.0	0.6	-0.1	0.2	-0.1	-0.1	0.1	0.2	-0.6	-0.3	0.1	0.1	0.1	-0.1	-0.1	-0.5	0.0	1.0	
employment.akl.city	0.2	-0.1	0.2	0.2	-0.1	-0.1	-0.1	0.1	-0.1	0.3	0.2	0.0	0.2	0.2	-0.1	-0.1	0.0	-0.1	-0.2	-0.2	-0.1	0.5	0.5	-0.7	0.0	0.3	1.0

B4.2 Stationarity analysis

In section 2.4.2 of the main report we note that the conventional approach in transport economics is to carry out econometric regressions with all of the variables defined in levels. However, with this approach, there is a risk that the regressions can lead to spurious results if the variables are classed as nonstationary (ie they exhibit strong trends over time).

Our approach to mitigate this risk is to take seasonal differences and to look at growth rates in patronage and explanatory variables between one quarter and the preceding quarters. There is still some risk of nonstationarity and/or insufficient variation in the explanatory variables so we have proceeded with formal testing to further mitigate against the risk of spurious results.

Table B.5 shows testing for stationarity or nonstationarity of key explanatory variables. Despite the reasonably short time-frame, there is evidence of stationarity amongst most of these variables. The main 'red flag' is employment which the KPSS test indicates is nonstationary. The main 'red flag' is employment which the KPSS test indicates is nonstationary. It is unlikely that employment growth is actually nonstationary; the failure of this test most likely reflects the fact that employment exhibited stable and steady growth rates throughout most of the period covered, but exhibited a sharp decline in late 2008 as the recession hit.

Given that, as discussed in section B4.1, employment and real retail sales also showed moderately high correlations with other explanatory variables, any estimates produced using these variables should be regarded with some caution.

Table B.5 Stationarity of continuous explanatory variables

		Augmented Dickey Fuller test for stationarity[a]			KPSS test for nonstationarity[a]			
		Null hypothesis: variable is nonstationary			Null hypothesis: variable is stationary			
Variable[b]	**Period**	**Critical value**	**p-value**	**Decision**	**Critical value**	**p-value**	**Decision**	**Conclusion**
%Δ in real petrol prices	1993-Q3 to 2010-Q1	-4.53	0.01	Reject null → series is stationary	0.179	>0.10	Do not reject null → series is stationary	Stationary
%Δ in real retail sales	2000-Q2 to 2010-Q1	-2.19	0.50	Do not reject null → series is nonstationary	0.182	>0.10	Do not reject null → series is stationary	Inconclusive
%Δ in employment	2000-Q2 to 2010-Q1	-2.51	0.37	Do not reject null → series is nonstationary	0.448	0.06	Reject null → series is nonstationary	Nonstationary

[a] The ADF test incorporated 4 lags and the KPSS test employed a long version of the truncation lag parameter, which had four to five lags.

[b] Service variables and real fare were excluded from the analysis because they representation 'one-off' structural changes that cannot plausibly be regarded as stationary, regardless of the results of empirical testing.

Table B.6 shows testing for stationarity or nonstationarity of dependent variables.

Table B.6 Stationarity of dependent variables (patronage)

			Augmented Dickey Fuller test for stationarity[a]			KPSS test for nonstationarity[a]			
			Null hypothesis: variable is nonstationary			Null hypothesis: variable is stationary			
Variable	**Line/s**	**Period**	**t-statistic**	**p-value**	**Decision**	**t-statistic**	**p-value**	**Decision**	**Conclusion**
%Δ in total patronage per quarter	Southern and eastern	1993-Q3 to 2010-Q2	-2.35	0.43	Do not reject null → series is nonstationary	0.224	>0.10	Do not reject null → series is stationary	Inconclusive
%Δ in total patronage per quarter	Western	1993-Q3 to 2010-Q2	-3.29	0.08	Reject null → series is stationary	0.113	>0.10	Do not reject null → series is stationary	Stationary

[a] The ADF test incorporated 4 lags and the KPSS test employed a long version of the truncation lag parameter, which had 5 lags.

B4.3 Endogeneity issues

In section 2.4.3 we note that endogeneity or 'reverse causation' is another statistical issue that needs to be given careful consideration. In particular, the econometric models adopted in this research project assume that patronage growth is 'caused' by service improvements. However, it is conceivable that transport operators improve service levels as a means of coping with patronage demand.

Our conclusions in regard to the risk of endogeneity are as follows:

- The graphical analysis of offpeak patronage (ie interpeak weekday, evening weekday and weekend) suggests that offpeak service improvements 'cause' offpeak patronage growth (see sections B3.3 to 3.5). Any growth in offpeak services is followed immediately by a 'burst' in offpeak patronage.
- The graphical analysis of peak patronage is not as compelling (see section B3.2). The relationship between peak-time patronage and peak-time service improvements is not clear; there was a 'burst' in peak-time patronage a year after the service improvements but we cannot be confident that this was caused by the service improvements.

We think that the impact of offpeak service improvements is relatively straightforward (especially if overcrowding is not a problem). An increase in frequency or an extension of hours makes the rail system more appealing to commuters and generates an immediate increase in patronage. The direction of causation is generally clear.

In contrast, the dynamics of peak-time patronage growth are more complex and the direction of causation can go in both directions. Additional peak-time services reduce overcrowding, improve reliability and reduce disruptions, hence encouraging higher patronage growth. But higher patronage growth also prompts Auckland Transport to increase the number of peak-time services.

A further complicating factor is that it can take time for peak-time service improvements to have an impact on peak-time patronage growth. It can time for peak-time service improvements to have the intended impact on service quality, and even longer for it to feed through and influence the perceptions of sceptical or frustrated patrons.

B5 Model building process

B5.1 Development of the total patronage per quarter model

The model building process began with building a general model that encompassed a broad collection of explanatory variables and key factors. This general model included the following:

- The use of dummy variables for Britomart allowed us to estimate the immediate impacts of Britomart on rail patronage growth.
- The use of pre-Britomart time trends and post-Britomart time trends allowed us to identify and distinguish the more prolonged and ongoing impacts of Britomart on rail patronage growth.
- Various dummy variables for events (introduction of DMUs, power crisis, Project Boston, network signalling problems, changes to student discounts and line maintenance).
- Various ‘standard’ explanatory variables (petrol price, Easter, real retail sales and employment).

Table B.7 shows how the general model was whittled down to produce the preferred model for total patronage per quarter. This dependent variable came from the first dataset from 1993–Q3 to 2010–Q1.

During the first iteration, we removed completion of double-tracking and SuperGold because they produced implausible signs that were also statistically significant (and hence potentially distorting the model). This produced model 2.

During the second iteration, we removed line maintenance (southern and eastern, January 2010) because it had an implausible sign. This produced model 3, which was the preferred model.

We regard these models as relatively less reliable because they employ aggregate patronage for each quarter, and do not segregate by time period. The models in sections B5.2 to B5.5 are regarded by the author as more accurate and hence given more weight.

Table B.7 Development of total patronage per quarter model

Time trends and explanatory variables		General model	Model 2	Model 3 (preferred)
Pre-Britomart time trends	Southern and eastern	1%**	1%**	1%**
	Western	4%***	4%***	4%***
Post-Britomart time trends	Southern and eastern	17%***	6%*	6%*
	Western	9%***	5%*	5%*
First year of Britomart (southern and eastern)		7%	8%	8%'
First year of Britomart (western)		8%*	10%**	10%**
Service trips added in Jul 94 (southern and eastern)[33]		0.81***	0.87***	0.87***
Service trips added in Jul 94 (western)		0.68***	0.72***	0.72***
Service trips added post-2001 (southern and eastern)		0.32	0.93***	0.90***

[33] Note that additional variables were included in the model to represent the delayed impact of the July 1994 service trips on patronage growth on both train lines. However, these variables are omitted here to prevent from unnecessarily distracting and confusing the audience.

Time trends and explanatory variables	General model	Model 2	Model 3 (preferred)
Service trips added post-2001 (western)	0.81***	0.51**	0.51**
Real rail fare	-0.49**	-0.14	-0.13
Real petrol price	-0.03	0.01	0.00
Petrol price $2.00 threshold	-15%	9%	9%
Replacement of existing engines with DMUs (Jul 93)	7%**	8%**	8%**
Closure of southern line due to Auckland CBD power crisis (southern and eastern, Feb 98)	-6%	-3%	-3%
Project Boston construction (western, Apr 04)	-18%***	-8%‘	-8%*
Completion of double tracking (western, Feb 05)	-30%***	Implausible sign	
Stagecoach Bus labour strike (May 95)	8%‘	8%‘	8%‘
Network signalling problem (Apr 07)	-9%*	-7%‘	-7%‘
Student discount increase (Feb 08)	6%	4%	4%
Line maintenance (southern and eastern, Dec 08)	4%	0%	0%
Line maintenance (western, Dec 08)	3%	-1%	-1%
Line maintenance (southern and eastern, Jan 10)	0%	3%	Implausible sign
Line maintenance (western, Jan 10)	-1%	-2%	-2%
Easter dummy	-4%**	-3%*	-3%*
Introduction of SuperGold Card (Oct 08)	-20%**	Implausible sign	

Note for symbols of statistical significance: *** → 0.1%, ** → 1%, * → 5%, ‘ →10%

B5.2 Development of the peak-time patronage model

As discussed in section B2.2, we concluded that the second dataset from 2002–Q3 to 2010–Q1 would produce more accurate estimates because the data could be split into peak-time, interpeak, evening and weekend, and hence we could more accurately control for the impact of service improvements. We therefore developed models for each of these time periods.

The general model for average peak-time patronage per weekday was similar to that for total patronage per quarter. One of the main differences was that we had only one variable representing the immediate impact of peak-time service improvements on peak-time patronage. We also allowed for delayed impacts of those peak-time services.

The other point of difference was that we created dummy variables to control for of the changeover anomalies discussed in table.B.2.

The general model was whittled down to produce the preferred model for peak-time patronage. We noted that a number of variables in the general had implausible signs; these variables were removed producing model 2, the preferred model.

Table B.8 Development of peak-time model

Time trends and explanatory variables		General model	Model 2 (preferred)
Pre-Britomart time trends	Southern and eastern	1%	5%
	Western	5%	5%
Post-Britomart time trends	Southern and eastern	7%*	9%***
	Western	4%	5%*
First year of Britomart (southern and eastern)		-1%	Implausible sign
First year of Britomart (western)		-4%	Implausible sign
Peak service trips	Immediate impact	0.29	0.15
	Subsequent year	0.54***	0.55***
Real rail fare		-0.84***	-0.89***
Real petrol price		0.08	0.08
Petrol price $2.00 threshold		-4%	Implausible sign
Real retail sales (Auckland city)		-0.05	-0.15
Employment (Auckland city)		1.43*	1.19*
Project Boston construction (western, Apr 04)		2%	Implausible sign
Completion of double tracking (western, Feb 05)		-7%	Implausible sign
Stagecoach Bus labour strike (May 05)		3%	2%
Changeover anomaly (southern and eastern)		10%**	10%**
Changeover anomaly (western)		9%**	8%**
Network signalling problem (Apr 07)		-3%	-3%
Student discount increase (Feb 08)		5%	3%
Line maintenance (southern and eastern, Dec 08)		-5%	-5%
Line maintenance (western, Dec 08)		-5%	-2%
Line maintenance (southern and eastern, Jan 10)		0%	-3%
Line maintenance (western, Jan 10)		-19%***	-19%***
Easter dummy		-4%‘	-3%‘
Introduction of SuperGold Card (Oct-08)		Not applicable	

Note for symbols of statistical significance: *** → 0.1%, ** → 1%, * → 5%, ‘ →10%

B5.3 Development of the interpeak patronage model

The general model for average interpeak patronage per weekday was basically the same as that shown in section B5.2 for peak patronage.

We examined the general model and noted that a number of variables in the general model ($2.00 petrol price threshold, completion of double-tracking) had implausible signs but were also statistically significant. These variables were removed from the next iteration and model 2 was produced.

During the next few iterations, a number of variables were removed due to implausible signs, hence leading to model 4, which was the preferred model.

Table B.9 Development of interpeak model

Time trends and explanatory variables		General model	Model 2	Model 3	Model 4 (preferred)
Pre-Britomart time trends	Southern and eastern	2%	7%	9%	8%
	Western	7%	14% '	17% *	16%**
Post-Britomart time trends	Southern and eastern	13%*	10%'	16%**	15%***
	Western	14% *	6%	12%*	10%***
First year of Britomart (southern and eastern)		25%***	39%***	37%***	37%***
First year of Britomart (western)		25%***	30%***	28%***	28%***
Interpeak service trips	immediate impact	0.55***	0.26*	0.33**	0.34***
	delayed impact	0.21***	0.00	0.08	0.10
Real rail fare		-0.93**	0.68‘	Implausible sign	
Real petrol price		0.13	-0.01	-0.05	Implausible sign
Petrol price $2.00 threshold		-60%***	Implausible sign		
Real retail sales (Auckland city)		-0.57	-0.42	-0.83	-0.71
Employment (Auckland city)		0.25	-0.59	-1.27	-1.15*
Project Boston construction (western Apr 04)		-38%***	-16%**	-18%***	-17%***
Completion of double tracking (western, Feb 05)		-41%***	Implausible sign		
Stagecoach Bus labour strike (May 05)		-4%	6%	-2%	Implausible sign
Changeover anomaly (southern and eastern)		7%	15%*	15%*	15%*
Changeover anomaly (western)		11%*	9%*	10%‘	9%‘
Network signalling problem (Apr 07)		1%	-2%	-2%	-1%
Student discount increase (Feb 08)		17%**	16%*	7%	8%
Line maintenance (southern and eastern, Dec 08)		-1%	-10%	-3%	-4%
Line maintenance (western, Dec 08)		-5%	-12%	-2%	-4%
Line maintenance (southern and eastern, Jan 10)		2%	-1%	-4%	-3%
Line maintenance (western, Jan 10)		-20%*	-12%	-14%‘	-14%‘
Easter dummy		-3%	0%	0%	0%
Introduction of SuperGold Card (Oct 08)		-19%	9%	-3%	Implausible sign

Note for symbols of statistical significance: *** → 0.1%, ** → 1%, * → 5%, ‘ →10%

B5.4 Development of the evening patronage model

The general model for average evening patronage per weekday was basically the same as that shown in section B5.2 for peak patronage.

Table B.10 shows how the general model was whittled down to the preferred model. During the first iteration, both completion of double tracking and SuperGold were removed because they were of counter-intuitive sign but also statistically significant. This produced model 2.

During the next iteration, we removed a number of other variables with counter-intuititive signs. This produced model 3, which was the preferred model.

Table B.10 Development of evening model

Time trends and explanatory variables		General model	Model 2	Model 3 (preferred)
Pre-Britomart time trends	Southern and eastern	6%	-3%	-1%
	Western	20%*	10%	12%
Post-Britomart time trends	Southern and eastern	24%**	12%*	10%**
	Western	28%**	11%‘	8%*
First year of Britomart (southern and eastern)		19%‘	13%	17%*
First year of Britomart (western)		8%	-6%	Implausible sign
Interpeak service trips	immediate impact	0.22*	0.36***	0.36***
	delayed impact	-0.09	-0.08	Implausible sign
Real rail fare		-0.67‘	-0.05	-0.13
Real petrol price		0.26	0.46‘	0.52*
Petrol price $2.00 threshold		-1%	19%	17%
Real retail sales (Auckland city)		1.44‘	2.53***	2.31***
Employment (Auckland city)		-1.28	-0.08	-0.36
Project Boston construction (western, Apr 04)		-19%*	-10%	-11%‘
Completion of double tracking (western, Feb 05)		-26%*	Implausible sign	
Stagecoach Bus labour strike (May 05)		11%	4%	5%
Changeover anomaly (southern and eastern)		11%‘	9%	9%
Changeover anomaly (western)		4%	1%	1%
Network signalling problem (Apr 07)		-7%	-9%	-9%
Student discount increase (Feb 08)		13%	19%	21%‘
Line maintenance (southern and eastern, Dec 08)		7%	-7%	-8%
Line maintenance (western, Dec 08)		-5%	-21%*	-22%*
Line maintenance (southern and eastern, Jan 10)		-8%	-7%	-6%
Line maintenance (western, Jan 10)		-33%***	-24%*	-24%*
Easter dummy		0%	0%	0%
Introduction of SuperGold Card (Oct 08)		-35%‘	Implausible sign	

Note for symbols of statistical significance: *** → 0.1%, ** → 1%, * → 5%, ‘ →10%

B5.5 Development of the weekend patronage model

The general model for weekend patronage per weekend equivalent was similar to that shown in sections B5.2 to B5.4. However, we drew a distinction between various types of improvements to weekend services.

Table B.11 shows how the general model was whittled down to the preferred model. The most serious observation in regard to the general model was that the coefficient for SuperGold was implausibly high; the estimate of an 86% increase in weekend patronage is inconsistent with the graphical analysis. The graphical analysis (see section B3.5 and figures B.9 to B.10) suggests that the impact of SuperGold on weekend patronage growth was modest at best. The removal of SuperGold produced model 2.

During the next few iterations we removed variables with implausible signs (*additional Sunday services* and *real rail fare*) producing model 3. The coefficient for the $2.00 petrol price threshold was implausibly high (and also inconsistent with the graphical analysis) so it was removed. The student discount also had an implausible sign so it was removed. These removals led to model 4. During the next few iterations, other implausible variables were removed, leading to model 6, which was the preferred model.

We note that the coefficients in table B.11 are not very robust, ie they fluctuate by large amounts and change sign depending on which explanatory variables are removed. We believe that this is due to underlying volatility in the weekend data and the models attempt to incorrectly 'explain' this volatility using dummy variables. We suggest that the findings produced for weekend data should therefore be interpreted with caution due to the lack of robustness.

Table B.11 Development of weekend model

Time trends and explanatory variables		General model	Model 2	Model 3	Model 4	Model 5	Model 6 (preferred)
Pre-Britomart time trends	Southern and eastern	-2%	22%	18%	11%	12%	12%
	Western	5%	29%*	24%'	17%	18%	18%'
Post-Britomart time trends	Southern and eastern	-7%	18%*	22%**	17%***	18%***	18%***
	Western	-13%	12%	20%*	15%***	14%***	14%***
Temporary opening effect of Britomart (southern and eastern)		81%***	66%**	75%**	74%**	73%**	74%***
Temporary opening effect of Britomart (western)		85%***	69%**	79%***	79%***	84%***	83%***
First year of Britomart (southern and eastern)		2%	28%	14%	10%	11%	11%
First year of Britomart (western)		-1%	25%	8%	3%	-1%	Implausible sign
Interpeak service trips	additional Saturday services	0.73**	0.73**	0.67**	0.63*	0.65**	0.65**
	introduction of Sunday services	0.32	0.11	0.19	0.25	0.28‘	0.28‘
	additional Sunday services	-0.95	-1.02	Implausible sign			
Real rail fare		1.70*	1.03	Implausible sign			
Real petrol price		0.71	0.18	0.21	0.49	0.50	0.48
Petrol price $2.00 threshold		127%**	48%	66%‘	Coefficient is implausibly high		
Real retail sales (Auckland city)		2.82	-0.51	0.10	0.28	0.31	0.21
Employment (Auckland city)		-0.08	-2.63	-2.94	-0.96	-1.30	-1.19
Project Boston construction (western, Apr 04)		-26%‘	-23%	-28%*	-30%*	-22%*	-22%*
Completion of double tracking (western, Feb 05)		-2%	-3%	-17%	-17%	Implausible sign	
Stagecoach bus labour strike (May 05)		27%‘	28%	21%	12%	5%	5%
Changeover anomaly (southern and eastern)		25%*	27%*	26%*	27%*	26%*	27%*
Changeover anomaly (western)		7%	12%	13%	13%	13%	13%
Network signalling problem (Apr 07)		-10%	-6%	-3%	-4%	-3%	Implausible sign
Student discount increase (Feb 08)		-8%	-3%	-20%	Implausible sign		
Line maintenance (southern and eastern, Dec 08)		-7%	17%	24%	12%	12%	
Line maintenance (western, Dec 08)		-70%***	-41%*	-28%'	-43%**	-41%**	-42%**
Line maintenance (southern and eastern, Jan 10)		11%	10%	7%	8%	6%	Implausible sign
Line maintenance (western, Jan 10)		-33%*	-37%*	-43%**	-41%*	-39%*	-39%*
Easter dummy		4%	-2%	-1%	-5%	-5%	-6%
Introduction of SuperGold Card (Oct 08)		86%**	Coefficient is implausibly high				

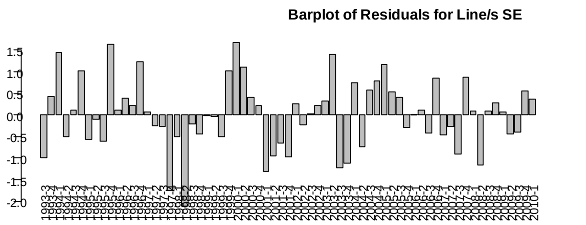
Note for symbols of statistical significance: *** → 0.1%, ** → 1%, * → 5%, ‘ →10%

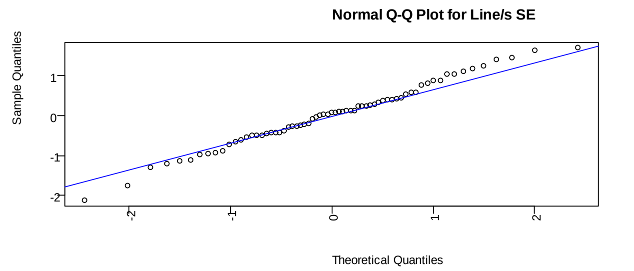
B6 Diagnostic analysis

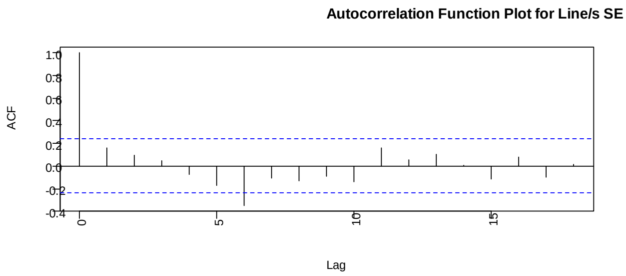
B6.1 Diagnostic analysis for the total patronage model

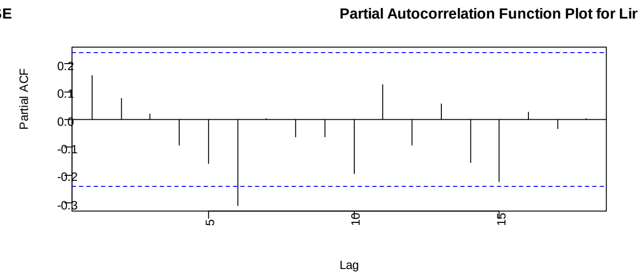
The figures below show diagnostic plots for the residuals from the final model for total patronage per quarter, as shown in section B5.1 and table B.6. This model was derived from the first dataset.

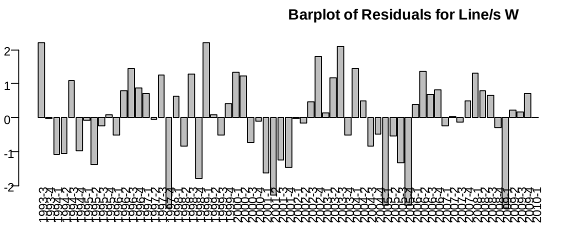
The diagnostic plots show that the residuals for both lines generally conform to key assumptions of normality. However, there is evidence of autocorrelation– this reinforces our decision, as discussed in section B2.2, to give more weight to the time models developed using the second dataset.

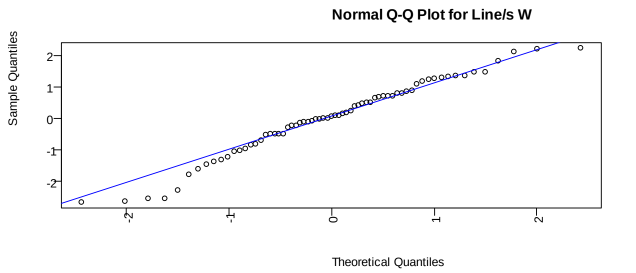


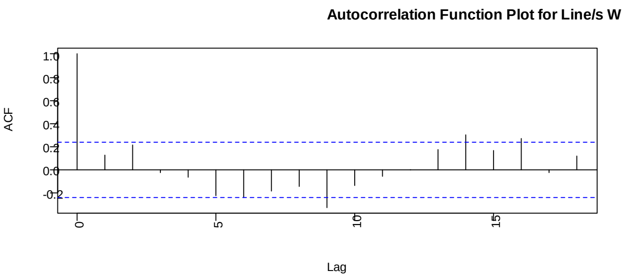


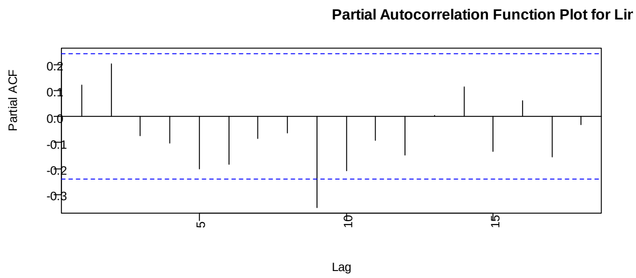








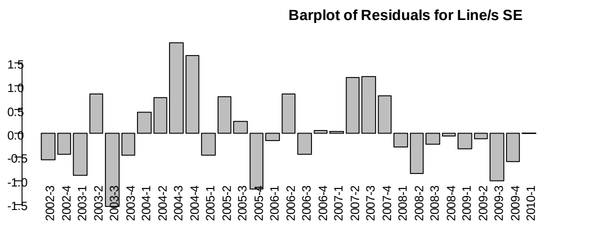


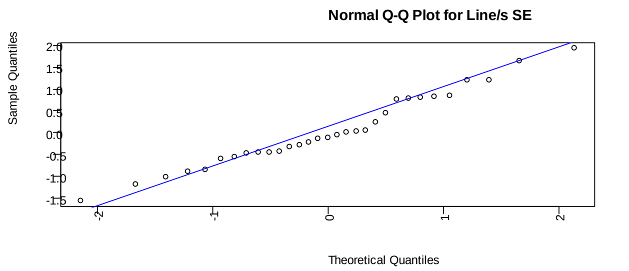


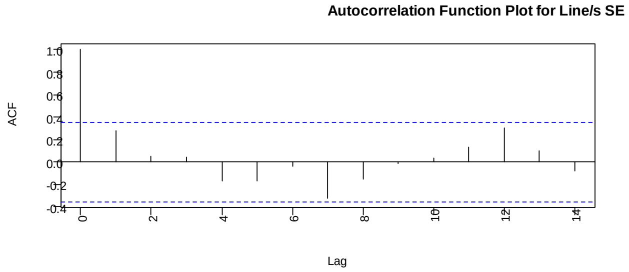
B6.2 Diagnostic analysis for the peak-time model

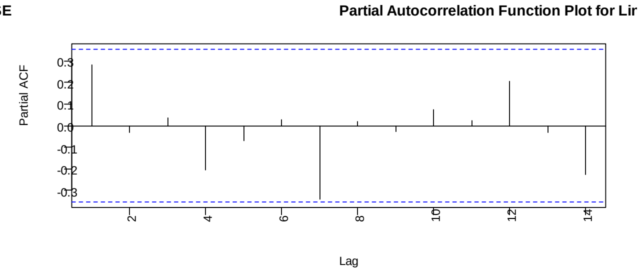
The figures below show diagnostic plots for the residuals from the final model for peak-time patronage, as shown in section B5.2 and table B.7.

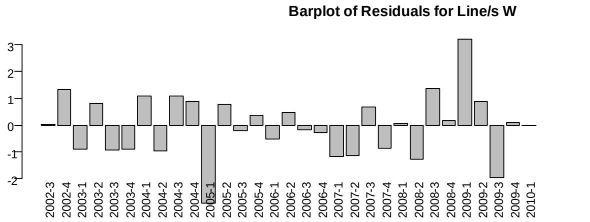
The diagnostic plots show that the residuals for both lines generally conform to key assumptions of normality. Furthermore, autocorrelation is low for the southern and eastern lines, and close to zero for the western line.

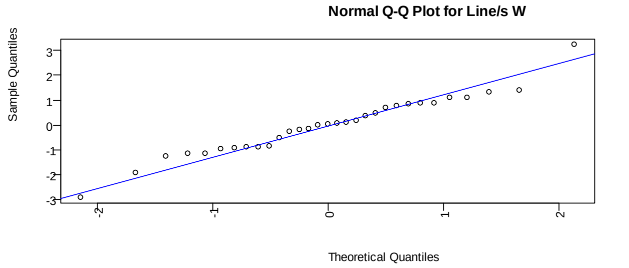


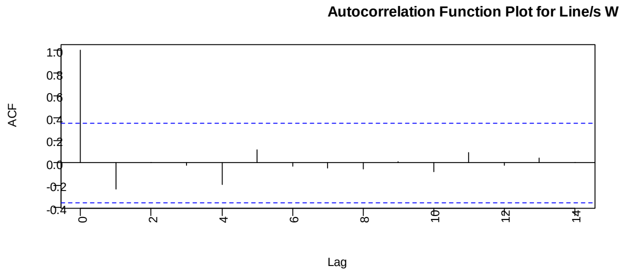


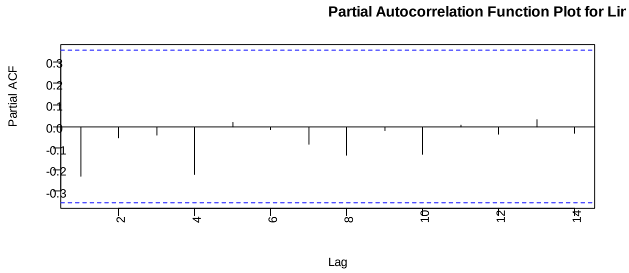








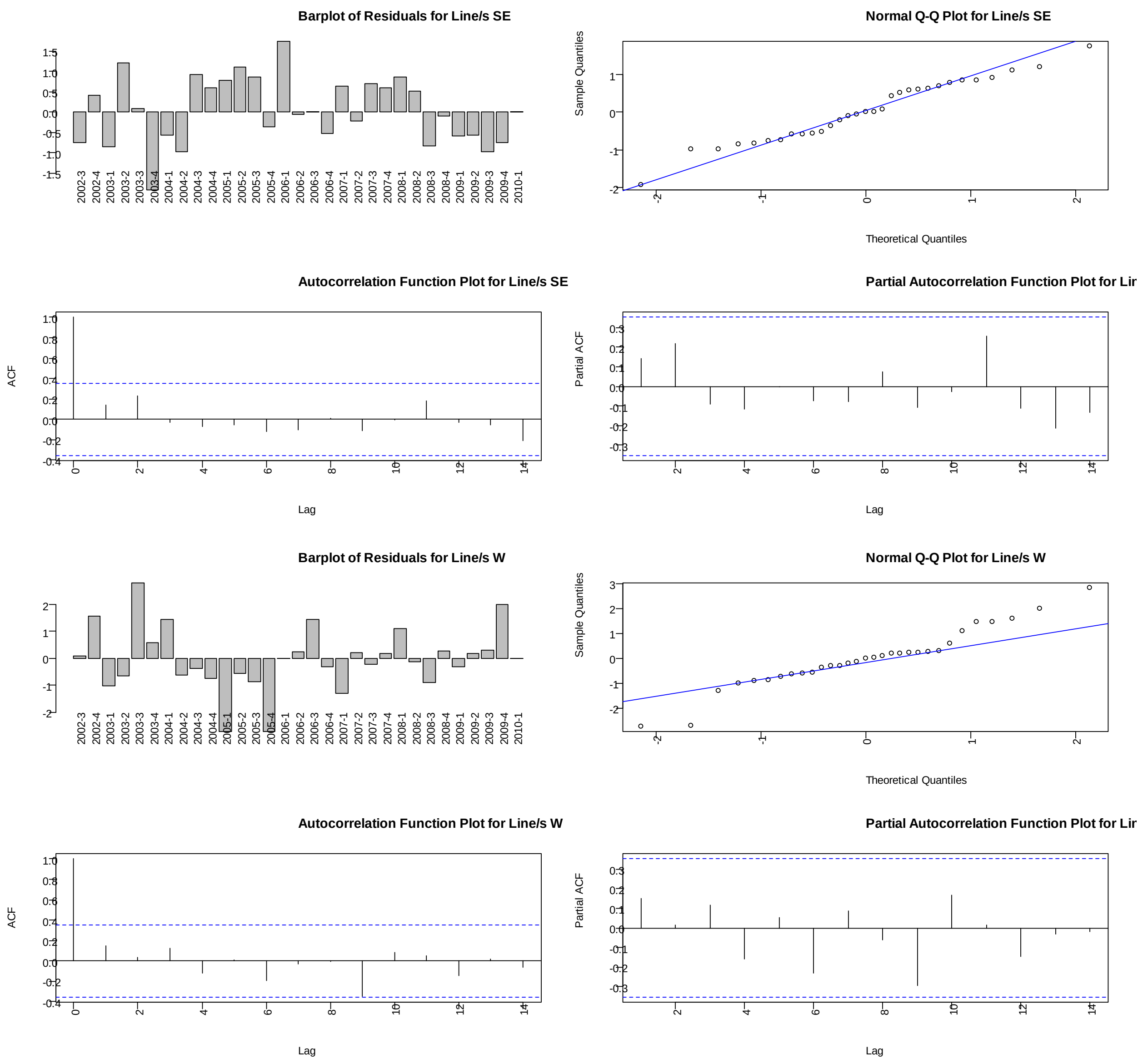




B6.3 Diagnostic analysis for the interpeak model

The figures below show diagnostic plots for the residuals from the final model for interpeak patronage, as shown in section B5.3 and table B.8.

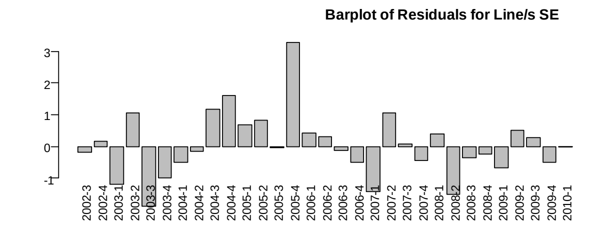
The diagnostic plots show that the residuals for both lines exhibit low levels of autocorrelation. That said, there is some evidence of 'clustering' behaviour in the barplot of residuals for the southern and eastern lines. Also, the residuals for the western line show evidence of non-normality; there is an excessive number of outliers, suggesting that a few key events or factors have been omitted from the model.

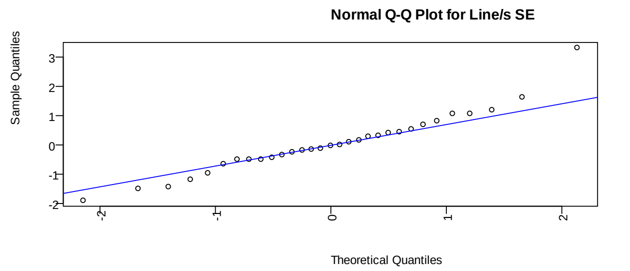


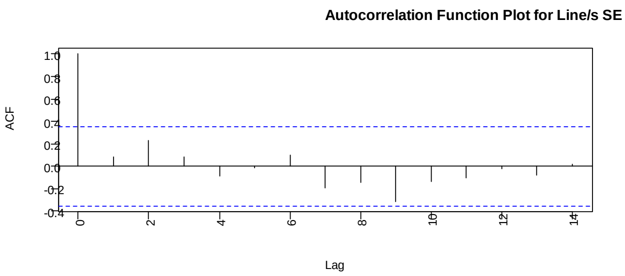
B6.4 Diagnostic analysis for the evening model

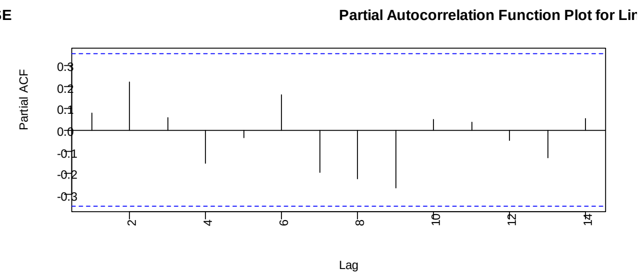
The following figures below show diagnostic plots for the residuals from the final model for evening patronage, as shown in section B5.4 and table B.9.

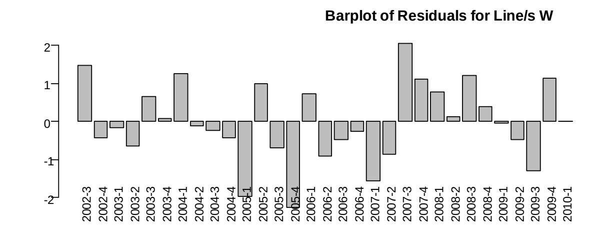
The diagnostic plots show that the residuals for both lines generally conform to key assumptions of normality and zero autocorrelation. There is a slight outlier in 2005 -Q4 on the southern and eastern lines, in which peak-time evening patronage was higher than expected, but an outlier of this magnitude is not unreasonable.

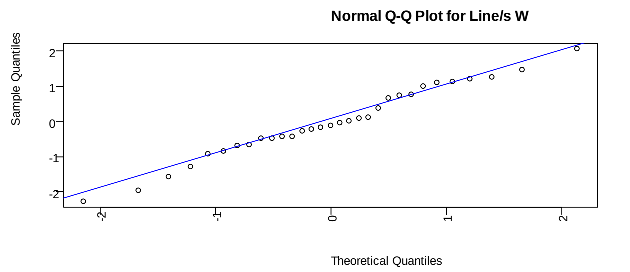


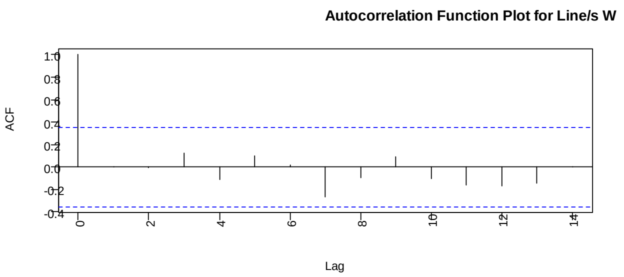


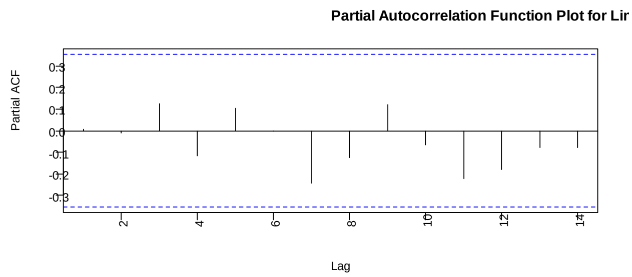








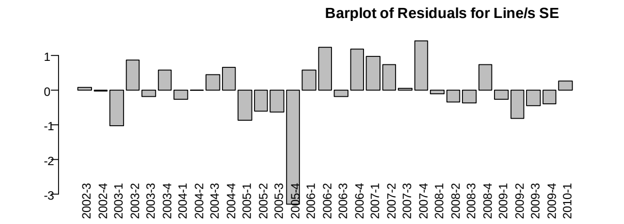


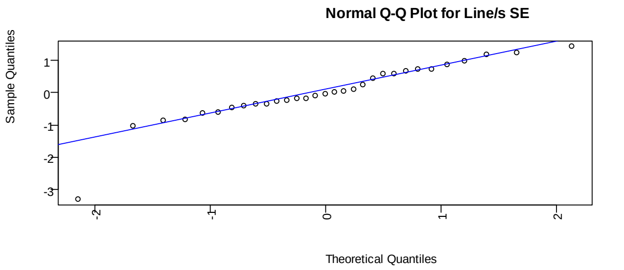


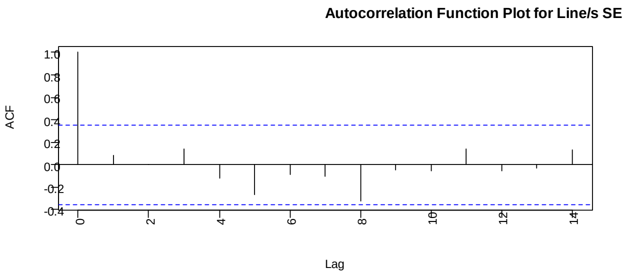
B6.5 Diagnostic analysis for the weekend model

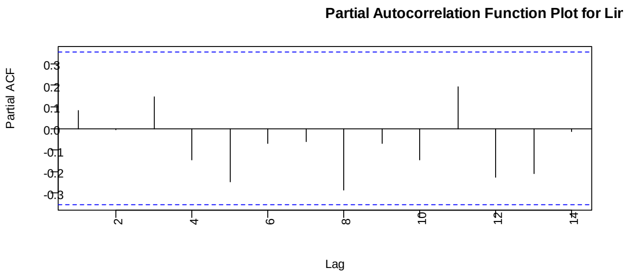
The figures below show diagnostic plots for the residuals from the final model for weekend patronage, as shown in section B5.5 and table B.10.

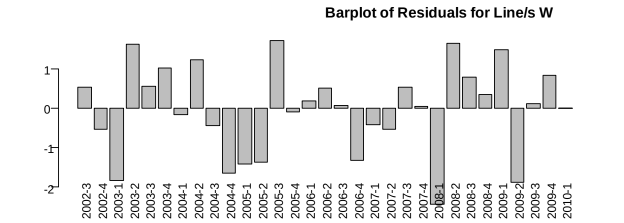
The diagnostic plots show that the residuals for both lines generally conform to key assumptions of normality and zero autocorrelation.

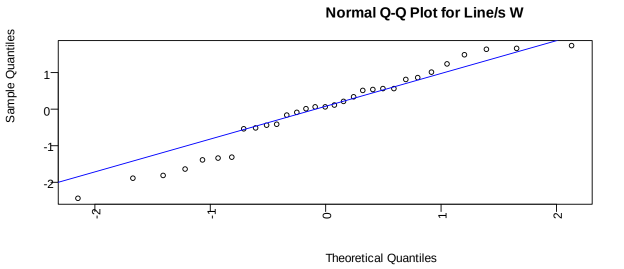


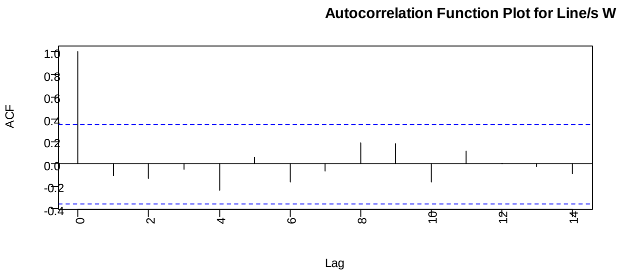


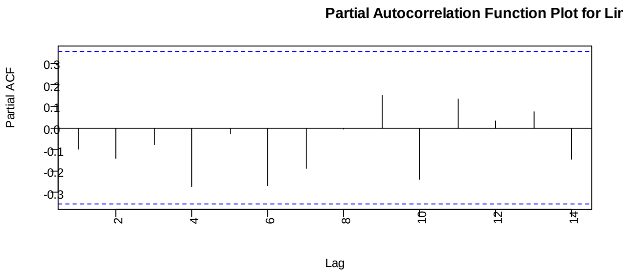












B7 Estimates and findings

This section presents the coefficients estimated using our econometric panel data model.

Table B.12 below shows our estimates for the impact of economic variables, broken down into peak weekday, interpeak weekday, evening weekday and weekend.

Table B.12 Estimates of coefficients for economic variables

Economic variables and events	Weekday			Weekend
	Peak	Interpeak	Evening	
Real rail fare elasticity	-0.89*** (-1.21, -0.56)	Removed due to implausible and volatile sign	-0.13 (-0.70, 0.44)	Removed due to implausible sign
Real petrol price cross-elasticity	0.08 (-0.15, 0.32)	Removed due to implausible sign	0.52* (0.03, 1.00)	0.48 (-0.26, 1.21)
$2.00 petrol price threshold dummy	Removed due to implausible sign	Removed due to implausible sign	17% (-22%, 55%)	Coefficient implausibly high
Real retail sales cross-elasticity	-0.15 (-0.62, 0.31)	-0.71 (-1.63, 0.20)	2.31*** (1.40, 3.22)	0.21 (-1.10, 1.51)
Employment cross-elasticity	1.19* (0.25, 2.13)	-1.15* (-2.24, -0.05)	-0.36 (-2.39, 1.66)	-1.19 (-4.15, 1.78)
Introduction of SuperGold Card dummy	Not applicable	Removed due to implausible sign	Removed due to implausible sign	Coefficient implausibly high
Increase in tertiary student discount	3% (-6%, 12%)	8% (-4%, 20%)	21%‘ (0%, 41%)	Removed due to implausible sign

Key findings from table B.12 are:

- Peak time patronage was highly responsive to fare increases, with a fare elasticity of -0.9, but fare increases had small or indiscernible impacts during the interpeak, evening or weekends.
- The impact of real petrol prices on patronage was modest during the peak and the interpeak, but had a more pronounced impact on evening and weekend patronage.
- Employment had a positive impact on peak-time patronage, as expected, but its impact could not be estimated with much accuracy.
- Real retail sales had a variable association with patronage growth, ranging from highly positive during the evening through to negative during the weekday peak.

Table B.13 shows the impact of miscellaneous events on rail patronage growth while table B.14 shows the impact of service timetable improvements on rail patronage growth.

Table B.13 Impacts of miscellaneous events on patronage growth

Impact of miscellaneous events		Weekday			Weekend
		Peak	Interpeak	Evening	
Pre-Britomart time trends	Southern and eastern	5% (-3%, 12%)	8% (-3%, 20%)	-1% (-16%, 14%)	12% (-13%, 36%)
	Western	5% (-1%, 11%)	16%** (6%, 26%)	12% (-2%, 25%)	18%‘ (-3%, 39%)
Post-Britomart time trends	Southern and eastern	9% *** (5%, 13%)	15%*** (10%, 19%)	10%** (3%, 17%)	18%*** (12%, 25%)
	Western	5%* (0%, 9%)	10%*** (6%, 15%)	8%* (1%, 16%)	14%*** (10%, 18%)
Temporary opening effect of Britomart (southern and eastern)					74%*** (35%, 112%)
Temporary opening effect of Britomart (western)					83%*** (56%, 110%)
First year of Britomart (southern and eastern)		Removed due to implausible sign	37%*** (23%, 51%)	17%* (2%, 33%)	11% (-20%, 42%)
First year of Britomart (western)		Removed due to implausible sign	28%*** (16%, 40%)	Removed due to implausible sign	Removed due to implausible sign
Project Boston construction (western, Apr 04)		Removed due to implausible sign	-17%*** (-25%, -9%)	-11%‘ (-22%, 0%)	-22%* (-41%, -4%)
Completion of double tracking (western, Feb 05)		Removed due to implausible sign	Removed due to implausible sign	Removed due to implausible sign	Removed due to implausible sign
Stagecoach Bus labour strike (May 95)		2% (-7%, 11%)	Removed due to implausible sign	5% (-11%, 22%)	5% (-20%, 30%)
Changeover anomaly (southern and eastern)		10%** (3%, 17%)	15%* (3%, 27%)	9% (-3%, 21%)	27%* (6%, 48%)
Changeover anomaly (western)		8%** (3%, 14%)	9%‘ (0%, 19%)	1% (-9%, 11%)	13% (-4%, 30%)
Network signalling problem (Apr 07)		-3% (-11%, 4%)	-1% (-13%, 11%)	-9% (-22%, 4%)	-3% (-24%, 19%)
Line maintenance (southern and eastern, Dec 08)		-5% (-16%, 6%)	-4% (-22%, 13%)	-8% (-29%, 14%)	Removed due to implausible sign
Line maintenance (western, Dec 08)		-2% (-11%, 7%)	-4% (-18%, 10%)	-22%* (-40%, -3%)	-42%** (-68%, -15%)
Line maintenance (southern and eastern, Jan 10)		-3% (-14%, 9%)	-3% (-22%, 15%)	-6% (-27%, 16%)	Removed due to implausible sign
Line maintenance (western, Jan 10)		-19%*** (-28%, -10%)	-14%' (-28%, 0%)	-24%* (-41%, -6%)	-39%* (-67%, -10%)
Easter dummy		-3%‘ (-6%, 0%)	0% (-5%, 6%)	0% (-6%, 7%)	-6% (-15%, 4%)

Key findings that can be drawn from table B.13 are:

- The completion of the Britomart development played a big role in the post-2003 growth spurt, both immediately (ie in the year after completion) and long-term (ie in subsequent years).
- The immediate impact of Britomart is most obvious during the 'off-peak' periods. In the year following the completion of Britomart:
  - there was approximately a 30%–40% jump in interpeak patronage
  - there were immediate jumps in evening and weekend patronage on the southern and eastern lines.
- The long-term impact of Britomart can be inferred from examination of the pre-Britomart and post-Britomart time trends. These time trends show growth even after the impacts of service improvements, rising petrol prices and other factors have been taken into account:
  - The western line had already been growing quite strongly prior to Britomart (see figure B.2) and the overall trend showed a minimal response to the completion of Britomart.
  - The southern and eastern lines exhibited a pronounced jump in time-trends (across every single time period) upon completion of Britomart.
- Project Boston had a discernibly negative impact ton rail patronage growth on the western line.
- The Stagecoach bus labour strikes were associated with positive growth in rail patronage. This supports our hypothesis that the bus labour strikes encouraged a permanent mode-shift to rail (see section C3.3 of appendix C for more detailed discussion). However, we note that these coefficients are not statistically significant.

Table B.14 Impacts of service timetable improvements on rail patronage growth

Service elasticities for timetable improvements		Weekday			Weekend
		Peak	Interpeak	Evening	
Service elasticity estimates for weekday service timetable changes	First year	0.15 (-1.21, -0.56)	0.34*** (0.15, 0.53)	0.36*** (0.22, 0.51)	
	Subsequent year	0.55*** (0.39, 0.72)	0.10 (-0.09, 0.29)	Removed due to implausible sign	
Service elasticity for weekend service timetable changes	Increased frequency on Saturday timetables				0.28' (-0.04, 0.59)
	Introduction of Sunday services				0.48 (-0.26, 1.21)
	Increased frequency on Sunday timetables				Removed due to implausible sign

- The impact of service improvements on peak-time patronage appears complex; the impact of additional peak services on patronage over the first year was small (+0.15) but there was a bigger impact (+0.55) over the subsequent year.
- The impact of service improvements during the interpeak and the evening is reasonably straightforward, with an immediate impact reflected in an elasticity of about +0.3.
- The impact of service improvements during the weekend indicate that the introduction of Sunday services had a higher service elasticity (+0.5) than the extension of existing Saturday timetables (+0.3). This is a plausible result.

Appendix C: Econometric analysis of patronage growth on the Auckland bus system

C1 Introduction

In section 5.4 of the main report we presented our conclusions regarding the contribution of explanatory variables to Auckland bus patronage growth over the nine-year period from 2001–Q2 to 2010–Q1. Then in section 5.5 we presented our findings in regard to elasticities and other estimates for those explanatory variables.

Those conclusions and findings are based on a thorough econometric methodology[34] that helps us understand as much as we can about what is driving patronage growth at a route level. We then bundle data from all the routes together and use an econometric tool (called a panel data model) to estimate what is driving patronage across a number of Auckland bus routes while controlling for any explanatory variables that are unique to particular routes such as maintenance disruptions or line-specific service improvements.

The following sections show how the econometric methodology was applied to analysis of Auckland bus patronage, and describe the analyses underlying our conclusions and findings.

- *C2 Data collection and data manipulation* – the analytical process begins with data collection. The data then has to be checked and manipulated into a form so it is suitable for econometric analysis.
- *C3 Graphical analysis* – we believe it is important to look at the data and make sense of it intuitively before proceeding onto econometric analysis. In section C3 we look at patronage growth along each of the main train lines and seek to explain and understand any trends or anomalies in the data. The observations here feed into the models tested in sections C4 to C7.
- *C4 Data analysis* – there are a number of statistical problems that can potentially undermine the validity of the econometric analysis (these problems are technically referred to as multicollinearity, spurious regression and endogeneity). In section C4 we show that we have examined the data for presence of these problems and have responded accordingly where there is evidence of a problem.
- *C5 Model building process* – the process of building models for patronage growth involves fitting general models and testing the contribution of the possible explanatory variables, removing those that look suspect or indeterminate, and whittling the model down to its core components. Section C5 describes the process by which each of the initial models was whittled down into preferred models.
- *C6 Diagnostic analysis* – the preferred model will still not be statistically valid unless the residuals of the model meet certain criteria. In section C6 we show our examination of the residuals of each individual line, in which we look for evidence of autocorrelation, non-normality or omitted variables.
- *C7 Estimates and findings* – in section C7 we show the estimates produced using the preferred models.

[34] See chapter 2 of the main report for presentation and explanation of the econometric methodology.

C2 Data collection and data manipulation

C2.1 Patronage data

The bus routes in Auckland city are serviced by a number of transport operators. We chose, for the purposes of this research project, to focus on bus routes operated by a specific transport operator (NZ Bus Ltd). There are a number of reasons for this:

- NZ Bus Ltd is the dominant transport operator in Auckland city so any conclusions drawn regarding its bus routes give us a good idea of what is happening to bus patronage in Auckland city more generally.
- The econometric approach employed for this research is novel and, to our knowledge, has never been applied at this level of detail to public transport data by other researchers. It therefore makes sense to test the approach on a subset of the data before applying the methods more widely.
- The econometric tools employed in this research are very data intensive so, again, it makes sense to test and refine the approach on a subset of the data before applying it more widely.

NZ Bus provided detailed patronage data, disaggregated by route, corridor, time of day and ticket-type, from 2001–Q2 to 2010–Q1. The first four quarters of this data were omitted from econometric analysis because we regarded, after discussion with NZ Bus, that it was not reliable. The detail of that data is very exciting and the analyses presented in this report, although reasonably sophisticated, are still only a taste of what can, and we anticipate, will be produced in the future.

The time periods employed by NZ Bus in their patronage data are based on the following Auckland Transport definitions:

- weekday peak (12am to 9am, 3pm to 6pm)
- weekday interpeak (9am to 3pm)
- weekday evening (6pm[35] to 12am)
- Saturday
- Sunday.

Section 2.2.1 of the main report describes the general approach used to manipulate patronage data into a form adequate for econometric modelling. For this dataset we followed this general approach and were able to produce average weekday patronage per quarter (by peak, interpeak and evening) and average weekend patronage per 'weekend equivalent' to use as dependent variables in the econometric modelling.

C2.2 Service data

NZ Bus also provided service data, disaggregated by route, corridor and time of day, from 2001–Q2 to 2010–Q1.

We decided to focus on analysing the data at a corridor level. A 'corridor' is a collection of routes that travel along roughly the same path. Table C.1 shows the routes contained within each corridor.

Analysing the data by corridor has several advantages:

- It reduces the amount of time involved in econometric analysis. There were 429 routes (including route variations) but 'only' 82 corridors.

[35] The SuperGold Card evening period starts at 6.30pm, instead of 6.00pm.

- It allows us to easily address concerns about cannibalisation. The introduction of a new route or the enhancement of an existing route may attract patronage but has the potential to detract patronage on surrounding routes in the same corridor. Analysis of the data by corridor allows us to look at the net impact of new routes or enhancements on the whole corridor.

Table C.1 Routes within each corridor

Corridor	Corridor name	Routes
01	Ponsonby	015,017,101,793
02	Richmond Road	024,025,027,028
03	Westmere	005,034,035
04	Pt Chevalier	042,043,045
005	Herne Bay	004,005,018,035
006	Unitec – Newmarket	006
007	Pt Chev – St Heliers	000,007,700
008	New Lynn Otahuhu	008,080
009	New Lynn Panmure	009,200
010	Ponsonby – Onehunga	010,011
10	Rosebank Road	102,107
11	Glendene	110,113,114,115,140,771
012	Herne Bay – Newmarket	012,018,412
12	Te Atatu Pen	018,048,049,121,122,774
013	#N/A	013
13	Ranui - Swanson	072,076,077,084,085,086,087,088,089,097,113,130,132,134,135,136,137,138, 140,360,771,773,778,779,798,980
014	Henderson Hopper	014
14	Sturges Road	014,070,072,079,090,142,144,149,720,770,777
15	Glen Eden	150,151,154,156,158,163,164,166,771,775
17	Titirangi	170,173,175,177,178,179,730,777,790
18	Sth Lynn	180,181,182,183,184,187,188,189
019	#N/A	019,020,021,022
19	Blockhouse Bay	190,191,192,193,194,196,197,198,199,206,207,771
21	New North Road	200,205,210,211,212,213,215,216,217,219,223,224,225,229
23	Sandringham	202,222,233,236,238,240,241,242,243,246,247,248,249
25	Dominion Road	222,225,226,250,253,255,256,258,260,262,265,266,267,288
27	Mt Eden Rd	100,270,273,274,275,277
28	Hospitals	283
29	Waikowhai	202,203,229,287,288,297,298,299
30	Manukau Rd	223,300,302,304,305,310,312,334,645
32	Mangere	290,324,327,328,330,332,334,336,338,344,347,348,351,354,359,442,490
37	Pakuranga – airport	363,364,374,375
39	Te Papapa	392

Corridor	Corridor name	Routes
42	Puhinui	428,444,490
43	Papatoetoe Exp	435
44	#N/A	443,444
45	Manurewa	451,452,453,454,455,456,458
47	Papakura	334,347,470,471,472,473,474,477,478
48	Otara	445,446,447,457,480,482,483,484,486,487,497,590
50	Port Waikato	050,50
51	Mt Wellington	211,248,288,445,500,502,511,512,520,522,532
53	Panmure – Otahuhu	530,540
55	#N/A	553,554,555,556,557,886,887
58	Ellerslie – Glen Innes	115,580,585,586,588,595,596,598
60	Victoria Ave	603,605,606,615
62	Remuera Rd	625,634,635,640,643,645,655,685,695
70	Portland Rd	703
71	Orakei	710,713,715,716,717
74	Glen Innes	745,746
75	Panmure	540,750,755,756,757
76	Glendowie	767,768,769
80	#N/A	800,801,802,803,804,910
81	Devonport	506,813,815,816
83	Beach Road	558,820,822,823,833,834,836,837,838,839,852,856,858,860,863,864,866,879
84	Sunnynook	840,843,844,845,847,873
87	East Coast Rd	010,011,557,558,585,760,850,860,870,874,875,877,878,879,881
89	Hibiscus Coast	049,604,668,669,890,893,894,895,896,897,898,899,991,994,995,996,998,999
90	#N/A	900,904,905
92	#N/A	920,921,922
94	#N/A	925,926,943,945,946,947,948
96	E C Bays – Newmarket	961,962,963,964
103	#N/A	103,203
104	#N/A	104,105
167	#N/A	167
456	#N/A	456
468	#N/A	468,469
475	Pukekohe	465,475,476,479,488,489,50
480	Keri Hill Loop	80,800
500	Panmure Loop	500
506	Glen Innes – Onehunga	412,506
550	Seaside Park	550
561	#N/A	561

Corridor	Corridor name	Routes
770	Newmarket – St Heliers	770,771
779	#N/A	779,780
791	Depot Shuttle	790,791
797	City Circuit	797
798	Link	798,799
873	Forest Hill	873,874
891	Albany – Takapuna	891
911	#N/A	911
913	Windy Ridge	913,914
952	Coronation Rd	952

We developed a two-stage process for identifying and selecting corridors for econometric analysis.

Stage 1 involved examining the service data available for all corridors and then assessing whether to discard the corridor or progress to stage 2. We only accepted corridors for further analysis if they met the following criteria:

- The service data was available for the whole period from 2001-Q2 to 2010-Q1.
- The service data did not appear corrupted by serious data problems or undue volatility.

Table C.2 documents the decisions made in stage 1.

Table C.2 Stage 1 of corridor selection – examination of service trip data

Area[36]	Corridor	Corridor name	Decision	Notes on decision to discard
Isthmus	01	Ponsonby	Progressed to stage 2	
Isthmus	02	Richmond Road	Progressed to stage 2	
Isthmus	03	Westmere	Progressed to stage 2	
Isthmus	04	Pt Chevalier	Progressed to stage 2	
Isthmus	005	Herne Bay	Progressed to stage 2	
Isthmus	006	Unitec – Newmarket	Discarded	Service data for corridor was not available until 2004 and there is evidence of corruption in the service data from 2009 onwards.
Isthmus	007	Pt Chev – St Heliers	Progressed to stage 2	
Isthmus	008	New Lynn Otahuhu	Discarded	Weekday service data dropped suspiciously in 2003 and ended in 2007. Weekend service data ended in 2003.
Isthmus	009	New Lynn Panmure	Discarded	Weekend service data mostly ceased to exist in 2003. Weekend service data ended in 2003.

[36] Areas as defined by NZ Bus.

Area[36]	Corridor	Corridor name	Decision	Notes on decision to discard
Isthmus	010	Ponsonby - Onehunga	Discarded	Corridor did not start until 2004, and there was a data issue in 2009.
Isthmus	10	Rosebank Road	Discarded	Corridor was discontinued in 2009.
West	11	Glendene	Progressed to stage 2	
Isthmus	012	Herne Bay - Newmarket	Discarded	Corridor was discontinued in 2009.
West	12	Te Atatu Pen	Progressed to stage 2	
West	13	Ranui - Swanson	Progressed to Stage 2	
West	014	Henderson Hopper	Discarded	Corridor did not start until 2003.
West	14	Sturges Road	Progressed to stage 2	
West	15	Glen Eden	Progressed to stage 2	
West	17	Titirangi	Progressed to stage 2	
West	18	Sth Lynn	Progressed to stage 2	
Isthmus	19	Blockhouse Bay	Discarded	A number of routes appear to have been removed in Aug 03, making this corridor inappropriate for analysis.
Isthmus	21	New North Road	Progressed to stage 2	
Isthmus	23	Sandringham	Progressed to stage 2	
Isthmus	25	Dominion Road	Progressed to stage 2	
Isthmus	27	Mt Eden Rd	Progressed to stage 2	
Isthmus	28	Hospitals	Discarded	Service data for this corridor was not available until Nov 03.
Isthmus	29	Waikowhai	Progressed to stage 2	
South	30	Manukau Rd	Progressed to stage 2	
South	32	Mangere	Progressed to stage 2	
South	37	Pakuranga – Airport	Discarded	Service data for this corridor was not available until 2004. Also, the increase in interpeak services was associated with decreases in PM peak services, making insights from analysis of this corridor less valuable.
Isthmus	39	Te Papapa	Progressed to stage 2	
South	42	Puhinui	Progressed to stage 2	
South	43	Papatoetoe Exp	Discarded	This corridor was inappropriate for analysis, due to a 300% fall in weekday services in Dec 03.
South	45	Manurewa	Progressed to stage 2	
South	47	Papakura	Progressed to stage 2	
South	48	Otara	Progressed to stage 2	

Area[36]	Corridor	Corridor name	Decision	Notes on decision to discard
South	50	Port Waikato	Discarded	This corridor was discarded from analysis, due to small numbers of services leading to volatility in year-on-year growth rates.
Isthmus	51	Mt Wellington	Progressed to stage 2	
Isthmus	53	Panmure - Otahuhu	Discarded	This corridor was discarded due to a number of complicating factors: the corridor was discontinued; there was a dramatic drop in peak services in 2002 and 2003; and there was considerable volatility in the weekend service data.
#N/A	55	#N/A	Discarded	Service data for this corridor was not available from Jul 05 onwards.
Isthmus	58	Ellerslie – Glen Innes	Progressed to stage 2	
Isthmus	60	Victoria Ave	Progressed to stage 2	
Isthmus	62	Remuera Rd	Progressed to stage 2	
Isthmus	70	Portland Rd	Discarded	Service data for this corridor was not available until Nov 03.
Isthmus	71	Orakei	Progressed to stage 2	
Isthmus	74	Glen Innes	Progressed to stage 2	
Isthmus	75	Panmure	Progressed to stage 2	
Isthmus	76	Glendowie	Progressed to stage 2	
North	81	Devonport	Progressed to stage 2	
North	83	Beach Road	Progressed to stage 2	
North	84	Sunnynook	Discarded	There was weekday service data missing in early 2004 and weekend service data missing in early 2005.
North	87	East Coast Rd	Progressed to stage 2	
Hibiscus	89	Hibiscus Coast	Progressed to stage 2	
Unspecified	90	Unspecified name	Discarded	Service data for this corridor was not available from Jul 05 onwards.
Unspecified	92	Unspecified name	Discarded	Service data for this corridor was not available from Jul 05 onwards.
Unspecified	94	Unspecified name	Discarded	Service data for this corridor was not available from Jul 05 onwards.
North	96	E C Bays – Newmarket	Discarded	Weekday service data complicated by route introduction and removal.
South	475	Pukekohe	Progressed to stage 2	
South	480	Keri Hill Loop	Discarded	This corridor was discarded due to volatility in the service data.
Isthmus	500	Panmure Loop	Discarded	This corridor did not start until 2004 and was discontinued in 2009.

Area[36]	Corridor	Corridor name	Decision	Notes on decision to discard
Isthmus	506	Glen Innes – Onehunga	Discarded	Corridor was discontinued in 2009.
Isthmus	550	Seaside Park	Discarded	This corridor was discarded due to volatility in the service data.
Unspecified	561	Unspecified name	Discarded	Service data for this corridor was not available from Jul 06 onwards.
Isthmus	770	Newmarket - St Heliers	Progressed to stage 2	
Isthmus	791	Depot shuttle	Discarded	The weekday data was potentially corrupted by volatility in the service data.
Isthmus	797	City Circuit	Discarded	The weekday data was potentially corrupted by volatility in the service data.
Isthmus	798	Link	Progressed to stage 2	
North	873	Forest Hill	Discarded	Service data for this corridor was not available until Jul 05.
North	891	Albany – Takapuna	Discarded	Service data for this corridor was not available until Jul 05.
North	913	Windy Ridge	Progressed to stage 2	
North	952	Coronation Rd	Discarded	Service data for this corridor was not available until Jul 05.

Stage 2 of corridor selection involved examining graphs of patronage growth and selecting corridors for econometric analysis. This stage is discussed later in section C3.

The service trip data was examined and tools were developed to deal with volatility and data errors. We were then able to discern the key service changes shown in the graphs in section C3.

C2.3 Other data

We collected and incorporated data on a number of explanatory variables: fares, petrol prices, retail sales and employment. Where applicable, these variables were then adjusted for inflation and hence the rest of the report refers to them as real fares, real petrol prices and real retail sales.

Retail sales and employment data was available for a number of territorial authorities in the Auckland region (notably, Auckland city, Waitakere city, Manukau city and Papakura district). For the sake of simplicity, we chose to focus on retail sales and employment in the 'Auckland city' territorial authority because we consider that employment, shopping and other activities in the Auckland CBD is strongly associated with most rail travel in the Auckland rail. Our research shows, for example, that over 60% of employment arises in Auckland city. Furthermore, the correlations between all of these authorities are very high anyway, so the growth rates in Auckland city act as a good proxy for the wider region.

We also collected data on cars licensed by territorial authority but, after examination we found evidence of substantial corruption in the data so it was discarded.

One major problem encountered during the course of this research was that NZ Bus Ltd had lost a lot of long-term staff, meaning that it was unable to provide extensive details or documentation of key events that might impact on bus patronage. In our discussions with some staff at Auckland Transport, they indicated that they did not have comprehensive documentation of key events either.

With the help of NZ Bus Ltd, Auckland Transport and the NZ Transport Agency, we were able to document the key events shown in table C.3.

Table C.3 Miscellaneous events and factors

Event	Months affected	Quarters affected	Notes relating to event	Corridors affected
Completion of Britomart	Jul 03	2003–Q3	The Britomart Development was completed in July 2003, enabling train lines to provide commuters with direct access to the Auckland CBD. This would have improved the appeal of the train lines and quite likely have had a negative impact on some bus corridors.	All corridors that compete with the train lines, but especially the southern train line
Negative publicity affecting numbers of foreign students	Mid 2004	2004–Q3 through 2005–Q2	From 2004–Q3, there was a decline in tertiary patronage. We have been informed there was negative publicity for New Zealand at this time and there was, subsequently, a large reduction in foreign students.	All corridors
Project Boston	Apr 04	2004–Q2 through to 2005–Q1	In 9 April 2004 the first stage of western line track duplication (aka 'Project Boston') commenced on the western train line. This limited train usage of the western line and appeared to have a discernible negative impact on rail patronage growth on this line; it seems plausible that this may have had a positive impact on competing bus corridors. 'Project Boston' was completed on 1 February 2005 and resulted in partial completion of double-tracking (see below).	All corridors that compete with the western train line
Fare changes	Aug 04, Nov 05, Apr 06, Jan 07, Apr 08, Feb 10	2004–Q3, 2005–Q4, 2006–Q2, 2007–Q1, 2008–Q2, 2010–Q1	There was a number of fare changes during the period covered.	All corridors
Partial completion of double-tracking on the western train line	Feb 05	2005–Q1	In February 2005, double-tracking between Mount Eden and Morningside was completed and an improved timetable was introduced.	All corridors that compete with the western train line
Labour strike for six days	May 05	2005–Q2	From 5 May 2005, there was a six-day labour strike by staff at Stagecoach (pre-NZ Bus). This appears to have had a permanent negative impact on patronage.	All corridors
Albany and Constellation bus stations open.	Nov 05	2005–Q3	In November 2005, these bus stations were opened and could potentially have had a positive impact on patronage.	Selected corridors

Event	Months affected	Quarters affected	Notes relating to event	Corridors affected
Completion of the Northern Busway	Feb 08	2008–Q2	The Northern Busway was completed in February 2008. It enhanced the appeal of bus travel and would be expected to have had a positive impact on corridors via the North Shore. In addition, an integrated ticket product was introduced at the same time, for North Shore patrons.	Corridors to/from the North Shore
Increase in student discount	Feb 08	2008–Q2 through 2009–Q2	The student discount for bus travel increased from 20% to 40%	All corridors
Crossing of the $2.00 nominal petrol price threshold	May 08 through Aug 08	2008–Q2, 2008–Q3	During the period from 22 May 2008 through to 13 August 2008 the nominal price of regular petrol crossed the $2.00 threshold. There is reason to believe that the crossing of this threshold may have been a key trigger for behavioural change. (However, is important to note that the impact of thresholds like the $2.00 mark is not concrete – it may reflect a number of other issues around the same time (eg media attention on 'peak oil') and may very well have changed as people have become accustomed to higher petrol prices.)	All corridors
Capacity issues		Mid-2008	There were capacity issues associated with the petrol price peaking in 2008–Q2 and 2008–Q3. This may have dampened some of the 'threshold' effects mentioned above, as well as encouraged some bus patrons to shift to rail.	
Threat of lockout/strike	Sep 09	2008–Q3	Industrial relations became tense with a lockout/strike planned for 9 September 2009, and plans were made for limited services. However, the lockout/strike was averted at the last minute.	All corridors
Grafton Bridge re-opened to buses only	Oct 09/ Dec 09	2009–Q4	In October 2009, Grafton Bridge was closed to car traffic and being bus only from 7am – 7pm. This sped up times for the 500+ services that travel from Newmarket to CBD each day. Bridge re-opened to buses only in October 2009. However, cars continued to use the bridge until fines were introduced in December 2009.	Corridors that travel via Grafton Bridge (Link, 28)
Introduction of SuperGold Card	Oct 08	2008–Q4	The SuperGold Card was introduced in Oct 08, providing free off-peak and weekend travel for persons over 65.	All corridors

Event	Months affected	Quarters affected	Notes relating to event	Corridors affected
Easter holidays	March or April depending on calendar	Q1 or Q2 depending on calendar	The Easter holidays occur sometimes in March and sometimes in April, depending on the calendar at the time. This can affect patronage because the timetables are more limited and because patrons are on holiday and hence less likely to use public transport.	All corridors

Table C.3 mentions a number of train service upgrades that would appear to have encouraged a mode-shift from bus to train: the opening of Britomart and the completion of double tracking on the Western line. There has also been a process of ongoing improvements to the frequency of services on the Auckland train lines. The introduction of feeder buses (in conjunction with these train service upgrades) may have magnified the amount of mode shift that resulted.

We decided that a few of the key events shown in table C.3 would be unlikely to have had a statistically discernible impact on patronage: the opening of the Albany and Constellation bus stops in November 2005; and the threat of lock-out/strike in September 2009. These events were therefore not included in the econometric modelling.

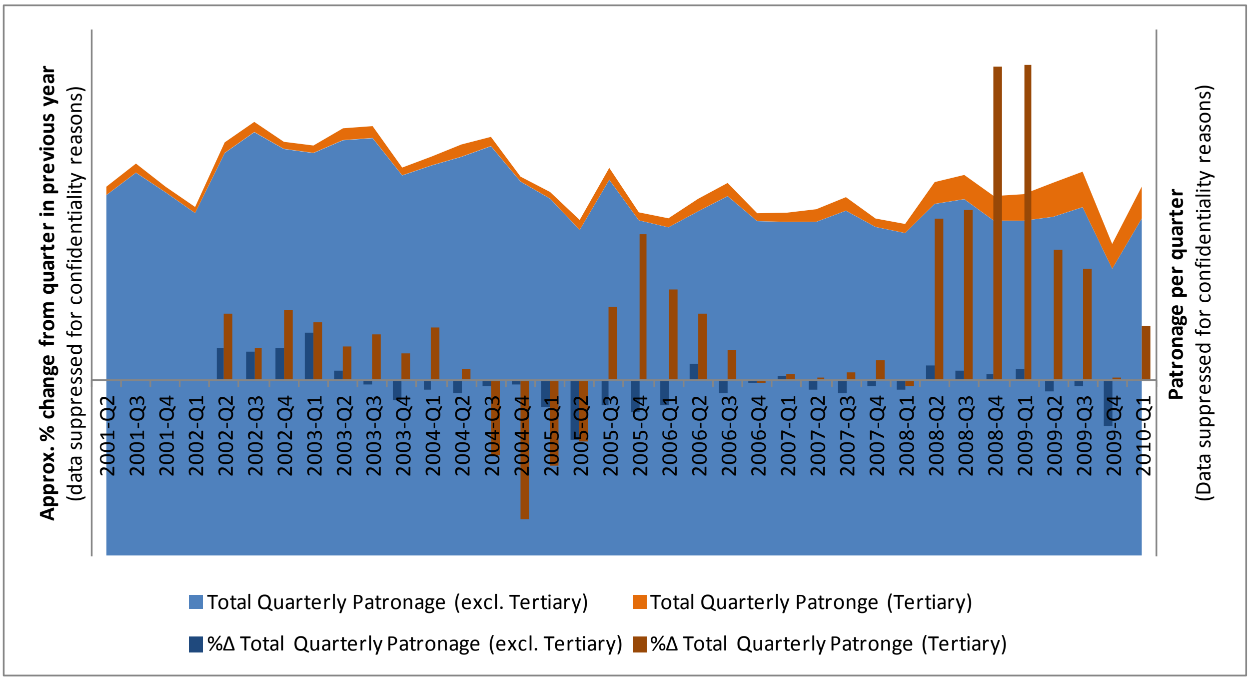
Some initiatives have not been included in table C.3 because they are too specific and numerous to document. In particular, Auckland Transport has introduced a number initiatives designed to influence the quality of bus services: priority bus lanes, signal pre-emption, and the various stages of development of real-time information. We see merit in using the panel data approach project to investigate the impacts of these initiatives. But incorporating these types of initiatives into the analysis requires a level of sophistication beyond that attempted by this research report; the two main challenges would be (1) categorising bus routes based on the lanes that they travel through, and (2) obtaining detailed data on the timing and nature of these improvements.

Table C.3 points out two key events that have contributed to volatility in tertiary student patronage:

- negative publicity affecting numbers of foreign students (mid-2004)
- increase in student discount (February 2008).

The contribution of these events to volatility in tertiary student patronage is illustrated in figure C.1.

Figure C.1 Volatility in tertiary student patronage



This volatility is a problem because, ideally, the econometric models employed should take these events into account. However, it may be difficult to discern the impact of these events on general patronage.

Our solution to this problem is straightforward. We removed tertiary student patronage from the data. Therefore, the following analyses (including graphical analysis and econometric modelling) all refer to patronage excluding tertiary students.[37]

C3 Graphical analysis

C3.1 Overview

This section describes the graphical analysis of patronage growth (excluding tertiary students) on individual bus corridors. For this research paper, there were two tasks.

The first task involved stage 2 of corridor selection – examining graphs of patronage growth and selecting corridors that were untarnished by unresolved issues, and hence appropriate for econometric analysis. This task is discussed in section C3.1

The second task involved examining graphs of patronage growth and identifying any 'explanatory' events that need to be taken into account by the econometric model. This task is discussed in section C3.2.

[37] One criticism of this approach may be that 'tertiary student patronage' only reflects tertiary students that buy the discounted tertiary student tickets – there may be other tertiary students who get normal tickets and who may experience similar volatility. This may be true to some extent, but we would argue that, if so, this is not of a discernible magnitude; figure C.1 shows that the publicity problems caused a drop in tertiary student patronage in 2004-Q3 but this was not accompanied by drop in 'general patronage excluding tertiary' at the same time. Similarly, the student discount increase caused a 40% to 50% increase in tertiary student patronage in 2008-Q2 but there is no evidence of a corresponding fall in 'general patronage excluding tertiary'.

Note that the graphs of patronage growth, for the sake of completeness, include all data available from 2001-Q2 through to 2010-Q1. However, as mentioned in section C2.1, the first four quarters from 2001-Q2 to 2002-Q1 were omitted from the econometric modelling stage because they were not regarded as reliable.

C3.2 Graphical analysis for the purposes of corridor selection

We examined graphs of patronage growth and identified a number of corridors that were appropriate for econometric analysis. This meant identifying a number of corridors with unresolved issues, most notably evidence of data corruption. The conclusions from this examination are summarised in table C.4.

Table C.4 Stage 2 of corridor selection – examination of patronage data

Area	Corridor	Corridor name	Decision	Notes on unresolved problems
Isthmus	01	Ponsonby	Selected for econometric analysis	
Isthmus	02	Richmond Road	Selected for econometric analysis	
Isthmus	03	Westmere	Selected for econometric analysis	
Isthmus	04	Pt Chevalier	Selected for econometric analysis	
Isthmus	005	Herne Bay	Selected for econometric analysis	
Isthmus	007	Pt Chev – St Heliers	Selected for econometric analysis	
West	11	Glendene	Selected for econometric analysis	
West	12	Te Atatu Pen	Selected for econometric analysis	
West	13	Ranui – Swanson	Selected for econometric analysis	
West	14	Sturges Road	Selected for econometric analysis	
West	15	Glen Eden	Selected for econometric analysis	
West	17	Titirangi	Selected for econometric analysis	
West	18	Sth Lynn	Unresolved problem	There was an unexplained 50% fall in evening patronage in 2005-Q3, which was reversed in 2008-Q2. Could be related to the low number of evening trips (approx. 1 or 2 each night).
Isthmus	21	New North Road	Selected for econometric analysis	
Isthmus	23	Sandringham	Unresolved problem	There is evidence of data corruption: wkday peak and wkday evening pax exhibited a sudden drop in 2003-Q3 followed by a reversal the following year back to original levels, suggesting a loss of data during the intervening period.
Isthmus	25	Dominion Road	Unresolved problem	There is evidence of data corruption: wkday peak and wkday evening pax exhibited a sudden drop in 2003-Q3 followed by a reversal the following year back to original levels, suggesting a loss of data during the intervening period.
Isthmus	27	Mt Eden Rd	Unresolved problem	There is evidence of data corruption: wkday peak and wkday evening pax exhibited a sudden drop in 2003-Q3 followed by a reversal the following year back to original levels, suggesting a loss of data during the intervening period.
Isthmus	29	Waikowhai	Unresolved problem	There is evidence of data corruption: wkday peak, wkday interpeak and wkday evening pax exhibited a sudden drop in 2003-Q3 followed by

Area	Corridor	Corridor name	Decision	Notes on unresolved problems
				a reversal the following year back to original levels, suggesting a loss of data during the intervening period.
South	30	Manukau Rd	Selected for econometric analysis	
South	32	Mangere	Selected for econometric analysis	
Isthmus	39	Te Papapa	Selected for econometric analysis	
South	42	Puhinui	Selected for econometric analysis	
South	45	Manurewa	Unresolved problem	There was an unexplained 30% fall in weekday peak patronage in 2006-Q3. However, this appears to be related to an increase in evening patronage around the same time.
South	47	Papakura	Selected for econometric analysis	
South	48	Otara	Selected for econometric analysis	
Isthmus	51	Mt Wellington	Unresolved problem	There is evidence of data corruption: wkday peak, wkday interpeak and wkday evening pax exhibited a sudden drop in 2003-Q3 followed by a reversal the following year back to original levels, suggesting a loss of data during the intervening period
Isthmus	58	Ellerslie - Glen Innes	Selected for econometric analysis	
Isthmus	60	Victoria Ave	Unresolved problem	There is evidence of data corruption: wkday peak, wkday interpeak and wkday evening pax exhibited a sudden drop in 2003-Q3 followed by a reversal the following year back to original levels, suggesting a loss of data during the intervening period
Isthmus	62	Remuera Rd	Unresolved problem	Wkday peak pax increased by 50% in 2004-Q4 for reasons that are not known. Wkday interpeak pax increased by about 80% around 2003-Q4 for reasons that are unknown. There is also evidence of data corruption: wkday evening pax exhibited a sudden drop in 2003-Q3 followed by a reversal the following year back to original levels, suggesting a loss of data during the intervening period
Isthmus	71	Orakei	Unresolved problem	There is evidence of data corruption: wkday peak, wkday interpeak and wkday evening pax exhibited a sudden drop in 2003-Q3 followed by a reversal the following year back to original levels, suggesting a loss of data during the intervening period
Isthmus	74	Glen Innes	Selected for econometric analysis	
Isthmus	75	Panmure	Unresolved problem	There is evidence of data corruption: wkday peak, wkday interpeak and wkday evening pax exhibited a sudden drop in 2003-Q3 followed by a reversal the following year back to original levels, suggesting a loss of data during the intervening period

Area	Corridor	Corridor name	Decision	Notes on unresolved problems
Isthmus	76	Glendowie	Unresolved problem	There is evidence of data corruption: wkday peak, wkday interpeak and wkday evening pax exhibited a sudden drop in 2003-Q3 followed by a reversal the following year back to original levels, suggesting a loss of data during the intervening period.
North	81	Devonport	Selected for econometric analysis	
North	83	Beach Road	Selected for econometric analysis	
North	87	East Coast Rd	Selected for econometric analysis	
Hibiscus	89	Hibiscus Coast	Selected for econometric analysis	
South	475	Pukekohe	Unresolved problem	There is excessive volatility in patronage growth.
Isthmus	770	Newmarket - St Heliers	Unresolved problem	There were unexplained patterns in patronage growth, which may be related to the fact that this bus corridor competes with the southern train-line.
Isthmus	798	Link	Selected for econometric analysis	
North	913	Windy Ridge	Unresolved problem	There was a 40% fall in evening patronage in 2005-Q3. This coincided with an increase in interpeak services, but that is an insufficient and unlikely explanation on its own.

C3.3 Graphical analysis for the purposes of identifying ‘explanatory’ events and describing general themes

In the period 2003-Q3 to 2006-Q3, there were a number of events that all occurred around the same time:

- In July 2003 the Britomart development was completed; this reduced demand for two types of bus corridors:
  - those that competed with the newly improved southern train line
  - those that would previously have transferred passengers from the old Bridge Road train station to the CBD.
- In February 2005, double-tracking between Mount Eden and Morningside was completed and an improved timetable was introduced. This enhanced the appeal of the western line.
- In May 2005, there was a six-day labour strike on all NZ Bus services.
- In November 2005, there was a general fare increase.

The most challenging aspect of the graphical analysis was identifying and then disentangling the impact of all these events during the 2003-Q3 to 2006-Q3 period.

Table C.5 shows how we categorised bus corridors and then used the emerging patterns to better understand the impact of the events discussed above:

- Corridors 01-04 all exhibited a sudden fall in patronage following the completion of the Britomart development, but patronage growth was constant thereafter. This makes sense because the extension of the train line through to the Britomart station in the Auckland CBD drew away passengers that would otherwise have transferred from the previous (Bridge Road) train station to the CBD (see section C3.3.1for more discussion of this subset of corridors).

- The bus corridors that 'compete' with the western line, interestingly, did not experience any loss of patronage upon completion of Britomart. However, there was a very large fall in patronage in 2005–Q1/Q2 (generally -10% to -15%) and we believe this was due to some combination of the completion of double tracking on the western line in February 2005 and labour strikes in May 2005.
- The bus corridors that 'compete' with the southern and eastern lines experienced a loss of patronage upon completion of Britomart and this continued for up to three years; we think this was because the extension of the train line into the Auckland CBD dramatically increased the appeal of rail as an option for Auckland commuters. Again, the labour strikes in May 2005 appear to have had an impact.

One of the confusing aspects of the labour strikes was that they seemed to have a variable effect across the system. We conclude that this was due to interrelationships with the rail system; it appears that the bus strikes encouraged patrons to make a permanent shift to alternative modes:

- Bus corridors in the North Shore were unaffected.
- Bus corridors that served suburbs in the northern part of central Auckland (ie Ponsonby, Richmond, Westmere, Pt Chevalier, Herne Bay) were largely unaffected.
- Bus corridors with routes parallel to the train lines were permanently affected, generally losing in the order of 10% to 15% of their patronage.
- Bus corridors that had routes in the vicinity of the train lines were also permanently affected, generally losing 5% to 10% of their patronage.

These issues have been incorporated into the econometric modelling process in the following manner:

- Patronage on bus corridors parallel to (and in the vicinity of) the southern line is assumed to be a function of the first year Britomart effect, the second year Britomart effect and the labour strike.
- Patronage on bus corridors parallel to (and in the vicinity of) the western line is assumed to be a function of Project Boston, the double-tracking completion and the labour strike.

Three bus corridors travel within the North Shore. With the exception of one corridor, the completion of the Northern Busway in 2008–Q1 does not appear to have had a discernible impact on patronage. These corridors are discussed in section C3.2.4.

Table C.5 Summary of key patterns observed via graphical analysis

Categorisation	Corridor	Corridor name	Sudden and immediate decline in patronage following completion of Britomart in 2003–Q3	Gradual decline in pax following completion of Britomart in 2003–Q3	Sudden decline in patronage in following double-tracking (2005–Q1) and labour strikes (2005–Q2)	Notes on relationship to rail network
Previously transferred rail passengers to CBD	1	Ponsonby	-30%		0%	The 01–04 bus corridors all transferred rail passengers to the CBD prior to the completion of Britomart They were therefore negatively affected by the completion of Britomart. We did not have access to historic network maps relating to these corridors and routes but an examination of the maps that are available, along with an examination of the corridor names, suggests that all these bus corridors go through catchment areas some distance north of the western train line.
	2	Richmond Road	-10%		0%	
	3	Westmere	-5%		0%	
	4	Pt Chevalier	-5%		-5%	
No relationship to trains	5	Herne Bay		0%	-5%	The 005 bus corridor serves catchments some distance north of the western train line.
	81	Devonport		0%	Impact difficult to discern	The North Shore bus corridors do not compete with any train lines.
	83	Beach Road		0%	0%	
	87	East Coast Rd		0%	0%	
	89	Hibiscus Coast		0%	Impact difficult to discern	
Parallel to western line	11	Glendene		0%	-15%	The 11 bus corridor runs parallel to the western line throughout its whole route between Henderson and Britomart.

Categorisation	Corridor	Corridor name	Sudden and immediate decline in patronage following completion of Britomart in 2003–Q3	Gradual decline in pax following completion of Britomart in 2003–Q3	Sudden decline in patronage in following double-tracking (2005–Q1) and labour strikes (2005–Q2)	Notes on relationship to rail network
	13	Ranui – Swanson		0%	-10%	The 13 bus corridor, like the 12 bus corridor, has bus routes that offer a more direct route from Te Atatu to Britomart. However, it also has a number of bus routes that run parallel to the western line, all the way from Henderson to Britomart.
	14	Sturges Road		0%	-5%	The 14 bus corridor contains a number of routes that, like the western train line, take patrons from Henderson to Britomart. Some of these routes go directly through the north-western motorway, but others run parallel to the western train line.
	15	Glen Eden		0%	-10%	The 15 bus corridor runs parallel to the western line between Glen Eden and Britomart.
	17	Titirangi		Impact difficult to discern	-25%	The 17 bus corridor runs parallel to the western line between New Lynn and Britomart.
	21	New North Road		0%	-15%	The 21 bus corridor overlaps considerably with the western line; most routes run parallel the the western line between Britomart and Mt Albert, and some even follow the line as far as Fruitvale Road.
In vicinity of western line	12	Te Atatu Pen		0%	-5%	The 12 bus corridor may complete to some extent with the western line, but it does not run parallel; in general it offers a more direct route from Te Atatu to to Britomart. The only exception is route 121, which runs parallel to the western line between Henderson and New Lynn.
	798	Link		0%	-10%	The Link service had a circular route around the Auckland CBD that, at one point, ran parallel to a portion of the western line. It was not, however, a good substitute for the rail services.

Categorisation	Corridor	Corridor name	Sudden and immediate decline in patronage following completion of Britomart in 2003-Q3	Gradual decline in pax following completion of Britomart in 2003-Q3	Sudden decline in patronage in following double-tracking (2005-Q1) and labour strikes (2005-Q2)	Notes on relationship to rail network
In vicinity of western and eastern lines	7	Pt Chev – St Heliers		-5%	-10%	The 007 bus corridor does not run alongside any train lines, but it does transport patrons across the CBD and serves as an alternative to a combination of the western and eastern train lines
Parallel to eastern line	74	Glen Innes		-10%	-10%	The 71 bus corridor runs alongside the eastern line, through to Panmure
Parallel to southern line	32	Mangere		-5%	-10%	The 32 bus corridor is a complex selection of routes, a number of which do run alongside the southern train line
	39	Te Papapa		-5% / -10%	-10%	The 39 bus corridor consists of a single route that runs parallel to the southern train line
	42	Puhinui		Impact difficult to discern	-10%	The 42 bus corridor runs parallel to the southern train line
						The patterns of negative growth differ from other corridors competing with the southern train line
	47	Papakura		-5%	-15%	The 47 bus corridor runs from Manuwera up to Otahuhu, alongside the southern train line
	48	Otara		-5%	-15%	The 48 bus corridor runs from Otara and then onto Great South Road, parallel to the southern train line
	58	Ellerslie - Glen Innes		-20%	-15%	The 58 bus corridor runs parallel to the southern train line from Britomart through to Ellerslie
In vicinity of southern line	30	Manukau Rd		No impact discerned	-10%	The 30 bus corridor starts near Britomart but diverts away from the southern train line as it goes down Manukau Road. It remains alongside the southern line but still some distance away from it.

C3.3.1 Graphical analysis of bus corridors that transferred rail patrons to the CBD

This sub-section has grouped together the bus corridors (01) Ponsonby, (02) Richmond Road, (03) and (04) Pt Chevalier. Booz Allen Hamilton (2005) noted that, prior to the completion of Britomart in July 2003, these bus corridors carried passengers who transferred from train to bus (at the old Beach Road train station) so they could travel directly into the CBD. Booz Allen Hamilton concluded these bus corridors lost patronage because Britomart made it easier for commuters to journey by train all the way into the CBD. Our graphical analysis reaffirms those conclusions.

The key findings from graphical analysis of bus corridors 01–04 are as follows:

- These corridors all showed a permanent drop in weekday peak and interpeak patronage in July 2003 (ie 2003–Q3). This drop was most pronounced on corridors 01 and 02.
- There was no discernible impact on weekday evening and weekend patronage in 2003–Q3.
- Unlike other bus corridors, the labour strikes in May 2005 (ie 2005–Q2) did not have a discernible impact on patronage.

The graphical analysis of each of the corridors is discussed in more detail below.

Key findings from graphical analysis of the (01) Ponsonby Corridor (Isthmus area)

- There was a 40% drop in peak weekday patronage and a 30% drop in offpeak weekday patronage in 2003–Q3. This drop was relatively immediate and was not followed by any further patronage loss. According to Booz Allen Hamilton (2005) this bus corridor lost patrons who (prior to Britomart) had transferred from rail onto the 02 corridor to complete their journey into the CBD.
- There were fluctuations in patronage growth from 2007–Q1 onwards that seemed to be correlated with petrol price movements around the same time

(graphs omitted for confidentiality reasons)

Key findings from graphical analysis of the (02) Richmond Road corridor (Isthmus area)

- There was a sharp and permanent drop in peak and interpeak patronage in 2003–Q3. The Richmond Road corridor serves catchment areas in the uppermost part of central Auckland that is some distance from the western train line. However, according to Booz Allen Hamilton (2005) this bus corridor lost patrons who (prior to Britomart) had transferred from rail onto the 02 corridor to complete their journey into the CBD.
- There were fluctuations in patronage growth from 2007–Q1 onwards that seemed to be correlated with petrol price movements around the same time.

(graphs omitted for confidentiality reasons)

Key findings from graphical analysis of the (03) (Isthmus area)

- The Westmere (03) bus corridor showed a modest permanent drop in peak-time patronage (about -5% to -10%) in 2003–Q3, consistent with the loss of transfer patronage to the Britomart development.

(graphs omitted for confidentiality reasons)

Key findings from graphical analysis of the (04) Pt Chevalier (Isthmus area)

The Pt Chevalier (04) bus corridor showed a modest permanent drop in peak-time patronage (about -15%) in 2003–Q3, consistent with the loss of transfer patronage to the Britomart development.

The main difference to the previous 01–03 bus corridors was a modest drop in patronage in 2005–Q2; however, the 04 bus corridor does run parallel (to some extent) with the western train line so the labour strikes in May 2005 and the completion of double-tracking on the western line in Feb 2005 may have encouraged a permanent mode-shift from bus to rail.

(graphs omitted for confidentiality reasons)

C3.3.2 Graphical analysis of bus corridors that compete with the western train line

This sub-section groups together the graphical analysis of corridors that appear to have been negatively affected by developments on the western train line:

- 007 – Pt Chevalier–St Heliers
- 11 – Glendene
- 12 – Te Atatu Pen
- 13 – Ranui–Swanson
- 14 – Sturges Road
- 15 – Glen Eden
- 17 – Titarangi
- 18 – Sth Lynn
- 21 – New North Road
- 23 – Sandringham

The impact of the western train line on competing ‘western’ bus corridors followed a remarkably consistent pattern:

- Interestingly, the completion of Britomart in 2003–Q3 did not generally have an impact on bus corridors that compete with the western line.
- Patronage fell sharply in 2005–Q1/Q2, coinciding with the February 2005 completion of double-tracking of the western train line between Mount Eden and Morningside and the May 2005 labour strikes, but was otherwise generally stable.

There were a few exceptions to the pattern described above.

- In particular, the (007) Pt Chevalier–St Heliers Corridor exhibited a fall in patronage following both the completion of Britomart in 2003-Q3 and the completion of double-tracking in 2005–Q2. However, we note that this bus corridor is unusual because it loops around central Auckland and effectively competes with both the western and eastern train lines.

Key findings from graphical analysis of the (007) Pt Chev – St Heliers corridor (Isthmus area)

- The Pt Chev – St Heliers (007) bus corridor is unusual because it does not run parallel to any of the train lines, but has experienced a decline in patronage since the completion of Britomart. There was also a pronounced fall in patronage around 2005–Q2 that is more commonly seen on corridors that compete with train lines (see table C.5).

  One possible explanation for this is that although the 007 bus corridor provides a direct route from Mt Albert to Glen Innes, the combination of the western train line and the eastern train line provides an alternative route to this.

The introduction of the SuperGold Card had a discernible impact on patronage; in October 2008 (ie 2003–Q4) there was an increase in both weekday interpeak patronage and weekend patronage.

(graphs omitted for confidentiality reasons)

Key findings from graphical analysis of the (11) Glendene corridor (west area)

The (11) Glendene corridor runs parallel to the western train line.

- There was a sharp and permanent decrease in patronage in 2005–Q1/Q2 across all time periods, most likely caused by some combination of the May 2005 labour strike and improvements on the western train line.
- There was an increase in Sunday services in 2003–Q3 but it did not appear to have any discernible impact on patronage growth.

(graphs omitted for confidentiality reasons)

Key findings from graphical analysis of the (12) Te Atatu Pen corridor (west area)

- There was a fall interpeak patronage in 2005–Q1/Q2, and it seems likely that this was due to improvements on the western train line; some of the routes on this corridor link up with the western train line.
- There was a positive impact of SuperGold on patronage, especially interpeak weekday patronage, from 2008–Q4 onwards.
- There was an unexplained drop-off in patronage growth (across all time periods) from 2009–Q2 onwards.
- There was considerable volatility in the weekend patronage data.

(graphs omitted for confidentiality reasons)

Key findings from graphical analysis of the (13) Ranui–Swanson corridor (west area)

- There was a sharp and permanent decrease in patronage in 2005–Q2 across all time periods, and this was probably due to some combination of the February 2005 completion of double-tracking and the May 2005 labour strikes.
- There was a positive impact of SuperGold on patronage, especially interpeak weekday patronage, from 2008–Q4 onwards.
- There was an increase in Sunday services in 2003–Q3 and this appears to have had a discernible impact (albeit delayed) on weekend patronage.

(graphs omitted for confidentiality reasons)

Key findings from graphical analysis of the (14) Sturges Road corridor (west area)

- There was a sharp and permanent decrease in patronage in 2005–Q1/Q2, most notably in the peak and weekend, but perhaps also at other times. This can probably be attributed to some combination of the completion of double-tracking (February 2005) and the labour strikes (May 2005).
- There were a number of increases in service trips in 2003–Q3, during the peak, weekday evening and weekend:
  - The additional service trips during the peak had no discernible impact on peak patronage.

- The additional service trips during the weekday evening and the additional Sunday services had a discernible impact on evening and weekend patronage.
- The increase in interpeak patronage in 2008-Q4 appears to be related to the introduction of the SuperGold Card.

(graphs omitted for confidentiality reasons)

Key findings from graphical analysis of the (15) Glen Eden corridor (west area)

- There was a sharp and permanent decrease in patronage in 2005-Q2 across all time periods, most likely attributable to competition with the western train line.
- There were a number of increases in service trips in 2003-Q3, during the weekday peak and weekend:
  - The additional service trips during the peak had no discernible impact on peak patronage
  - The additional Sunday services had no discernible impact on weekend patronage.

(graphs omitted for confidentiality reasons)

Key findings from graphical analysis of the (17) Titirangi corridor (west area)

- There was a decrease in interpeak services on this corridor in 2003-Q3 and this change had a pronounced impact on interpeak patronage.
- There was a decrease in patronage around 2005-Q2 across all time periods. This decrease was not as sudden and 'clean' as it was on other west area corridors, but we still have reason to believe that it was due to some combination of the completion of double-tracking on the western train line and the labour strikes (May 2005).
- There was a slight increase in evening services on this corridor in 2008-Q4 but this did not have a discernible impact on patronage.
- The increase in interpeak and weekend patronage in 2008-Q4 appears to be related to the introduction of the SuperGold Card.

(graphs omitted for confidentiality reasons)

Key findings from graphical analysis of the (18) Sth Lynn corridor (west area)

- There was a sharp and permanent decrease in patronage in 2005-Q2 across all time periods, which seems most likely attributable to competition with the western train line.
- The weekday evening data exhibited evidence of data corruption: there was a dramatic fall in patronage in 2005-Q3 followed by a dramatic increase in patronage in 2008-Q2, suggesting a loss of data during the intervening period.
- There were unexplained falls in patronage (across all time periods) from 2009-Q2 onwards.
- The weekend patronage data exhibited considerable volatility.

Due to the last three points raised above, but primarily the data corruption issue, this corridor was excluded from econometric analysis.

(graphs omitted for confidentiality reasons)

Key findings from graphical analysis of the (21) new North Road corridor (Isthmus area)

- There was an increase in weekday peak services from 2002–Q2 through to 2004–Q1 followed by a decrease in 2004-Q3. The impacts of these changes on peak-time patronages are difficult to clearly discern.
- There was an increase in weekday interpeak services from 2002–Q2 through to 2004–Q1 followed by a decrease in 2005–Q2. Those changes in interpeak services had a discernible impact on interpeak patronage.
- There was a sharp and permanent decrease in patronage in 2005–Q2 across all time periods most likely because this bus corridor runs parallel to the western train line. The decrease in interpeak noted above probably coincides with the western train line.
- There were unexplained falls in patronage (across all time periods) from 2009–Q2 onwards.

(graphs omitted for confidentiality reasons)

Key findings from graphical analysis of the (23) Sandringham corridor (Isthmus area)

- There is evidence of data corruption in the weekday peak and weekday evening patronage data. There was a sudden drop in patronage in 2003–Q3 followed by a reversal the next year back to original levels, suggesting a loss of data in the intervening period.
- There was a decrease in weekday interpeak services in 2005–Q2 and this had a discernible negative impact on weekday interpeak patronage. It is not clear whether the western train line also played a role but, based on the weekend data, there is evidence that it did.
- There were unexplained falls in patronage (across all time periods) from 2008–Q4 onwards, but perhaps related to the introduction of the SuperGold Card.

This corridor was excluded from econometric modelling primarily because of the evidence of data corruption mentioned above.

(graphs omitted for confidentiality reasons)

C3.3.3 Graphical analysis of bus corridors that compete with the southern and eastern train lines

This sub-section has grouped together the graphical analysis of corridors that appear to have been negatively affected by developments on the southern and eastern train lines:

- 30 – Manukau Rd
- 32 – Mangere
- 39 – Te Papapa
- 42 – Puhinui
- 47 – Papakura
- 48 – Otara
- 51 – Mt Wellington
- 58 – Glen Innes
- 60 – Victoria Ave
- 62 – Remuera Rd

- 71 – Orakei
- 74 – Glen Innes
- 75 – Panmure
- 770 – Newmarket – St Heliers

The impact of the southern and eastern train lines on competing 'southern' bus corridors followed a remarkably consistent pattern:

- There was an overall downward trend in bus patronage following the completion of Britomart, but
- There were also two distinct periods where the fall in patronage was very pronounced:
  - following the completion of Britomart in 2003-Q3
  - around 2005-Q2.

Key findings from graphical analysis of the (30) Manukau Road corridor (south area)

We note that the (30) Manukau Road corridor possibly provides a more direct route to parts of the Mangere region, and hence does not compete directly with the southern train lines. Nevertheless, it is possible that the southern train line contributed to some of the downward trend seen below.

- There was a sharp and permanent decrease in patronage (across all time periods) in 2005-Q2. The reasons for this are not clear, especially given there were no dramatic changes on the southern train line around this time.
- There was an overall downward trend in patronage (across all time periods).
- The introduction of the SuperGold Card seemed to have a positive impact on interpeak and weekend patronage growth in 2008-Q4.

(graphs omitted for confidentiality reasons)

Key findings from graphical analysis of the (32) Mangere corridor (south area)

- There was a period of gradual decline from 2003-Q3 until 2006-Q1, most likely due to competition with the southern train line.
- There was an overall downward trend in patronage (across all time periods).
- The introduction of the SuperGold Card seemed to have a positive impact on interpeak and weekend patronage growth in 2008-Q4.

(graphs omitted for confidentiality reasons)

Key findings from graphical analysis of the (39) Te Papapa corridor (Isthmus area)

We note that the (39) Te Papapapa corridor follows a path that is very similar to the southern train line.

- There was a period of negative growth from 2003-Q3 until 2006-Q1, and it seems reasonable to attribute this to improvements on the southern train line. The level of negative growth was highest immediately after the completion of Britomart (2003-Q3) and in 2005-Q2.
- There was a sharp and permanent decrease in patronage in 2005-Q2 across all periods.
- There was an overall downward trend in patronage (across all time periods).

(graphs omitted for confidentiality reasons)

Key findings from graphical analysis of the (42) Puhinui corridor (south area)

- This corridor runs alongside the southern train line, but the patterns of growth are not as clear as on other south area corridors. In particular, there was no immediate impact loss of peak patronage in 2003-Q3 when Britomart was introduced.
- There was an overall downward trend in patronage (across all time periods).
- The introduction of the SuperGold Card seemed to have a positive impact on weekday interpeak and weekend patronage growth in 2008-Q4.

(graphs omitted for confidentiality reasons)

Key findings from graphical analysis of the (47) Papakura corridor (south area)

- There was a general downward trend, most pronounced from 2003-Q3 to 2006-Q1, and again it seems reasonable to attribute this to improvements on the southern train line. The level of negative growth was highest immediately after the completion of Britomart (2003-Q3) and in 2005-Q2.
- There were improvements in interpeak services in 2003-Q4 but the impact on interpeak patronage was perhaps modest. Peak service trips and evening services were also adjusted, with indiscernible impacts on patronage.
- The introduction of the SuperGold Card seemed to have a positive impact on weekday interpeak and weekend patronage growth in 2008-Q4.

(graphs omitted for confidentiality reasons)

Key findings from graphical analysis of the (48) Otara corridor (south area)

- There was a general downward trend, most pronounced from 2003-Q3 to 2006-Q1, and again it seems reasonable to attribute this to improvements on the southern train line. The level of negative growth was generally highest immediately after the completion of Britomart (2003-Q3) and in 2005-Q2.
- The introduction of the SuperGold Card seemed to have a positive impact on weekday interpeak patronage growth in 2008-Q4.

(graphs omitted for confidentiality reasons)

Key findings from graphical analysis of the (51) Mt Wellington corridor (Isthmus area)

- There is evidence of data corruption in the weekday peak, weekday interpeak and weekday evening patronage data. There was a sudden drop in patronage in 2003-Q3 followed by a reversal the next year back to original levels, suggesting a loss of data in the intervening period.
- If we look at the weekend data there was a general downward trend, most pronounced from 2003-Q3 to 2006-Q1, and again it seems reasonable to attribute this to improvements on the southern train line. The level of negative growth was generally highest immediately after the completion of Britomart (2003-Q3) and in 2005-Q2.

This corridor was excluded from econometric modelling primarily because of the evidence of data corruption mentioned above.

(graphs omitted for confidentiality reasons)

Key findings from graphical analysis of the (58) Ellerslle – Glen Innes corridor (Isthmus area)

- There was a general downward trend, most pronounced from 2003–Q3 to 2006–Q1, and again it seems reasonable to attribute this to improvements on the southern train line. The level of negative growth was generally highest immediately after the completion of Britomart (2003–Q3) and in 2005–Q2.
- The introduction of the SuperGold Card seemed to have a positive impact on weekday interpeak patronage growth in 2008–Q4.

(graphs omitted for confidentiality reasons)

Key findings from graphical analysis of the (60) Victoria Avenue corridor (Isthmus area)

- There is evidence of very serious data corruption in the weekday peak, weekday interpeak and weekday evening patronage data. There was a sudden drop in patronage in 2003–Q3 followed by a reversal the next year back to original levels, suggesting a loss of data in the intervening period.
- If we look at the weekend data there was a general downward trend, most pronounced from 2003–Q3 to 2006–Q1, and again it seems reasonable to attribute this to improvements on the southern train line. The level of negative growth was generally highest immediately after the completion of Britomart (2003–Q3) and in 2005–Q2.

The introduction of the SuperGold Card seemed to have a positive impact on weekday interpeak patronage growth in 2008–Q4.This corridor was excluded from econometric modelling primarily because of the evidence of data corruption mentioned above.

(graphs omitted for confidentiality reasons)

Key findings from graphical analysis of the (62) Remuera Road corridor (Isthmus area)

- There is evidence of very serious data corruption in the weekday evening patronage data. The sudden drop in patronage in 2003–Q3 followed by a reversal the next year back to original levels suggests a loss of data during the intervening period
- There were unusual jumps in patronage that cannot be explained. Interpeak patronage increased by 2003–Q4 and peak patronage increased by about 50% in 2004–Q4.
- If we look at the weekend data there was a general downward trend, most pronounced from 2003–Q3 to 2006–Q1, and again it seems reasonable to attribute this to improvements on the southern train line. The level of negative growth was generally highest immediately after the completion of Britomart (2003–Q3) and in 2005–Q2.
- There were unexplained falls in patronage (across all time periods) from 2009–Q4 onwards.

This corridor was omitted from econometric modelling, due to the evidence of serious data corruption mentioned above and the unexplained jump in patronage in 2003–Q4.

(graphs omitted for confidentiality reasons)

Key findings from graphical analysis of the (71) Orakei corridor (Isthmus area)

- There is evidence of serious data corruption in the weekday peak, weekday interpeak and weekday evening patronage data. The sudden drop in patronage in 2003–Q3 followed by a reversal the next year back to original levels suggests a loss of data during the intervening period.
- If we look at the weekend data there was a general downward trend, most pronounced from 2003–Q3 to 2006–Q1, and again it seems reasonable to attribute this to improvements on the southern train

line. The level of negative growth was generally highest immediately after the completion of Britomart (2003–Q3) and in 2005–Q2.

- There was an unusual jump in weekday peak and weekend patronage growth in 2008–Q1, and the reasons for this have not been identified.

This corridor was omitted from econometric modelling, due to the evidence of serious data corruption mentioned above.

(graphs omitted for confidentiality reasons)

Key findings from graphical analysis of the (74) Glen Innes corridor (Isthmus area)

- If we look at the weekend data there was a general downward trend, most pronounced from 2003–Q3 to 2006–Q1, and again it seems reasonable to attribute this to improvements on the southern train line. The level of negative growth was generally highest immediately after the completion of Britomart (2003–Q3) and in 2005–Q2.
- There were unexplained falls in patronage (across all time periods) from 2008–Q4 onwards.

(graphs omitted for confidentiality reasons)

Key findings from graphical analysis of the (75) Panmure corridor (Isthmus area)

- There is evidence of serious data corruption in the weekday peak, weekday interpeak and weekday evening patronage data. The sudden drop in weekday peak and weekday evening patronage in 2003–Q3 followed by a reversal the next year back to original levels suggests a loss of data in the intervening years.
- If we look at the weekend data there was a general downward trend, most pronounced from 2003–Q3 to 2006–Q1, and again it seems reasonable to attribute this to improvements on the southern train line. The level of negative growth was generally highest immediately after the completion of Britomart (2003–Q3) and in 2005–Q2.
- The introduction of the SuperGold Card seemed to have a positive impact on weekday interpeak patronage growth in 2008–Q4.

This corridor was omitted from econometric modelling, due to the evidence of serious data corruption mentioned above.

(graphs omitted for confidentiality reasons)

Key findings from graphical analysis of the (76) Glendowie corridor (Isthmus area)

- There is evidence of serious data corruption in the weekday peak, weekday interpeak and weekday evening patronage data. The sudden drop in weekday peak and weekday evening patronage in 2003–Q3 followed by a reversal the next year back to original levels suggests a loss of data during the intervening period.
- If we look at the weekend data there was an unusual pattern: patronage growth was positive in 2003–Q3, whereas it was negative at the same time in other corridors. In light of the data corruption problems mentioned above, an explanation for this pattern was not sought.
- The introduction of the SuperGold Card seemed to have a positive impact on weekday interpeak patronage growth in 2008–Q4.

This corridor was omitted from econometric modelling, due to the evidence of serious data corruption mentioned above.

(graphs omitted for confidentiality reasons)

C3.3.4 Graphical analysis of North Shore bus corridors

This sub-section collects together all of the North Shore bus corridors. Section C2.2 notes that a number of North Shore bus corridors were discarded from analysis, due to limitations in the service trip data.

The remaining North Shore corridors were then examined:

- 81 – Devonport
- 83 – Beach Road
- 87 – East Coast Rd
- 913 – Windy Ridge

We note that we could not identify a significant impact of the Northern Busway on patronage along any of these corridors. One exception was perhaps the (87) East Coast Rd which showed a jump in peak patronage around this time.

Key findings from graphical analysis of the (81) Devonport corridor (north area)

- There was a dramatic reduction in the number of service trips (across all time periods) in 2005–Q3, and this had a notable negative impact on patronage.
- The introduction of the SuperGold Card seemed to have a positive impact on weekday interpeak patronage growth in 2008–Q4.

(graphs omitted for confidentiality reasons)

Key findings from graphical analysis of the (83) Beach Road corridor (north area)

- There were increases in weekday service trips (across all time periods) in 2002–Q4; the peak and interpeak services had no discernible impact on patronage growth, but there was a modest increase in evening patronage.
- There were decreases in weekday services from 2005 to 2008. These had a discernible negative impact on patronage.
- Patronage growth (across all time periods) was negative from about 2007–Q2 to 2009–Q3 for reasons that are not known.

(graphs omitted for confidentiality reasons)

Key findings from graphical analysis of the (87) East Coast Road corridor

- There were increases in weekday service trips (across all time periods) in 2002–Q4 during the peak, interpeak and evening. These had a positive impact on patronage growth.
- There were further changes to weekday service trips (again across all time periods) from 2005 to 2008, with mixed results in terms of the impact on patronage growth.

(graphs omitted for confidentiality reasons)

C3.3.5 Graphical analysis of remaining bus corridors

This sub-section collects together the remaining bus corridors. These are corridors that do not appear to compete with the train lines and are not likely to be affected by the Northern Busway:

- 005 – Herne Bay

- 25 – Dominion Road
- 27 – Mt Eden Road
- 29 – Waikowhai
- 45 – Manurewa
- 89 - Hibiscus Coast

The most notable findings from this section are:

- The (005) Herne Bay, (25) Dominion Road and (29) Waikowhai corridors all exhibited downward trends in patronage despite not being near train-lines. This suggests that other factors were at play.
- The (25) Dominion Road, (27) Mt Eden Road and (29) Waikowhai corridors all exhibited evidence of data corruption and were discarded from further analysis.

Key findings from graphical analysis of the (005) Herne Bay corridor (Isthmus area)

- Peak patronage exhibited almost constant patronage, while interpeak and evening data exhibited steady declines.
- There was a slight decrease in peak services in 2003-Q3, but it had no discernable impact on patronage growth.
- There was a slight fall in 2005-Q2, which coincided with improvements and patronage growth on the western line, but an examination of the network maps suggests that the routes along this corridor do not compete significantly with the western line.

There was no weekend patronage data.

(graphs omitted for confidentiality reasons)

Key findings from graphical analysis of the (25) Dominion Road corridor (Isthmus area)

We note that the (25) Dominion Road corridor serves catchment areas that are virtually all some distance from Auckland train lines. Therefore, the patronage declines shown in the graphs below cannot be attributed to improved train services.

- There was a (permanent) drop in weekday peak patronage in 2003-Q3.
- There is evidence of data corruption in the weekday evening patronage data. There was a sudden drop in patronage in 2003-Q3 followed by a reversal the following year back to original levels, suggesting a loss of data during the intervening period.
- There were declines in patronage (across all time periods) for the two-year period from about 2005-Q4 to 2007-Q3. This could be due to the fare increase around 2005-Q4 or to service trip decreases around that time; however, we note that the service improvements in 2003-Q3 did not produce discernible patronage increases.
- There were unexplained falls in patronage (across all time periods) from 2008-Q4 onwards.

This corridor was excluded from further analysis primarily because of the evidence of data corruption mentioned above.

(graphs omitted for confidentiality reasons)

Key findings from graphical analysis of the (27) Mt Eden Road corridor (Isthmus area)

- There is evidence of data corruption in the weekday peak and weekday evening patronage data. There was a sudden drop in patronage in 2003–Q3 followed by a reversal the following year back to original levels, suggesting a loss of data during the intervening period.
- There were improvements in services during the weekday peak, weekday interpeak and weekday evening. These services appear to have had a discernible but modest impact on weekday interpeak and evening patronage, but no discernible impact on peak patronage.

This corridor was excluded from further analysis primarily because of the evidence of data corruption mentioned above.

(graphs omitted for confidentiality reasons)

Key findings from graphical analysis of the (29) Waikowhai corridor (Isthmus area)

- There is evidence of data corruption in the weekday peak, weekday interpeak and weekday evening patronage data. There was a sudden drop in patronage in 2003–Q3 followed by a reversal the next year back to original levels, suggesting a loss of data during the intervening period
- There were unexplained falls in patronage (across all time periods) from 2008–Q4 onwards.
- This corridor exhibited a constant downward trend in patronage, which is mysterious given that it does not compete very closely with either of the train lines.

This corridor was excluded from econometric modelling primarily because of the evidence of data corruption mentioned above.

(graphs omitted for confidentiality reasons)

Key findings from graphical analysis of the (45) Manurewa corridor (south area)

We note that this corridor does not seem to compete with the southern train line.

- There was an unusual permanent fall in peak patronage in 2006–Q3, but this may have been related to the increase in evening services.
- There were improvements in interpeak services in 2003–Q4 but the impact on interpeak patronage was perhaps modest.
- The introduction of the SuperGold Card seemed to have a positive impact on weekday interpeak patronage growth in 2008–Q4.

This corridor was excluded from econometric modelling primarily because of the unexplained fall in peak patronage in 2006–Q3.

(graphs omitted for confidentiality reasons)

Key findings from graphical analysis of the (89) Hibiscus Coast corridor (Hibiscus area)

- There were decreases in weekday service trips in 2005–Q3 during the peak and interpeak, with a corresponding increase in weekday evening services. Despite the increase in evening services, there was a discernible fall in patronage across all time periods.

(graphs omitted for confidentiality reasons)

C4 Data analysis

C4.1 Multicollinearity analysis

As noted in section 2.4.1 of the main report, high correlations between explanatory variables can make econometric estimation difficult. This section uses correlation tables to examine the extent to which such correlations might be problematic.

Table C.6 shows correlations between the explanatory variables for the period corresponding to the patronage data. In general the observed correlations are remarkably low, and we attribute this to the use of corridor level data and a panel data approach.

A number of these correlations are not problematic:

- There are moderate-to-high correlations between the service trip variables, most notably the +0.8 correlation between wk.peak.trips and wk.evening.trips, but these correlations are generally not too bothersome because we estimate separate regression models for each of these time periods.
- There is a -0.6 correlation between 'Project Boston' and the completion of double tracking on the western line and this shows that it is difficult to distinguish between two effects:
  - 'Project Boston' limited train usage on the western line and may have contributed to a boost in patronage on competing bus corridors that fell back once double-tracking was completed, but
  - The completion of double-tracking would have also caused a fall in bus patronage on competing bus corridors because it made rail transport more desirable.

We consider, after looking at the graphical evidence, that 'Project Boston' did not have a discernible impact on bus patronage so it was excluded from econometric modelling. But the subsequent completion of double tracking did have a discernible impact so it was included in econometric modelling.

- There are moderate correlations between the May 2005 labour strike and a number of other explanatory variables: the +0.5 correlation with the ongoing impact of Britomart on the south and east line; the +0.4 correlation with the February 2005 completion of double tracking on the western line, the +0.4 correlation with the adult fare increases (most notably in November 2005) and the +0.4 correlation with petrol price changes. These correlations reflect the fact that a number of events all occurred around the same time and disentangling their effects is challenging. However, we believe that the panel data approach allows us to more accurately control for the impact of these 'confounding' events[38].
- There are a number of high correlations involving the August 2008 increase in student discount, most notably the +0.9 correlation with the October 2008 introduction of the SuperGold Card. However, tertiary student patronage was removed from the analysis (see section C2.3) so this problem was avoided. Further extensions of this research in the future using a market-segment approach could isolate the impact of student patronage.

[38] The panel data approach using corridor-level data allows us to disentangle and isolate the impacts of these 'confounding' events because some of these events only affect certain corridors (ie Britomart only affects bus corridors that compete with the southern and eastern lines, double tracking only affects bus corridors that compete with the western line, and the labour strike only appears to affect corridors that compete with the train lines).

Table C.6 Correlations between explanatory variables for the period from 2003-Q2 to 2010-Q1

	wk.peak.trips	*wk.interpeak.trips*	*wk.evening.trips*	*sat.sun.trips.sat.portion*	*sat.sun.trips.sun.portion*	*c01.Britomart.effect.2003Q3*	*c02.Britomart.effect.2003Q3*	*c03.Britomart.effect.2003Q3*	*c04.Britomart.effect.2003Q3*	*SE.Britomart.effect.2003Q3*	*SE.Britomart.effect.2004Q3*	*SE.Britomart.effect.2005Q3*	*WT.Double.Tracking.Feb05*	*Project.Boston.Apr04*	*labour.strike.May05.permanent*	*Grafton.Bridge.reopened.Oct09*	*real.adult.bus.fare*	*real.senior.bus.fare*	*real.petrol.price*	*petrol.price.threshold.dummy.2dollar*	*student.discount.dummy.Aug08*	*supergoldcard.dummy.Oct08*	*Easter.dummy*	*real.retail.sales.akl.city*	*employment.akl.city*
wk.peak.trips	1.0																								
wk.interpeak.trips	0.4	1.0																							
wk.evening.trips	0.8	0.2	1.0																						
sat.sun.trips.sat.portion	0.1	-0.1	0.2	1.0																					
sat.sun.trips.sun.portion	0.3	-0.1	0.3	0.4	1.0																				
c01.Britomart.effect.2003Q3	-0.1	0.0	0.0	0.0	0.0	1.0																			
c02.Britomart.effect.2003Q3	0.0	0.0	0.0	0.0	0.0	0.0	1.0																		
c03.Britomart.effect.2003Q3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.0																	
c04.Britomart.effect.2003Q3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.0																
SE.Britomart.effect.2003Q3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.0															
SE.Britomart.effect.2004Q3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	-0.1	1.0														
SE.Britomart.effect.2005Q3	0.0	-0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	-0.1	-0.1	1.0													
WT.Double.Tracking.Feb05	0.0	-0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	-0.1	-0.1	-0.1	1.0												
Project.Boston.Apr04	0.1	0.0	0.0	0.0	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	-0.6	1.0											
labour.strike.May05.permanent	-0.1	-0.2	-0.1	0.1	0.1	0.0	0.0	0.0	0.0	-0.1	0.0	0.5	0.4	-0.4	1.0										
Grafton.Bridge.reopened.Oct09	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.0									
real.adult.bus.fare	0.0	-0.1	-0.1	0.1	0.0	0.0	0.0	0.0	0.0	-0.1	0.0	0.3	0.1	-0.1	0.4	0.0	1.0								
real.senior.bus.fare	-0.1	-0.2	-0.1	0.1	0.0	0.0	0.0	0.0	0.0	-0.1	0.0	0.4	0.1	-0.1	0.5	0.0	0.8	1.0							
real.petrol.price	-0.1	-0.2	-0.1	0.1	0.1	0.0	0.0	0.0	0.0	0.0	0.1	0.3	0.1	0.0	0.4	0.0	0.2	0.4	1.0						
petrol.price.threshold.dummy.2dollar	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	-0.2	0.0	0.6	1.0					
student.discount.dummy.Aug08	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	-0.1	-0.1	-0.1	-0.1	0.0	-0.2	0.0	-0.5	-0.4	-0.4	-0.2	1.0				
supergoldcard.dummy.Oct08	0.0	0.0	0.0	0.0	-0.1	0.0	0.0	0.0	0.0	-0.1	-0.1	-0.1	-0.1	0.0	-0.2	0.0	-0.4	-0.3	-0.7	-0.5	0.9	1.0			
Easter.dummy	0.0	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	-0.1	0.1	-0.3	0.0	0.0	0.0	-0.1	-0.3	0.0	0.0	1.0		
real.retail.sales.akl.city	0.2	0.1	0.1	0.0	0.1	0.1	0.1	0.1	0.1	0.4	0.1	-0.1	0.0	0.2	-0.1	0.0	0.1	-0.1	-0.1	-0.1	-0.6	-0.4	0.0	1.0	
employment.akl.city	0.1	0.0	0.0	0.0	0.1	0.1	0.1	0.1	0.1	0.2	0.2	0.1	0.2	0.0	0.2	-0.1	0.1	0.2	0.5	0.5	-0.5	-0.6	0.0	0.3	1.0

- There are also moderate correlations between the October 2008 introduction of the SuperGold Card and economic variables including petrol prices (-0.7) real retail sales (-0.4) and employment (-0.6). These correlations are largely unavoidable but we suggest that extensions of this research in the future using a market segment approach could mitigate this problem.

C4.2 Stationarity analysis

In section 2.4.2 of the main report we noted that the conventional approach in transport economics is to carry out econometric regressions with all of the variables defined in levels. However, with this approach, there is a risk that the regressions can lead to spurious results if the variables are classed as nonstationary (ie they exhibit strong trends over time).

Our approach to mitigate this risk is to take seasonal differences and to look at growth rates in patronage and explanatory variables between one quarter and the preceding quarters. There is still some risk of nonstationarity and/or insufficient variation in the explanatory variables so we have proceeded with formal testing to further mitigate against the risk of spurious results.

Table C.7 shows testing for stationarity or nonstationarity of key explanatory variables. Despite the reasonably short time-frame, there is evidence of stationarity amongst most of these variables. The main 'red flag' is employment which the KPSS test indicates is nonstationary. It is unlikely that employment growth is actually nonstationary; the failure of this test most likely reflects the fact that employment exhibited stable and steady growth rates throughout most of the period covered, but exhibited a sharp decline in late 2008 as the recession hit.

Table C.7 Stationarity of continuous explanatory variables

		Augmented Dickey Fuller Test for stationarity[a]			KPSS test for nonstationarity[a]			
		Null hypothesis: variable is nonstationary			Null hypothesis: variable is stationary			
Variable[b]	**Period**	**Critical value**	**p-value**	**Decision**	**Critical value**	**p-value**	**Decision**	**Conclusion**
%Δ in real petrol prices	1993–Q3 to 2010–Q1	-4.53	0.01	Reject null → series is stationary	0.179	>0.10	Do not reject null → series is stationary	Stationary
%Δ in real retail sales	2000–Q2 to 2010–Q1	-2.19	0.50	Do not reject null → series is nonstationary	0.182	>0.10	Do not reject null → series is stationary	Inconclusive
%Δ in employment	2000–Q2 to 2010–Q1	-2.51	0.37	Do not reject null → series is nonstationary	0.448	0.06	Reject null → series is nonstationary	Nonstationary

(a) The ADF test incorporated 4 lags and the KPSS test employed a long version of the truncation lag parameter, which had 4–5 lags.

(b) Service variables and real fare were excluded from the analysis because they represent 'one-off' structural changes that cannot plausibly be regarded as stationary, regardless of the results of empirical testing.

Tables C.8 to C.11 show stationarity/nonstationarity testing for the dependent variables for all of the selected bus corridors. The general trend was for the testing to be either inconclusive or for evidence of stationarity. There were a few corridors where there was evidence of nonstationarity, but only during the interpeak or the evening. Our judgement was that this was most likely due to more volatility in patronage growth during offpeak times (eg introduction of SuperGold Card, service improvements); therefore, these corridors were retained but they were examined more carefully during the diagnostic analysis stage.

Table C.8 Stationarity of dependent variable (peak patronage)

			Augmented Dickey Fuller Test for stationarity(a)			KPSS test for nonstationarity(a)			
			Null hypothesis: variable is nonstationary			Null hypothesis: variable is stationary			
Variable	**Corridor**	**Period**	**t-statistic**	**p-value**	**Decision**	**t-statistic**	**p-value**	**Decision**	**Conclusion**
%Δ in peak patronage	1	2001-Q3 to 2010-Q1	-3.30	0.09	Reject null at 10% sig. → series is stationary	0.089	>0.10	Do not reject null → series is stationary	Stationary
%Δ in peak patronage	2	2001-Q3 to 2010-Q1	-2.94	0.21	Do not reject null → series is nonstationary	0.086	>0.10	Do not reject null → series is stationary	Inconclusive
%Δ in peak patronage	3	2001-Q3 to 2010-Q1	-3.40	0.07	Do not reject null → series is nonstationary	0.061	>0.10	Do not reject null → series is stationary	Inconclusive
%Δ in peak patronage	4	2001-Q3 to 2010-Q1	-3.82	0.03	Reject null at 5% sig. → series is stationary	0.116	>0.10	Do not reject null → series is stationary	Stationary
%Δ in peak patronage	5	2001-Q3 to 2010-Q1	-2.66	0.32	Do not reject null → series is nonstationary	0.202	>0.10	Do not reject null → series is stationary	Inconclusive
%Δ in peak patronage	7	2001-Q3 to 2010-Q1	-2.41	0.41	Do not reject null → series is nonstationary	0.061	>0.10	Do not reject null → series is stationary	Inconclusive
%Δ in peak patronage	11	2001-Q3 to 2010-Q1	-2.25	0.48	Do not reject null → series is nonstationary	0.110	>0.10	Do not reject null → series is stationary	Inconclusive
%Δ in peak patronage	12	2001-Q3 to 2010-Q1	-2.37	0.43	Do not reject null → series is nonstationary	0.098	>0.10	Do not reject null → series is stationary	Inconclusive
%Δ in peak patronage	13	2001-Q3 to 2010-Q1	-2.20	0.50	Do not reject null → series is nonstationary	0.071	>0.10	Do not reject null → series is stationary	Inconclusive
%Δ in peak patronage	14	2001-Q3 to 2010-Q1	-2.97	0.20	Do not reject null → series is nonstationary	0.100	>0.10	Do not reject null → series is stationary	Inconclusive

			Augmented Dickey Fuller Test for stationarity(a)			KPSS test for nonstationarity(a)			
			Null hypothesis: variable is nonstationary			Null hypothesis: variable is stationary			
Variable	**Corridor**	**Period**	**t-statistic**	**p-value**	**Decision**	**t-statistic**	**p-value**	**Decision**	**Conclusion**
%Δ in peak patronage	15	2001-Q3 to 2010-Q1	-1.87	0.63	Do not reject null → series is nonstationary	0.122	>0.10	Do not reject null → series is stationary	Inconclusive
%Δ in peak patronage	17	2001-Q3 to 2010-Q1	-2.23	0.48	Do not reject null → series is nonstationary	0.134	>0.10	Do not reject null → series is stationary	Inconclusive
%Δ in peak patronage	21	2001-Q3 to 2010-Q1	-2.20	0.50	Do not reject null → series is nonstationary	0.329	>0.10	Do not reject null → series is stationary	Inconclusive
%Δ in peak patronage	30	2001-Q3 to 2010-Q1	-2.75	0.28	Do not reject null → series is nonstationary	0.087	>0.10	Do not reject null → series is stationary	Inconclusive
%Δ in peak patronage	32	2001-Q3 to 2010-Q1	-2.02	0.57	Do not reject null → series is nonstationary	0.070	>0.10	Do not reject null → series is stationary	Inconclusive
%Δ in peak patronage	39	2001-Q3 to 2010-Q1	-2.71	0.30	Do not reject null → series is nonstationary	0.078	>0.10	Do not reject null → series is stationary	Inconclusive
%Δ in peak patronage	42	2001-Q3 to 2010-Q1	-1.55	0.75	Do not reject null → series is nonstationary	0.074	>0.10	Do not reject null → series is stationary	Inconclusive
%Δ in peak patronage	47	2001-Q3 to 2010-Q1	-2.28	0.47	Do not reject null → series is nonstationary	0.096	>0.10	Do not reject null → series is stationary	Inconclusive
%Δ in peak patronage	48	2001-Q3 to 2010-Q1	-2.25	0.48	Do not reject null → series is nonstationary	0.067	>0.10	Do not reject null → series is stationary	Inconclusive
%Δ in peak patronage	58	2001-Q3 to 2010-Q1	-2.70	0.30	Do not reject null → series is nonstationary	0.077	>0.10	Do not reject null → series is stationary	Inconclusive
%Δ in peak patronage	74	2001-Q3 to 2010-Q1	-2.17	0.51	Do not reject null → series is nonstationary	0.090	>0.10	Do not reject null → series is stationary	Inconclusive
%Δ in peak patronage	81	2001-Q3 to 2010-Q1	-2.23	0.48	Do not reject null → series is nonstationary	0.119	>0.10	Do not reject null → series is stationary	Inconclusive
%Δ in peak patronage	83	2001-Q3 to 2010-Q1	-1.72	0.68	Do not reject null → series is nonstationary	0.305	>0.10	Do not reject null → series is stationary	Inconclusive

			Augmented Dickey Fuller Test for stationarity(a)			KPSS test for nonstationarity(a)			
			Null hypothesis: variable is nonstationary			Null hypothesis: variable is stationary			
Variable	**Corridor**	**Period**	**t-statistic**	**p-value**	**Decision**	**t-statistic**	**p-value**	**Decision**	**Conclusion**
%Δ in peak patronage	87	2001-Q3 to 2010-Q1	-2.12	0.53	Do not reject null → series is nonstationary	0.088	>0.10	Do not reject null → series is stationary	Inconclusive
%Δ in peak patronage	89	2001-Q3 to 2010-Q1	-2.39	0.42	Do not reject null → series is nonstationary	0.172	>0.10	Do not reject null → series is stationary	Inconclusive
%Δ in peak patronage	798	2001-Q3 to 2010-Q1	-2.59	0.34	Do not reject null → series is nonstationary	0.074	>0.10	Do not reject null → series is stationary	Inconclusive

(a) The ADF test incorporated 4 lags and the KPSS test employed a long version of the truncation lag parameter, which had 3 lags.

Table C.9 Stationarity of dependent variable (interpeak patronage)

			Augmented Dickey Fuller Test for stationarity(a)			KPSS test for nonstationarity(a)			
			Null hypothesis: variable is nonstationary			Null hypothesis: variable is stationary			
Variable	**Corridor**	**Period**	**t-statistic**	**p-value**	**Decision**	**t-statistic**	**p-value**	**Decision**	**Conclusion**
%Δ in interpeak patronage	1	2001-Q3 to 2010-Q1	-4.71	0.01	Reject null at 1% sig. → series is stationary	>0.107	>0.10	Do not reject null → series is stationary	Stationary
%Δ in interpeak patronage	2	2001-Q3 to 2010-Q1	-4.12	0.02	Reject null at 5% sig. → series is stationary	0.21	>0.10	Do not reject null → series is stationary	Stationary
%Δ in interpeak patronage	3	2001-Q3 to 2010-Q1	-3.52	0.06	Reject null at 10% sig. → series is stationary	>0.100	>0.10	Do not reject null → series is stationary	Stationary
%Δ in interpeak patronage	4	2001-Q3 to 2010-Q1	-2.96	0.20	Do not reject null → series is nonstationary	0.22	>0.10	Do not reject null → series is stationary	Inconclusive

			Augmented Dickey Fuller Test for stationarity(a)			KPSS test for nonstationarity(a)			
			Null hypothesis: variable is nonstationary			Null hypothesis: variable is stationary			
Variable	**Corridor**	**Period**	**t-statistic**	**p-value**	**Decision**	**t-statistic**	**p-value**	**Decision**	**Conclusion**
%Δ in interpeak patronage	5	2001-Q3 to 2010-Q1	-2.83	0.25	Do not reject null → series is nonstationary	>0.103	>0.10	Do not reject null → series is stationary	Inconclusive
%Δ in interpeak patronage	7	2001-Q3 to 2010-Q1	-2.73	0.29	Do not reject null → series is nonstationary	0.29	>0.10	Do not reject null → series is stationary	Inconclusive
%Δ in interpeak patronage	11	2001-Q3 to 2010-Q1	-2.77	0.27	Do not reject null → series is nonstationary	0.45	0.06	Reject null at 10% → series is nonstationary	Nonstationary
%Δ in interpeak patronage	12	2001-Q3 to 2010-Q1	-2.99	0.19	Do not reject null → series is nonstationary	0.30	>0.10	Do not reject null → series is stationary	Inconclusive
%Δ in interpeak patronage	13	2001-Q3 to 2010-Q1	-2.29	0.46	Do not reject null → series is nonstationary	0.31	>0.10	Do not reject null → series is stationary	Inconclusive
%Δ in interpeak patronage	14	2001-Q3 to 2010-Q1	-2.62	0.33	Do not reject null → series is nonstationary	0.22	>0.10	Do not reject null → series is stationary	Inconclusive
%Δ in interpeak patronage	15	2001-Q3 to 2010-Q1	-2.00	0.57	Do not reject null → series is nonstationary	0.39	0.08	Reject null at 10% → series is nonstationary	Nonstationary
%Δ in interpeak patronage	17	2001-Q3 to 2010-Q1	-3.82	0.03	Reject null at 5% sig. → series is stationary	0.46	0.05	Reject null at 10% → series is nonstationary	Inconclusive
%Δ in interpeak	21	2001-Q3 to 2010-Q1	-1.95	0.59	Do not reject null → series is nonstationary	0.30	>0.10	Do not reject null → series is stationary	Inconclusive

			Augmented Dickey Fuller Test for stationarity(a)			KPSS test for nonstationarity(a)			
			Null hypothesis: variable is nonstationary			Null hypothesis: variable is stationary			
Variable	**Corridor**	**Period**	**t-statistic**	**p-value**	**Decision**	**t-statistic**	**p-value**	**Decision**	**Conclusion**
patronage									
%Δ in interpeak patronage	30	2001-Q3 to 2010-Q1	-2.36	0.43	Do not reject null → series is nonstationary	>0.105	>0.10	Do not reject null → series is stationary	Inconclusive
%Δ in interpeak patronage	32	2001-Q3 to 2010-Q1	-2.14	0.52	Do not reject null → series is nonstationary	0.47	0.05	Reject null at 10% → series is nonstationary	Nonstationary
%Δ in interpeak patronage	39	2001-Q3 to 2010-Q1	-2.95	0.21	Do not reject null → series is nonstationary	0.30	>0.10	Do not reject null → series is stationary	Inconclusive
%Δ in interpeak patronage	42	2001-Q3 to 2010-Q1	-2.58	0.35	Do not reject null → series is nonstationary	0.29	>0.10	Do not reject null → series is stationary	Inconclusive
%Δ in interpeak patronage	47	2001-Q3 to 2010-Q1	-1.74	0.67	Do not reject null → series is nonstationary	0.37	0.09	Reject null at 10% → series is nonstationary	Nonstationary
%Δ in interpeak patronage	48	2001-Q3 to 2010-Q1	-1.56	0.74	Do not reject null → series is nonstationary	0.41	0.07	Reject null at 10% → series is nonstationary	Nonstationary
%Δ in interpeak patronage	58	2001-Q3 to 2010-Q1	-3.58	0.05	Reject null at 5% sig. → series is stationary	0.30	>0.10	Do not reject null → series is stationary	Stationary
%Δ in interpeak patronage	74	2001-Q3 to 2010-Q1	-2.51	0.38	Do not reject null → series is nonstationary	0.22	>0.10	Do not reject null → series is stationary	Inconclusive
%Δ in	81	2001-Q3 to	-1.84	0.63	Do not reject null →	0.21	>0.10	Do not reject null → series is	Inconclusive

			Augmented Dickey Fuller Test for stationarity(a)			KPSS test for nonstationarity(a)			
			Null hypothesis: variable is nonstationary			Null hypothesis: variable is stationary			
Variable	**Corridor**	**Period**	**t-statistic**	**p-value**	**Decision**	**t-statistic**	**p-value**	**Decision**	**Conclusion**
interpeak patronage		2010-Q1			series is nonstationary			stationary	
%Δ in interpeak patronage	83	2001-Q3 to 2010-Q1	-2.33	0.45	Do not reject null → series is nonstationary	>0.108	>0.10	Do not reject null → series is stationary	Inconclusive
%Δ in interpeak patronage	87	2001-Q3 to 2010-Q1	-1.73	0.68	Do not reject null → series is nonstationary	0.26	>0.10	Do not reject null → series is stationary	Inconclusive
%Δ in interpeak patronage	89	2001-Q3 to 2010-Q1	-1.92	0.60	Do not reject null → series is nonstationary	0.23	>0.10	Do not reject null → series is stationary	Inconclusive
%Δ in interpeak patronage	798	2001-Q3 to 2010-Q1	-2.90	0.23	Do not reject null → series is nonstationary	0.24	>0.10	Do not reject null → series is stationary	Inconclusive

(a) The ADF test incorporated 4 lags and the KPSS test employed a long version of the truncation lag parameter, which had 3 lags.

Table C.10 Stationarity of dependent variable (evening patronage)

			Augmented Dickey Fuller Test for stationarity(a)			KPSS test for nonstationarity(a)			
			Null hypothesis: variable is nonstationary			Null hypothesis: variable is stationary			
Variable	**Corridor**	**Period**	**t-statistic**	**p-value**	**Decision**	**t-statistic**	**p-value**	**Decision**	**Conclusion**
%Δ in evening patronage	1	2001-Q3 to 2010-Q1	-4.03	0.02	Reject null at 5% sig. → series is stationary	0.07	>0.10	Do not reject null → series is stationary	Stationary
%Δ in evening patronage	2	2001-Q3 to 2010-Q1	-3.79	0.03	Reject null at 5% sig. → series is stationary	0.19	>0.10	Do not reject null → series is stationary	Stationary
%Δ in evening patronage	3	2001-Q3 to 2010-Q1	-5.55	0.01	Reject null at 1% sig. → series is stationary	0.21	>0.10	Do not reject null → series is stationary	Stationary
%Δ in evening patronage	4	2001-Q3 to 2010-Q1	-4.20	0.01	Reject null at 1% sig. → series is stationary	0.21	>0.10	Do not reject null → series is stationary	Stationary
%Δ in evening patronage	5	2001-Q3 to 2010-Q1	-3.17	0.12	Do not reject null → series is nonstationary	0.26	>0.10	Do not reject null → series is stationary	Inconclusive
%Δ in evening patronage	7	2001-Q3 to 2010-Q1	-1.83	0.64	Do not reject null → series is nonstationary	0.17	>0.10	Do not reject null → series is stationary	Inconclusive
%Δ in evening patronage	11	2001-Q3 to 2010-Q1	-2.44	0.40	Do not reject null → series is nonstationary	0.25	>0.10	Do not reject null → series is stationary	Inconclusive
%Δ in evening patronage	12	2001-Q3 to 2010-Q1	-4.49	0.01	Reject null at 1% sig. → series is stationary	0.28	>0.10	Do not reject null → series is stationary	Stationary
%Δ in evening patronage	13	2001-Q3 to 2010-Q1	-1.91	0.61	Do not reject null → series is nonstationary	0.20	>0.10	Do not reject null → series is stationary	Inconclusive
%Δ in evening patronage	14	2001-Q3 to 2010-Q1	-3.18	0.12	Do not reject null → series is nonstationary	0.37	0.09	Reject null at 10% → series is nonstationary	Nonstationary
%Δ in evening patronage	15	2001-Q3 to 2010-Q1	-2.14	0.52	Do not reject null → series is nonstationary	0.22	>0.10	Do not reject null → series is stationary	Inconclusive
%Δ in evening patronage	17	2001-Q3 to 2010-Q1	-3.04	0.17	Do not reject null → series is nonstationary	0.14	>0.10	Do not reject null → series is stationary	Inconclusive

			Augmented Dickey Fuller Test for stationarity(a)			KPSS test for nonstationarity(a)			
			Null hypothesis: variable is nonstationary			Null hypothesis: variable is stationary			
Variable	**Corridor**	**Period**	**t-statistic**	**p-value**	**Decision**	**t-statistic**	**p-value**	**Decision**	**Conclusion**
%Δ in evening patronage	21	2001-Q3 to 2010-Q1	-3.18	0.12	Do not reject null → series is nonstationary	0.44	0.06	Reject null at 10% → series is nonstationary	Nonstationary
%Δ in evening patronage	30	2001-Q3 to 2010-Q1	-2.68	0.31	Do not reject null → series is nonstationary	0.32	>0.10	Do not reject null → series is stationary	Inconclusive
%Δ in evening patronage	32	2001-Q3 to 2010-Q1	-2.19	0.50	Do not reject null → series is nonstationary	0.15	>0.10	Do not reject null → series is stationary	Inconclusive
%Δ in evening patronage	39	2001-Q3 to 2010-Q1	-3.14	0.13	Do not reject null → series is nonstationary	0.31	>0.10	Do not reject null → series is stationary	Inconclusive
%Δ in evening patronage	42	2001-Q3 to 2010-Q1	-1.64	0.71	Do not reject null → series is nonstationary	0.18	>0.10	Do not reject null → series is stationary	Inconclusive
%Δ in evening patronage	47	2001-Q3 to 2010-Q1	-2.02	0.57	Do not reject null → series is nonstationary	0.18	>0.10	Do not reject null → series is stationary	Inconclusive
%Δ in evening patronage	48	2001-Q3 to 2010-Q1	-2.86	0.24	Do not reject null → series is nonstationary	0.20	>0.10	Do not reject null → series is stationary	Inconclusive
%Δ in evening patronage	58	2001-Q3 to 2010-Q1	-3.26	0.09	Reject null at 10% sig. → series is stationary	0.12	>0.10	Do not reject null → series is stationary	Stationary
%Δ in evening patronage	74	2001-Q3 to 2010-Q1	-2.46	0.39	Do not reject null → series is nonstationary	0.14	>0.10	Do not reject null → series is stationary	Inconclusive
%Δ in evening patronage	81	2001-Q3 to 2010-Q1	-2.55	0.36	Do not reject null → series is nonstationary	0.10	>0.10	Do not reject null → series is stationary	Inconclusive
%Δ in evening patronage	83	2001-Q3 to 2010-Q1	-1.47	0.78	Do not reject null → series is nonstationary	0.25	>0.10	Do not reject null → series is stationary	Inconclusive
%Δ in evening patronage	87	2001-Q3 to 2010-Q1	-1.84	0.64	Do not reject null → series is nonstationary	0.25	>0.10	Do not reject null → series is stationary	Inconclusive
%Δ in evening	89	2001-Q3 to	-2.17	0.51	Do not reject null →	0.16	>0.10	Do not reject null → series is	Inconclusive

			Augmented Dickey Fuller Test for stationarity(a)			KPSS test for nonstationarity(a)			
			Null hypothesis: variable is nonstationary			Null hypothesis: variable is stationary			
Variable	Corridor	Period	t-statistic	p-value	Decision	t-statistic	p-value	Decision	Conclusion
patronage		2010-Q1			series is nonstationary			stationary	
%Δ in evening patronage	798	2001-Q3 to 2010-Q1	-3.17	0.12	Do not reject null → series is nonstationary	0.21	>0.10	Do not reject null → series is stationary	Inconclusive

(a) The ADF test incorporated 4 lags and the KPSS test employed a long version of the truncation lag parameter, which had 3 lags.

Table C.11 Stationarity of dependent variable (weekend patronage)

			Augmented Dickey Fuller Test for stationarity(a)			KPSS test for nonstationarity(a)			
			Null hypothesis: variable is nonstationary			Null hypothesis: variable is stationary			
Variable	Corridor	Period	t-statistic	p-value	Decision	t-statistic	p-value	Decision	Conclusion
%Δ in weekend patronage	1	2001-Q3 to 2010-Q1	-4.86	0.01	Reject null at 1% sig. → series is stationary	0.08	>0.10	Do not reject null → series is stationary	Stationary
%Δ in weekend patronage	2	2001-Q3 to 2010-Q1	-4.90	0.01	Reject null at 1% sig. → series is stationary	0.08	>0.10	Do not reject null → series is stationary	Stationary
%Δ in weekend patronage	3	2001-Q3 to 2010-Q1	-3.43	0.07	Reject null at 10% sig. → series is stationary	0.17	>0.10	Do not reject null → series is stationary	Stationary
%Δ in weekend patronage	4	2001-Q3 to 2010-Q1	-3.64	0.04	Reject null at 5% sig. → series is stationary	0.10	>0.10	Do not reject null → series is stationary	Stationary
%Δ in weekend patronage	7	2001-Q3 to 2010-Q1	-1.80	0.65	Do not reject null → series is nonstationary	0.18	>0.10	Do not reject null → series is stationary	Inconclusive
%Δ in weekend patronage	11	2001-Q3 to 2010-Q1	-2.77	0.27	Do not reject null → series is nonstationary	0.16	>0.10	Do not reject null → series is stationary	Inconclusive
%Δ in weekend patronage	12	2001-Q3 to 2010-Q1	-4.17	0.01	Reject null at 1% sig. → series is stationary	0.10	>0.10	Do not reject null → series is stationary	Stationary
%Δ in weekend	13	2001-Q3 to	-2.35	0.44	Do not reject null → series is	0.12	>0.10	Do not reject null → series is	Inconclusive

			Augmented Dickey Fuller Test for stationarity(a)			KPSS test for nonstationarity(a)			
			Null hypothesis: variable is nonstationary			Null hypothesis: variable is stationary			
Variable	**Corridor**	**Period**	**t-statistic**	**p-value**	**Decision**	**t-statistic**	**p-value**	**Decision**	**Conclusion**
patronage		2010-Q1			nonstationary			stationary	
%Δ in weekend patronage	14	2001-Q3 to 2010-Q1	-2.06	0.55	Do not reject null → series is nonstationary	0.08	>0.10	Do not reject null → series is stationary	Inconclusive
%Δ in weekend patronage	15	2001-Q3 to 2010-Q1	-2.28	0.46	Do not reject null → series is nonstationary	0.12	>0.10	Do not reject null → series is stationary	Inconclusive
%Δ in weekend patronage	17	2001-Q3 to 2010-Q1	-2.76	0.28	Do not reject null → series is nonstationary	0.20	>0.10	Do not reject null → series is stationary	Inconclusive
%Δ in weekend patronage	21	2001-Q3 to 2010-Q1	-3.49	0.06	Reject null at 10% sig. → series is stationary	0.29	>0.10	Do not reject null → series is stationary	Stationary
%Δ in weekend patronage	30	2001-Q3 to 2010-Q1	-3.09	0.15	Do not reject null → series is nonstationary	0.20	>0.10	Do not reject null → series is stationary	Inconclusive
%Δ in weekend patronage	32	2001-Q3 to 2010-Q1	-2.28	0.46	Do not reject null → series is nonstationary	0.27	>0.10	Do not reject null → series is stationary	Inconclusive
%Δ in weekend patronage	39	2001-Q3 to 2010-Q1	-3.52	0.06	Reject null at 10% sig. → series is stationary	0.23	>0.10	Do not reject null → series is stationary	Stationary
%Δ in weekend patronage	47	2001-Q3 to 2010-Q1	-2.08	0.54	Do not reject null → series is nonstationary	0.24	>0.10	Do not reject null → series is stationary	Inconclusive
%Δ in weekend patronage	48	2001-Q3 to 2010-Q1	-1.49	0.77	Do not reject null → series is nonstationary	0.20	>0.10	Do not reject null → series is stationary	Inconclusive
%Δ in weekend patronage	58	2001-Q3 to 2010-Q1	-2.55	0.36	Do not reject null → series is nonstationary	0.12	>0.10	Do not reject null → series is stationary	Inconclusive
%Δ in weekend patronage	74	2001-Q3 to 2010-Q1	-2.16	0.51	Do not reject null → series is nonstationary	0.11	>0.10	Do not reject null → series is stationary	Inconclusive
%Δ in weekend patronage	83	2001-Q3 to 2010-Q1	-1.98	0.58	Do not reject null → series is nonstationary	0.19	>0.10	Do not reject null → series is stationary	Inconclusive
%Δ in weekend	87	2001-Q3 to	-2.11	0.53	Do not reject null → series is	0.20	>0.10	Do not reject null → series is	Inconclusive

			Augmented Dickey Fuller Test for stationarity(a)			KPSS test for nonstationarity(a)			
			Null hypothesis: variable is nonstationary			Null hypothesis: variable is stationary			
Variable	**Corridor**	**Period**	**t-statistic**	**p-value**	**Decision**	**t-statistic**	**p-value**	**Decision**	**Conclusion**
patronage		2010-Q1			nonstationary			stationary	
%Δ in weekend patronage	89	2001-Q3 to 2010-Q1	-3.56	0.05	Reject null at 5% sig. → series is stationary	0.27	>0.10	Do not reject null → series is stationary	Stationary
%Δ in weekend patronage	798	2001-Q3 to 2010-Q1	-2.56	0.35	Do not reject null → series is nonstationary	0.12	>0.10	Do not reject null → series is stationary	Inconclusive

(a) The ADF test incorporated 4 lags and the KPSS test employed a long version of the truncation lag parameter, which had 3 lags.

C4.3 Endogeneity Issues

In section 2.4.3 of the main report we note that endogeneity or 'reverse causation' is another statistical issue that needs to be given careful consideration. In particular, the econometric models adopted in this research project assume that patronage growth is 'caused' by service improvements. However, it is conceivable that transport operators improve service levels as a means of coping with patronage demand.

In regard to analysis of the Auckland bus corridors, we regard the risk of endogeneity as low.

- As section 2.4.3 notes, the use of data at the corridor level minimises the risk of endogeneity because service improvements show up as 'lumpy' at a corridor level and their impact on patronage generally shows up as a clear 'jump' in patronage growth. We were given data on patronage and service changes on a number of bus corridors in Auckland so we were able to exploit all of these variations between routes.
- The seasonal difference approach, in conjunction with the use of data at the corridor level, also avoids the endogeneity problems associated with nonstationary data. A bus corridor may exhibit an unusually high time trend for patronage growth and this may prompt Auckland Transport to increase services on that bus corridor; however, the subsequent patronage growth will only be attributed to the increased services if they lead to patronage growth higher than the time trend.

C5 Model building process

C5.1 Development of the peak-time patronage model

The model building process began with building a general model that encompassed a broad collection of explanatory variables and key factors.

The structure of the general model was heavily influenced by the graphical analysis shown in section C3.2. It therefore incorporates assumptions relating to the analysis in that section.

- The Britomart development in July 2003 is assumed to have had an immediate impact on corridors 01–04 that had previously transferred rail passengers.
- The Britomart development is assumed to have had both an immediate and a protracted impact on demand for bus corridors that compete with the southern and eastern rail lines.
- The partial completion of double-tracking on the western line in February 2005 is assumed to have had an immediate impact on demand for bus corridors that compete with the western line.
- The labour strike in May 2006 is assumed to have had an permanent impact on demand for all bus corridors in the 'vicinity' of the rail lines but no impact on those further away (eg North Shore).

The general model also incorporates various 'standard' explanatory variables (petrol prices, SuperGold, Easter, real retail sales and employment) as well as service elasticities relating to particular corridors and dates.

Table C.12 shows how the general model for peak-time patronage was whittled down to the preferred model. During the first iteration we removed the third-year impact of Britomart on bus corridors that compete with the southern and eastern line because it had an implausible sign, hence producing model 2. The implication of this removal is that Britomart had a negative impact on bus patronage but it only lasted for about two years after Britomart was completed.

During the next iteration we removed the dummy variable for Easter (due to no discernible impact) and the variable for Grafton Bridge re-opening (due to an implausible sign). This led to model 3.

As discussed in section C6.1 the diagnostic analysis suggested there were some omitted events or factors that appeared to influence patronage growth on bus corridors 14, 21 and 89. These corridors were therefore removed, leading to the preferred model, model 4.

We note that we retained peak-time service elasticities even if they were negative. We did this because we wanted to calculate average peak-time elasticities (as shown in table 5.3 in the main report). If we excluded unusually low or negative service elasticities but kept the unusually high elasticities then the average elasticity would not be representative of the average impact throughout the Auckland bus system.

Table C.12 Development of peak-time patronage model[39]

Time trends and explanatory variables		General model	Model 2	Model 3	Model 4 (preferred)
Time trend	Ponsonby (01)	X%	X%	X%	1%
	Richmond Road (02)	X%	X%	X%	-1%
	Westmere (03)	X%	X%	X%	-1%
	Pt Chevalier (04)	X%	X%	X%	X%
	Herne Bay (005)	X%	X%	X%	X%
	Pt Chev – St Heliers (007)	X%	X%	X%	X%
	Glendene (11)	X%	X%	X%	X%
	Te Atatu Pen (12)	X%	X%	X%	X%
	Ranui – Swanson (13)	X%	X%	X%	X%
	Sturges Road (14)	X%	X%	X%	Omitted
	Glen Eden (15)	X%	X%	X%	X%
	Titirangi (17)	X%	X%	X%	X%
	New North Road (21)	X%	X%	X%	Omitted
	Manukau Rd (30)	X%	X%	X%	X%
	Mangere (32)	X%	X%	X%	X%
	Te Papapa (39)	X%	X%	X%	X%
	Puhinui (42)	X%	X%	X%	X%
	Papakura (47)	X%	X%	X%	X%
	Otara (48)	X%	X%	X%	X%
	Ellerslie – Glen Innes (58)	X%	X%	X%	X%
	Glen Innes (74)	X%	X%	X%	X%
	Devonport (81)	X%	X%	X%	X%
	Beach Road (83)	X%	X%	X%	X%
	East Coast Rd (87)	X%	X%	X%	X%
	Hibiscus Coast (89)	X%	X%	X%	Omitted
	Link (798)	X%	X%	X%	X%

[39] Note that time trends have been omitted from the publically-available version of table C.12 for confidentiality reasons.

Time trends and explanatory variables		General model	Model 2	Model 3	Model 4 (preferred)
Impact of Britomart on routes that previously transferred patrons to the Auckland CBD					
	Ponsonby (01)	-42%***	-42%***	-42%***	-42%***
	Richmond Road (02)	-16%***	-16%***	-16%***	-16%***
	Westmere (03)	-14%***	-14%***	-14%***	-14%**
	Pt Chevalier (04)	-14%***	-14%***	-14%***	-14%**
Impact of Britomart on bus corridors that compete with the southern and eastern lines					
	Impact over the first year	-8%***	-8%***	-8%***	-8%***
	Impact over second year	-5%***	-6%***	-6%***	-6%***
	Impact over the third year	3% '	Implausible sign		
Impact of double-tracking completion on bus corridors that compete with the western line		-14%***	-15%***	-15%***	-16%***
Impact of the labour strike on bus corridors that compete with either train line		-5%**	-4%**	-4%**	-4%**
Real bus fare (adult)		-0.31***	-0.30***	-0.31***	-0.30***
Real petrol price		0.03	0.03	0.03	0.03
Nominal $2.00 petrol price threshold		2%	2%	2%	3%
Real retail sales (Auckland city)		-0.22***	-0.22***	-0.22***	-0.19**
Employment (Auckland city)		0.76***	0.76***	0.76***	0.79***
Easter		0%	0%	Zero coefficient	
Service improvement elasticities	Herne Bay (005) – Jul 04	0.30	0.29	0.29	0.28
	Ranui - Swanson (13) – Aug 03	-0.33	-0.31	-0.31	-0.33
	Sturges Road (14) – Aug 03	-0.20	-0.19	-0.19	Omitted
	Glen Eden (15) – Aug 03	0.01	0.03	0.03	0.00
	New North Road (21) – Mar 03	0.55	0.57	0.57	Omitted
	– Aug 03	0.46	0.43	0.43	Omitted
	Papakura (47) – Dec 07	0.32	0.32	0.32	0.32
	– Feb 09	0.06	0.06	0.06	0.09
	Devonport (81) – Jul 05	0.42***	0.42***	0.42***	0.42***
	Beach Road (83) – Nov 02	0.21	0.21	0.21	0.22
	– Feb 08	0.83**	0.84**	0.84**	0.85**
	East Coast Rd (87) – Oct 02	0.61*	0.61*	0.61*	0.61*
	– Jul 05	-0.05	-0.06	-0.06	-0.10
	Hibiscus Coast (89) – Jul 05	3.07***	3.11***	3.10***	Omitted
Grafton Bridge re-opened		-2%	-3%	Implausible sign	

Note for symbols of statistical significance: *** → 0.1%, ** → 1%, * → 5%, ‘ →10%

C5.2 Development of the interpeak patronage model

A general model was developed for interpeak patronage similar to that shown in section C5.1 for peak patronage. Table C.13 shows how the general model for interpeak patronage was whittled down to the preferred model.

During the first iteration we removed the third-year impact of Britomart on bus corridors that compete with the southern and eastern line because it had an implausible sign. We also removed the dummy variable for Easter due to an implausible sign. These removals produced model 2.

During the next iteration we removed the nominal $2.00 petrol price threshold because it had the implausible sign, resulting in model 3.

As discussed in section C6.1 the diagnostic analysis suggested there were some omitted events or factors that appeared to influence patronage growth on bus corridors 14, 21 and 89. These corridors were therefore removed, leading to the preferred model, model 4.

As with the peak patronage model we retained offpeak service elasticities even if they had a negative sign because we did not want to bias the averages.

Table C.13 Development of interpeak patronage model[40]

Time trends and explanatory variables		General model	Model 2	Model 3	Model 4 (preferred)
Time trend	**Ponsonby (01)**	X%	X%	X%	X%
	Richmond Road (02)	X%	X%	X%	X%
	Westmere (03)	X%	X%	X%	X%
	Pt Chevalier (04)	X%	X%	X%	X%
	Herne Bay (005)	X%	X%	X%	X%
	Pt Chev – St Heliers (007)	X%	X%	X%	X%
	Glendene (11)	X%	X%	X%	X%
	Te Atatu Pen (12)	X%	X%	X%	X%
	Ranui – Swanson (13)	X%	X%	X%	X%
	Sturges Road (14)	X%	X%	X%	Omitted
	Glen Eden (15)	X%	X%	X%	X%
	Titirangi (17)	X%	X%	X%	X%
	New North Road (21)	X%	X%	X%	Omitted
	Manukau Rd (30)	X%	X%	X%	X%
	Mangere (32)	X%	X%	X%	X%
	Te Papapa (39)	X%	X%	X%	X%
	Puhinui (42)	X%	X%	X%	X%
	Papakura (47)	X%	X%	X%	X%
	Otara (48)	X%	X%	X%	X%
	Ellerslie – Glen Innes (58)	X%	X%	X%	X%

[40] Note that time trends have been omitted from the publically available version of table C.13 for confidentiality reasons.

Time trends and explanatory variables		General model	Model 2	Model 3	Model 4 (preferred)
	Glen Innes (74)	X%	X%	X%	X%
	Devonport (81)	X%	X%	X%	X%
	Beach Road (83)	X%	X%	X%	X%
	East Coast Rd (87)	X%	X%	X%	X%
	Hibiscus Coast (89)	X%	X%	X%	Omitted
	Link (798)	X%	X%	X%	X%
Impact of Britomart on routes that previously transferred patrons to the Auckland CBD					
	Ponsonby (01)	-27%***	-27%***	-27%***	-26%***
	Richmond Road (02)	-17%***	-16%***	-17%***	-16%***
	Westmere (03)	-6%	-5%	-5%	-5%
	Pt Chevalier (04)	-1%	-1%	-1%	-1%
Impact of Britomart on bus corridors that compete with the south and east line					
	Impact over the first year	-7%***	-8%***	-8%***	-9%***
	Impact over second year	-1%	-2%‘	-2%‘	-3%*
	Impact over the third year	4%*	Implausible sign		
Impact of double-tracking completion on bus corridors that compete with the west line		-5%*	-6%**	-6%**	-6%**
Impact of the labour strike on bus corridors that compete with either train line		-9%***	-8%***	-8%***	-8%***
Real bus fare (adult)		-0.27***	-0.31***	-0.28***	-0.24***
Real petrol price		0.02	0.02	0.02	0.02
Nominal $2.00 petrol price threshold		1%	-3%	Implausible sign	
Real retail sales (Auckland city)		-0.24***	-0.31***	-0.28***	-0.27***
Employment (Auckland city)		-0.04	-0.02	-0.02	-0.08
Easter		1%*	Implausible sign		
Introduction of SuperGold Card		12%	10%***	11%***	11%***
Interpeak service elasticities	Titirangi (17) – Aug 03	1.36***	1.37***	1.38***	1.40***
	New North Road (21) – Mar 03	1.19	1.26	1.26	Omitted
	– Jun 05	0.19	0.23	0.23	Omitted
	Papakura (47) – Aug 05	0.44	0.32	0.32	0.34
	– Oct 06	-0.14	-0.14	-0.15	-0.17
	Devonport (81) – Jul 05	0.37	0.40	0.39	0.43
	Beach Road (83) – Nov 02	0.16	0.16	0.16	0.16
	– Feb 06	0.10	0.09	0.09	0.09
	– Feb 08	0.57*	0.57*	0.58*	0.58*
	East Coast Rd (87) – Oct 02	0.35***	0.35***	0.35***	0.35***
	– Feb 06	0.61‘	0.60‘	0.60‘	0.60‘

Time trends and explanatory variables		General model	Model 2	Model 3	Model 4 (preferred)
	– Feb 08	0.82***	0.81***	0.82***	0.82***
	Hibiscus Coast (89) – Jul 05	0.73***	0.75***	0.74***	Omitted
Grafton Bridge re-opened		2%	1%	1%	1%

Note for symbols of statistical significance: *** → 0.1%, ** → 1%, * → 5%, ' →10%

C5.3 Development of the evening patronage model

A general model was developed for evening patronage similar to that shown in section C5.1 for peak patronage. Table C.14 shows how the general model for evening patronage was whittled down to the preferred model.

During the first iteration we removed the third-year impact of Britomart on bus corridors that compete with the southern and eastern lines because it had an implausible sign. We also removed the dummy variable for Easter due to an implausible sign. These removals produced model 2.

During the next iteration we removed real petrol price and the Grafton Bridge re-opening because these variables had implausible signs. This led to the model 3.

As discussed in section C6.1 the diagnostic analysis suggested there were some omitted events or factors that appeared to influence patronage growth on bus corridors 14, 21 and 89. These corridors were therefore removed, leading to the preferred model, model 4.

Table C.14 Development of evening patronage model[41]

Time trends and explanatory variables		General model	Model 2	Model 3	Model 4 (preferred)
Time trend	Ponsonby (01)	X%	X%	X%	X%
	Richmond Road (02)	X%	X%	X%	X%
	Westmere (03)	X%	X%	X%	X%
	Pt Chevalier (04)	X%	X%	X%	X%
	Herne Bay (005)	X%	X%	X%	X%
	Pt Chev – St Heliers (007)	X%	X%	X%	X%
	Glendene (11)	X%	X%	X%	X%
	Te Atatu Pen (12)	X%	X%	X%	X%
	Ranui – Swanson (13)	X%	X%	X%	X%
	Sturges Road (14)	X%	X%	X%	Omitted
	Glen Eden (15)	X%	X%	X%	X%
	Titirangi (17)	X%	X%	X%	X%
	New North Road (21)	X%	X%	X%	Omitted
	Manukau Rd (30)	X%	X%	X%	X%
	Mangere (32)	X%	X%	X%	X%

[41] Note that time trends have been omitted from the publically available version of table C.14 for confidentiality reasons.

Time trends and explanatory variables	General model	Model 2	Model 3	Model 4 (preferred)
Te Papapa (39)	X%	X%	X%	X%
Puhinui (42)	X%	X%	X%	X%
Papakura (47)	X%	X%	X%	X%
Otara (48)	X%	X%	X%	X%
Ellerslie – Glen Innes (58)	X%	X%	X%	X%
Glen Innes (74)	X%	X%	X%	X%
Devonport (81)	X%	X%	X%	X%
Beach Road (83)	X%	X%	X%	X%
East Coast Rd (87)	X%	X%	X%	X%
Hibiscus Coast (89)	X%	X%	X%	Omitted
Link (798)	X%	X%	X%	X%
Impact of Britomart on routes that previously transferred patrons to the Auckland CBD				
Ponsonby (01)	-11%*	-11%*	-11%*	-10%*
Richmond Road (02)	-8%	-7%	-7%	-6%
Westmere (03)	-2%	-2%	-2%	-2%
Pt Chevalier (04)	-7%	-7%	-7%	-6%
Impact of Britomart on bus corridors that compete with the south and east line				
Impact over the first year	-7%***	-8%***	-8%***	-8%***
Impact over second year	-4%*	-5%***	-5%***	-6%***
Impact over the third year	6%**	Implausible sign		
Impact of double-tracking completion on bus corridors that compete with the west line	-5%*	-7%**	-7%**	-8%**
Impact of the labour strike on bus corridors that compete with either train line	-11%***	-9%***	-9%***	-10%***
Real bus fare (adult)	-0.12	-0.16 '	-0.16 '	-0.12
Real petrol price	-0.05	-0.03	Implausible sign	
Nominal $2.00 petrol price threshold	9% *	4%	4%	5%
Real retail sales (Auckland city)	-0.06	-0.14	-0.12	-0.09
Employment (Auckland city)	0.48**	0.56**	0.54**	0.52**
Easter	1%	Implausible sign		
Introduction of SuperGold Card	3%	1%	2%	2%
Interpeak service elasticities				
Ranui - Swanson (13) – Oct 08	-0.01	0.05	0.03	0.08
Sturges Road (14) – Aug 03	0.18**	0.20***	0.20	Omitted
Titirangi (17) – Nov 08	1.28***	1.40***	1.40***	1.61***
Devonport (81) – Jul 05	0.67*	0.67*	0.67***	0.67***
Beach Road (83) – Oct 02	0.47**	0.48**	0.49*	0.51*
– Jul 05	1.29	1.27	1.25**	1.26**

Time trends and explanatory variables		General model	Model 2	Model 3	Model 4 (preferred)
	– Dec 09	0.82	0.81	0.80	0.82
	East Coast Rd (87) – Oct 02	0.24	0.25	0.25	0.26
	– Jul 05	0.14	0.11	0.09	0.03
	– Feb 08	0.30	0.31	0.30	0.27
	Hibiscus Coast (89) – Jul 05	-0.19	-0.23	-0.24	Omitted
Grafton Bridge re-opened		-2%	-2%	Implausible sign	

Note for symbols of statistical significance: *** → 0.1%, ** → 1%, * → 5%, ‘ →10%

C5.4 Development of the weekend patronage model

A general model was developed for evening patronage similar to that shown in section C5.1 for peak patronage. Table C.15 shows how the general model for weekend patronage was whittled down to the preferred model.

During the first iteration we removed the impact of Britomart on the Westmere (04) corridor and the nominal $2.00 petrol price threshold from the general model. For both of these explanatory variables the signs were implausible but statistically significant; we removed them first to prevent distortions to the remaining variables.

During the second iteration we removed real petrol price, the introduction of SuperGold, and the Grafton Bridge explanatory variables from model 2. This produced model 3.

As discussed in section C6.1 the diagnostic analysis suggested there were some omitted events or factors that appeared to influence patronage growth on bus corridors 14, 21 and 89. These corridors were therefore removed, leading to the preferred model, model 4.

As previously, we retained the weekend service elasticities even if they had a negative sign because we did not want to bias the averages.

Table C.15 Development of weekend patronage model

Time trends and explanatory variables		General model	Model 2	Model 3	Model 4 (preferred)
Time trend	Ponsonby (01)	X%	X%	X%	X%
	Richmond Road (02)	X%	X%	X%	X%
	Westmere (03)	X%	X%	X%	X%
	Pt Chevalier (04)	X%	X%	X%	X%
	Pt Chev – St Heliers (007)	X%	X%	X%	X%
	Glendene (11)	X%	X%	X%	X%
	Te Atatu Pen (12)	X%	X%	X%	X%
	Ranui – Swanson (13)	X%	X%	X%	X%
	Sturges Road (14)	X%	X%	X%	Omitted
	Glen Eden (15)	X%	X%	X%	X%
	Titirangi (17)	X%	X%	X%	X%
	New North Road (21)	X%	X%	X%	Omitted

Time trends and explanatory variables		General model	Model 2	Model 3	Model 4 (preferred)
	Manukau Rd (30)	X%	X%	X%	X%
	Mangere (32)	X%	X%	X%	X%
	Te Papapa (39)	X%	X%	X%	X%
	Papakura (47)	X%	X%	X%	X%
	Otara (48)	X%	X%	X%	X%
	Ellerslie - Glen Innes (58)	X%	X%	X%	X%
	Glen Innes (74)	X%	X%	X%	X%
	Beach Road (83)	X%	X%	X%	X%
	East Coast Rd (87)	X%	X%	X%	X%
	Hibiscus Coast (89)	X%	X%	X%	Omitted
	Link (798)	X%	X%	X%	X%
Impact of Britomart on routes that previously transferred patrons to the Auckland CBD					
	Ponsonby (01)	1%	-1%	-1%	-2%
	Richmond Road (02)	-3%	-5%	-5%	-6%
	Westmere (03)	7%**	Implausible sign		
	Pt Chevalier (04)	-8%	-10%	-10%	-11%
Impact of Britomart on bus corridors that compete with the southern and eastern lines					
	Impact over the first year	-2%	-5%	-5%*	-6%
	Impact over second year	-7%**	-8%***	-8%***	-8%***
	Impact over the third year	0%	0%	-3%	-2%
Impact of double-tracking completion on bus corridors that compete with the western line		-14%***	-14%***	-14%***	-15%***
Impact of the labour strike on bus corridors that compete with either train line		-10%**	-9%*	-9%**	-10%**
Real bus fare (adult)		-0.49***	-0.45***	-0.42***	-0.42***
Real petrol price		-0.05	-0.10‘	Implausible sign	
Nominal $2.00 petrol price threshold		-10%*	Implausible sign		
Real retail sales (Auckland city)		-0.57***	-0.32**	-0.23*	-0.21*
Employment (Auckland city)		0.18	0.09	0.00	0.07
Easter		-2%*	-1%	-1%	-1%
Introduction of SuperGold Card		-4%*	-2%	Implausible sign	
Interpeak service elasticities	Pt Chev – St Heliers (007), Apr 09	0.43	0.44	0.36	0.39
	Glendene (11), Aug 03	-0.33	-0.57	-0.59	-0.64
	Ranui – Swanson (13), Aug 03	0.43	0.27	0.25	0.22
	Sturges Road (14), Aug 03	0.12	0.04	0.02	Omitted
	Glen Eden (15), Aug 03	0.10	-0.01	-0.02	-0.04
	Titirangi (17), Aug 03	-3.32***	-3.81***	-3.83***	-3.94***

Time trends and explanatory variables		General model	Model 2	Model 3	Model 4 (preferred)
	Manukau Rd (30), Nov 03	1.15	1.19	1.27	1.29
	Papakura (47), Oct 06	-0.28	-0.44	-0.44	-0.45
	Beach Road (83), Jul 02	1.04	0.97	1.00	0.98
	– Jul-05	0.29	0.33	0.29	0.28
	East Coast Rd (87) – Jul 02	0.53	0.47	0.48	0.48
	– Jul 05	0.80	0.97	0.91	0.86
	– Feb 08	-0.79‘	-0.76‘	-0.74	-0.73
	Hibiscus Coast (89) – Jul 05	-0.25	-0.23	-0.24	Omitted
Grafton Bridge re-opened		-3%	-2%	Implausible sign	

Note for symbols of statistical significance: *** → 0.1%, ** → 1%, * → 5%, ‘ →10%

C6 Diagnostic analysis

C6.1 Overview

The following sections show diagnostic analysis of the models for peak weekday patronage (section C6.2) interpeak weekday patronage (section C6.3) evening weekday patronage (section C6.4) and weekend patronage (section C6.5). In most cases, our diagnostic analysis concluded that the residuals associated with each of the bus corridors were consistent enough with normality and that autocorrelation was low.

However, there were a few bus corridors where the deviations observed were sufficiently concerning and observed across a number of time periods. We decided to omit them from the preferred models:

- Corridors 14 and 21 showed evidence of a ‘structural change’ around 2007–Q3, suggesting an important factor or event had been omitted. This was observed in the diagnostic analysis for peak weekday data and evening weekday data.
- Corridor 89 also showed evidence of a ‘structural change’ around 2008–Q1/Q2, again suggesting an important factor or event had been omitted. This was observed in the diagnostic analysis across all time periods.

The anomalies identified above demonstrate the merits of the panel data approach advocated by this research project. During the model building stage (see section C5) we attempted to incorporate all the feasible factors that might affect patronage growth at either a network level or specific to particular bus corridors. However, despite these efforts, some events or factors on a particular bus corridor may have been missed, and the results above show that this omission will often be picked up during diagnostic analysis if a panel data approach is employed.

With the panel data approach advocated by this research project, the researcher can then choose how do deal with the potential omission; in the case of this research project we did not have sufficient data on events that far back in time so we have chosen to omit corridors 14, 21 and 89 from the preferred model.

C6.2 Diagnostic analysis for the peak patronage model

The figures below show diagnostic plots for the residuals from model 3 for peak-time patronage, as shown in table C.12.

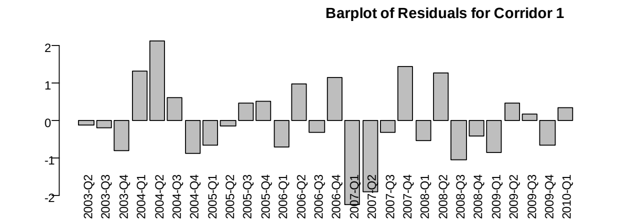
The diagnostic plots show that the residuals for most of the corridors are consistent with the assumption of normality. Furthermore, autocorrelation is low or non-existent for most corridors.

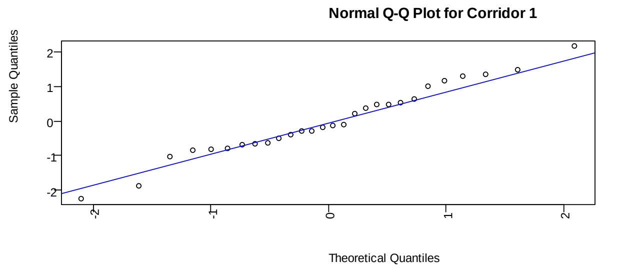
Corridors 14 and 21 show evidence of a 'structural change' around 2007–Q3. The residuals were predominantly negative from this point onwards, which implies we have omitted some unexplained event or factor that caused a drop-off in growth rates on these bus corridors.

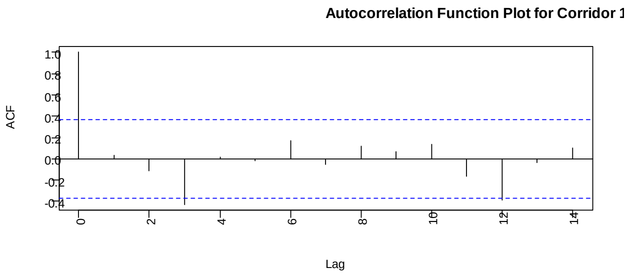
Corridor 47 exhibits a few concerning characteristics. The distribution seems to have quite 'heavy tails' and the barplot of residuals shows 'clusters' of positive and negative residuals (even though this does not show up as autocorrelation in the autocorrelation function (ACF) or partial autocorrelation function (PACF) plots). On balance, we decided to retain corridor 47.

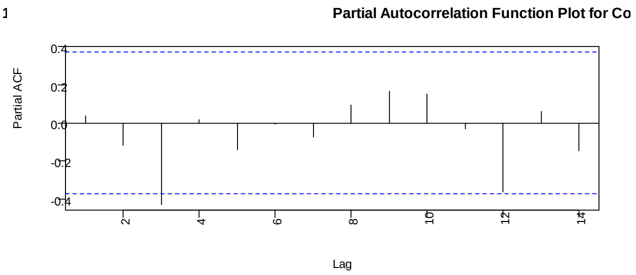
Corridor 89 shows evidence of a 'structural change' around 2008–Q2. The residuals are predominantly positive from this point onwards; this implies we have omitted some unexplained event or factor that caused a burst in growth on this bus corridor.

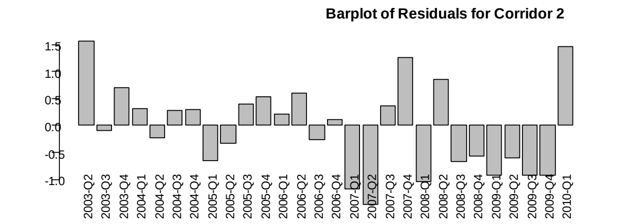
As noted in section C6.1, the deviations observed for bus corridors 14, 21 and 89 were deemed serious enough that they were omitted from the preferred model.

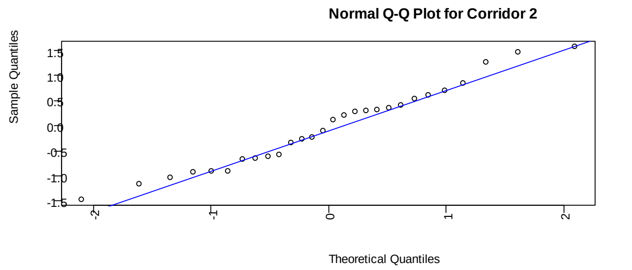


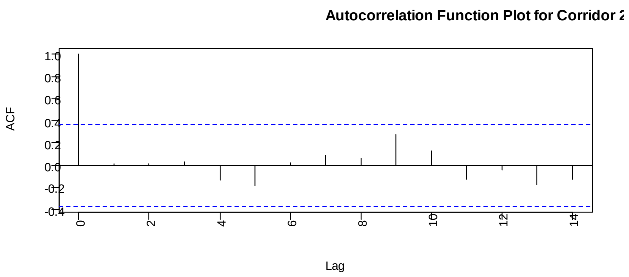


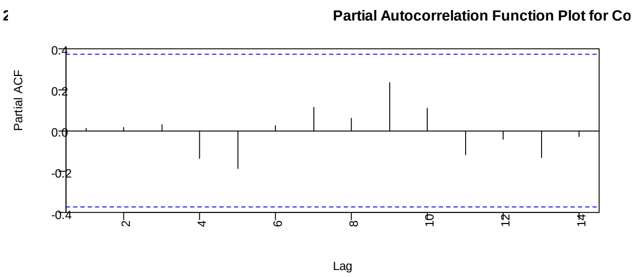


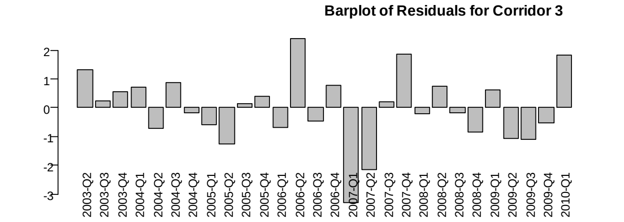


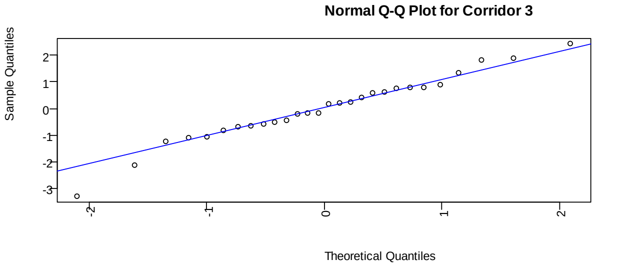


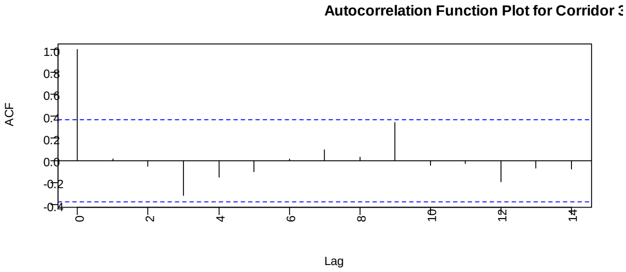


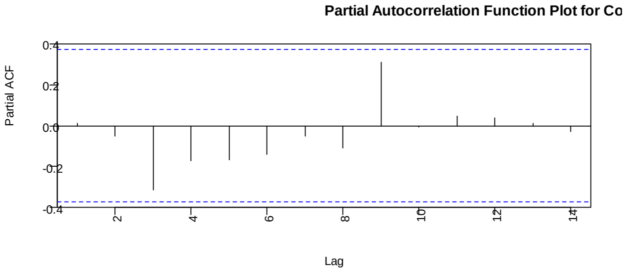


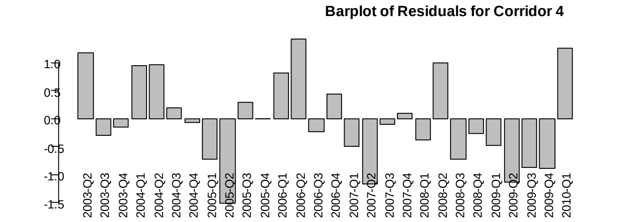


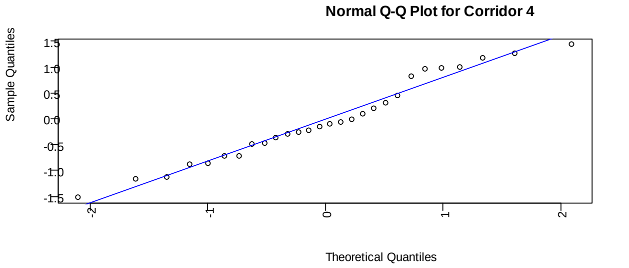

Barplot of Residuals for Corridor 3

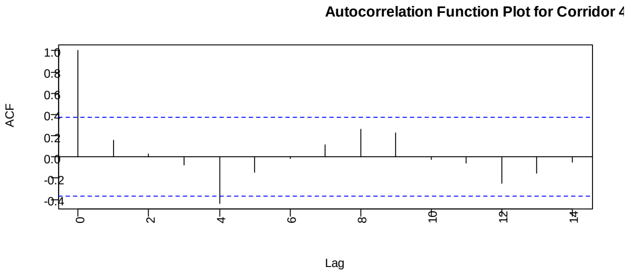

Normal Q-Q Plot for Corridor 3
Sample Quantiles
Theoretical Quantiles

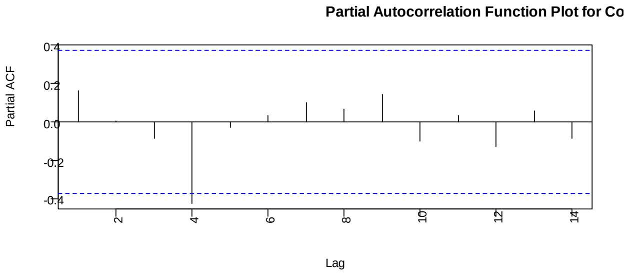

Autocorrelation Function Plot for Corridor 3
ACF
Lag

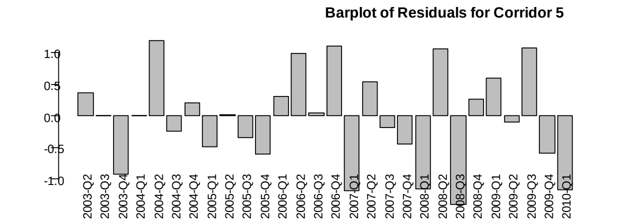

Partial Autocorrelation Function Plot for Co
Partial ACF
Lag


Barplot of Residuals for Corridor 4


Normal Q-Q Plot for Corridor 4
Sample Quantiles
Theoretical Quantiles


Autocorrelation Function Plot for Corridor 4
ACF
Lag


Partial Autocorrelation Function Plot for Co
Partial ACF
Lag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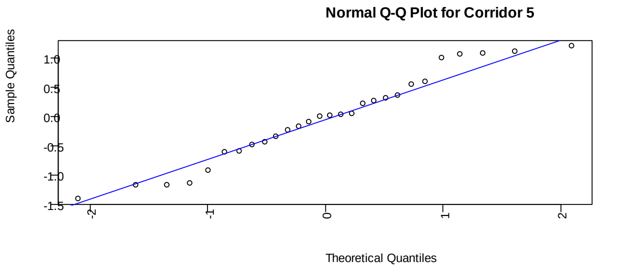
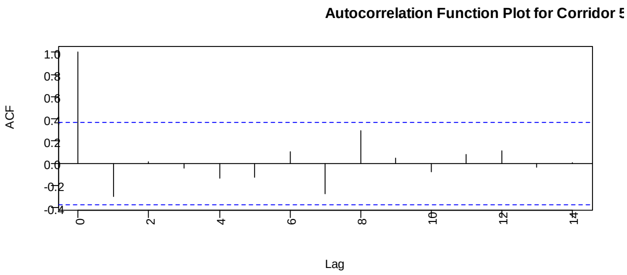

Normal Q-Q Plot for Corridor 5
Sample Quantiles
Theoretical Quantiles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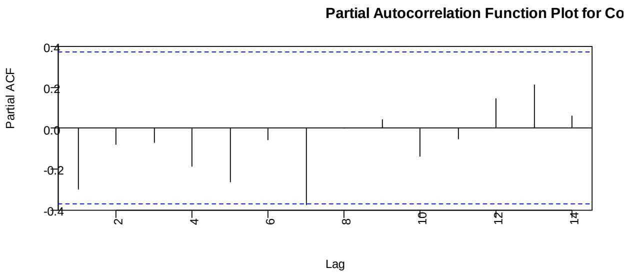
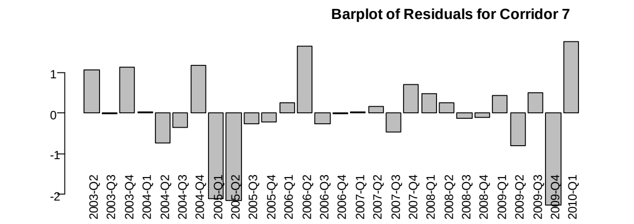
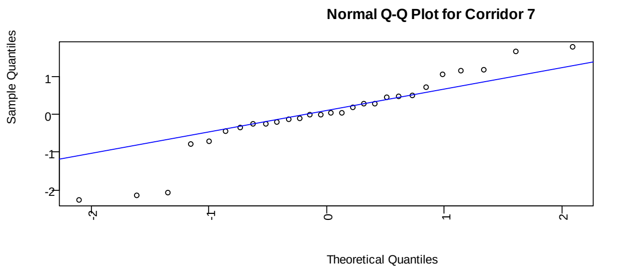
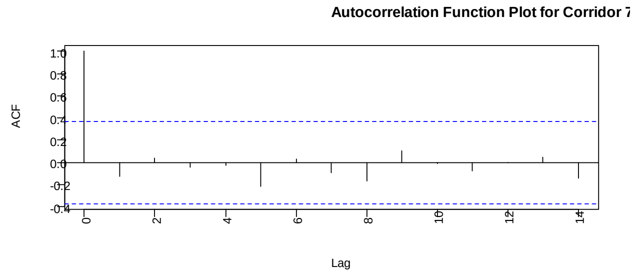
ACF
Lag


Partial Autocorrelation Function Plot for Co
Partial ACF
Lag


Barplot of Residuals for Corridor 7


Normal Q-Q Plot for Corridor 7
Sample Quantiles
Theoretical Quantiles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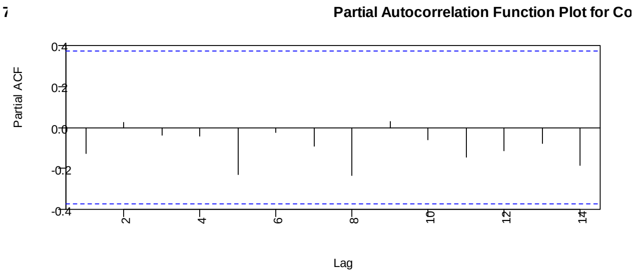
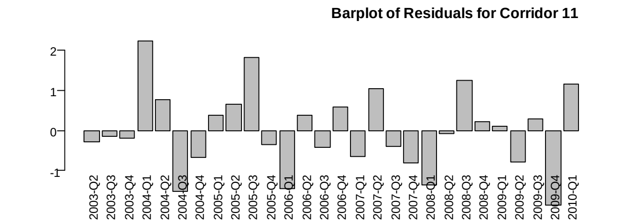
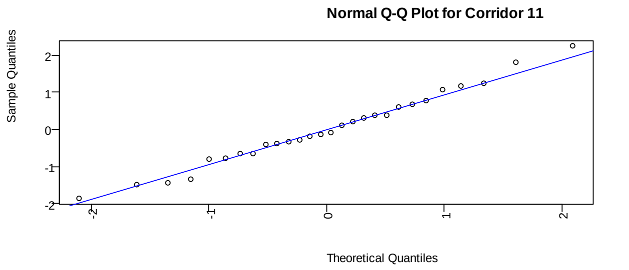
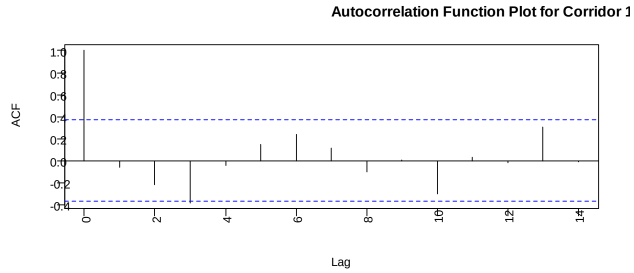
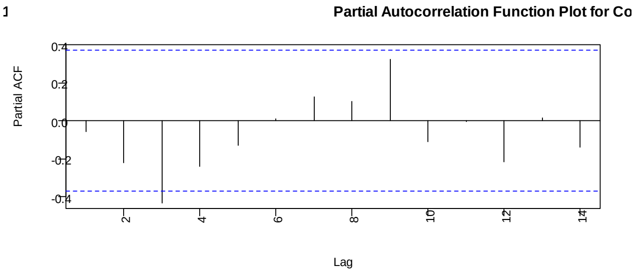
ACF
Lag

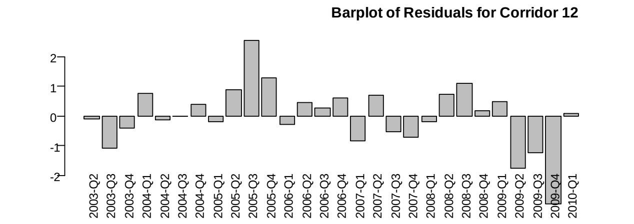

Partial Autocorrelation Function Plot for Co
Partial ACF
Lag

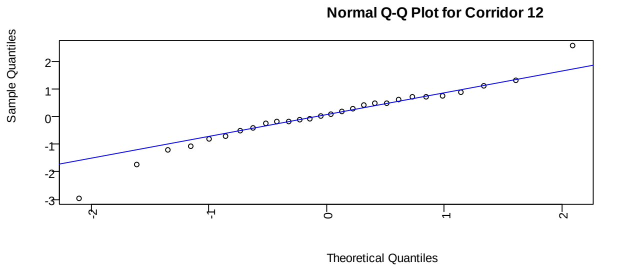

Barplot of Residuals for Corridor 11

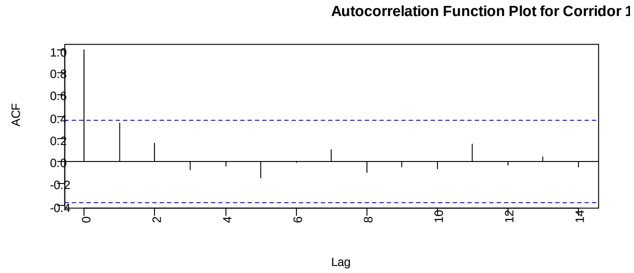

Normal Q-Q Plot for Corridor 11
Sample Quantiles
Theoretical Quantiles

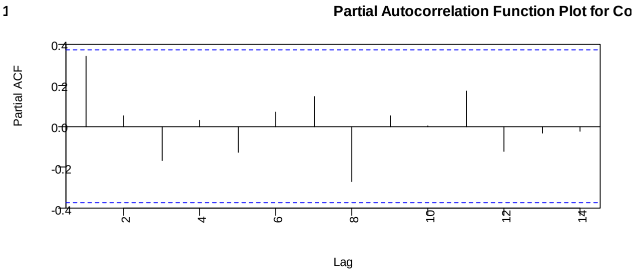

Autocorrelation Function Plot for Corridor 1
ACF
Lag

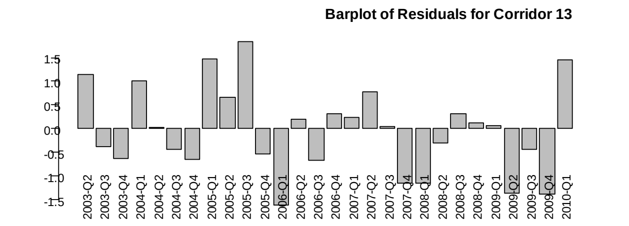

Partial Autocorrelation Function Plot for Co
Partial ACF
Lag

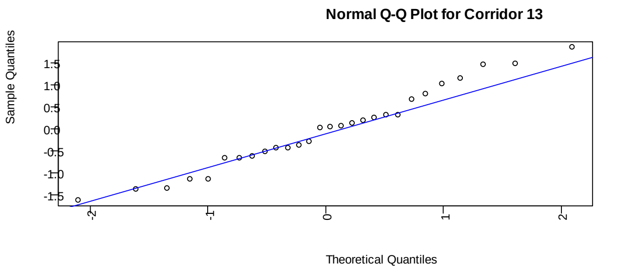

Barplot of Residuals for Corridor 12

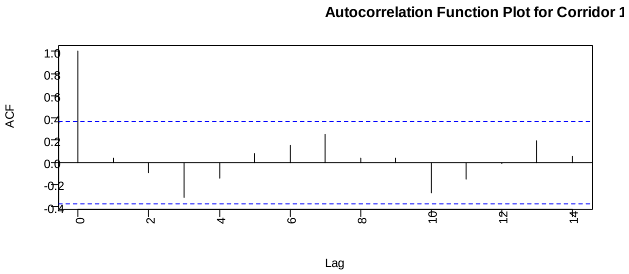

Normal Q-Q Plot for Corridor 12
Sample Quantiles
Theoretical Quantiles

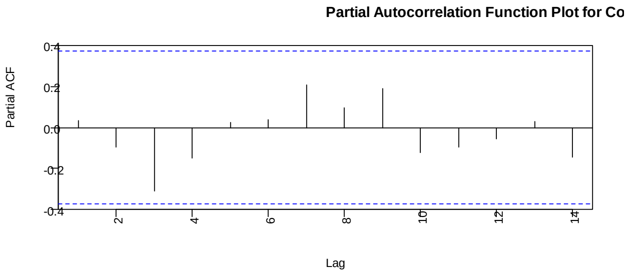

Autocorrelation Function Plot for Corridor 1
ACF
Lag

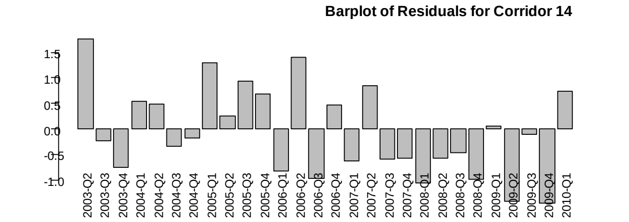

Partial Autocorrelation Function Plot for Co
Partial ACF
Lag

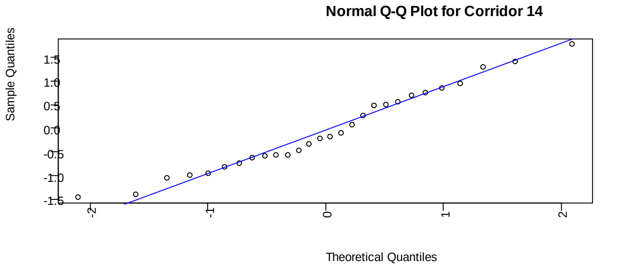

Barplot of Residuals for Corridor 13

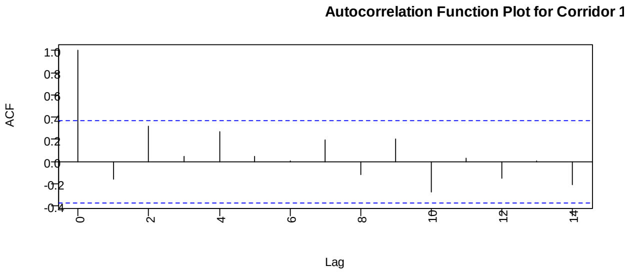

Normal Q-Q Plot for Corridor 13
Sample Quantiles
Theoretical Quantiles

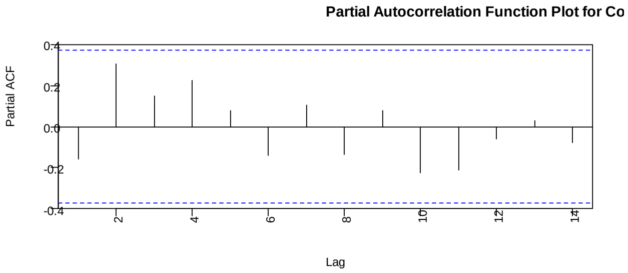

Autocorrelation Function Plot for Corridor 1
ACF
Lag

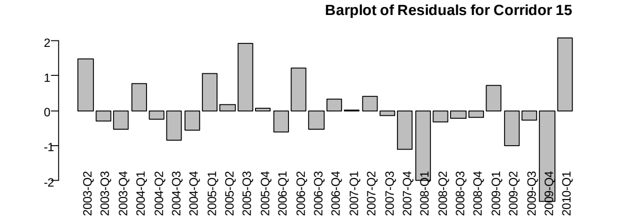

Partial Autocorrelation Function Plot for Co
Partial ACF
Lag

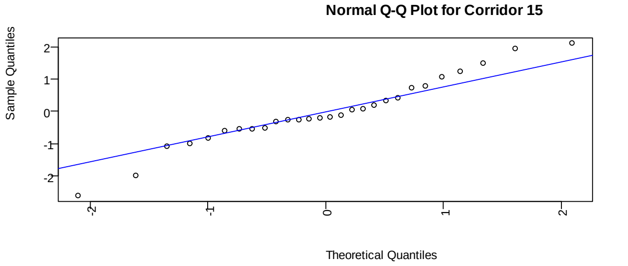

Barplot of Residuals for Corridor 14

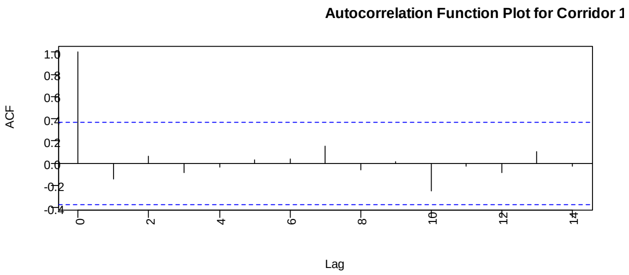

Normal Q-Q Plot for Corridor 14
Sample Quantiles
Theoretical Quantiles

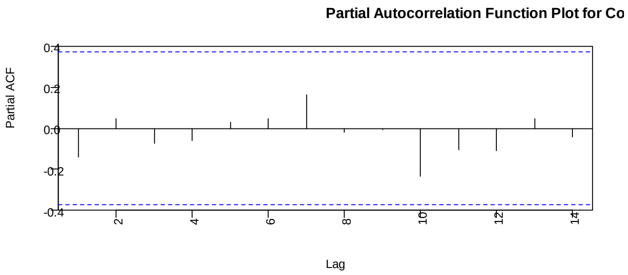

Autocorrelation Function Plot for Corridor 1
ACF
Lag

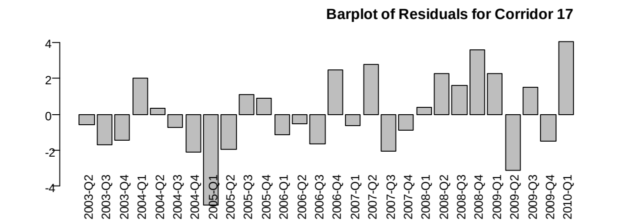

Partial Autocorrelation Function Plot for Co
Partial ACF
Lag

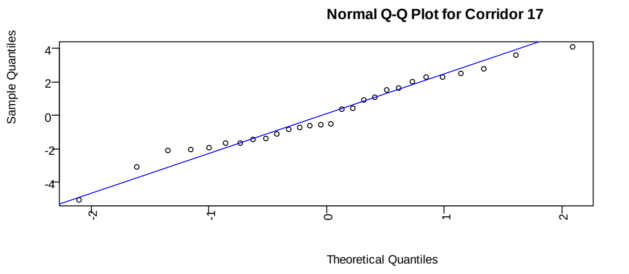

Barplot of Residuals for Corridor 15

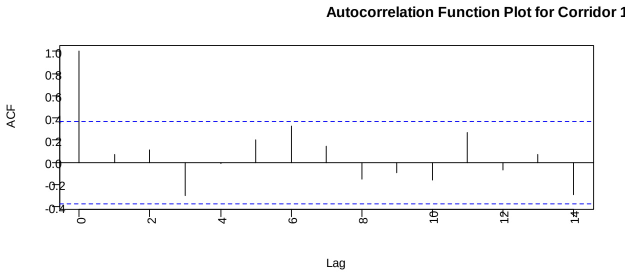

Normal Q-Q Plot for Corridor 15
Sample Quantiles
Theoretical Quantiles

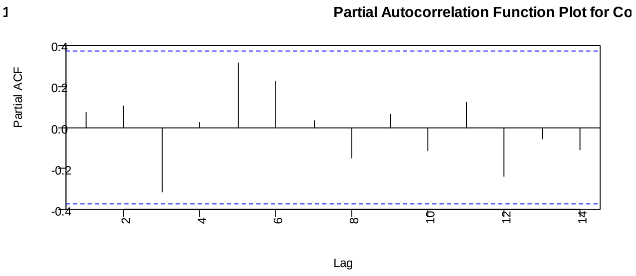

Autocorrelation Function Plot for Corridor 1
ACF
Lag

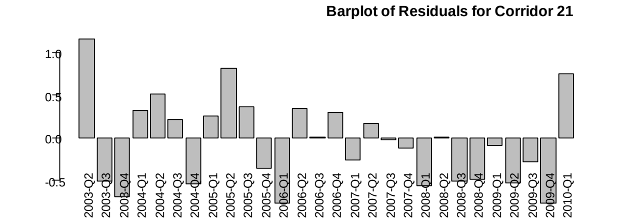

Partial Autocorrelation Function Plot for Co
Partial ACF
Lag

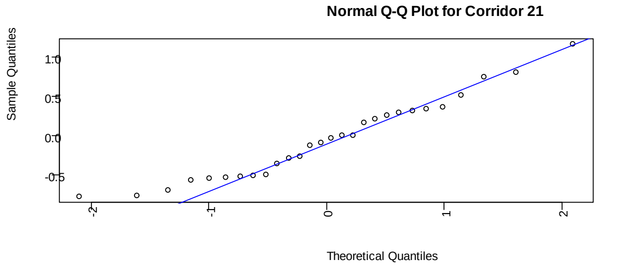

Barplot of Residuals for Corridor 17

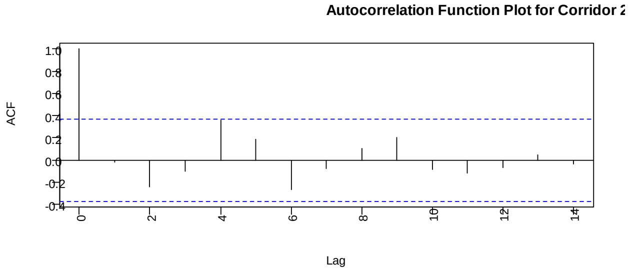

Normal Q-Q Plot for Corridor 17
Sample Quantiles
Theoretical Quantiles

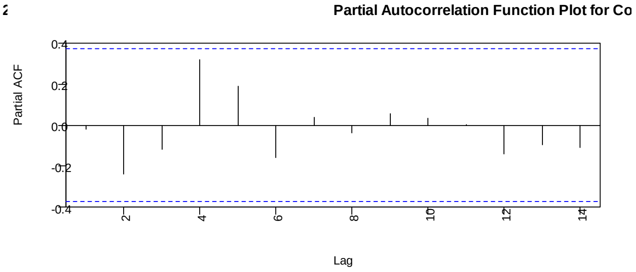

Autocorrelation Function Plot for Corridor 1
ACF
Lag

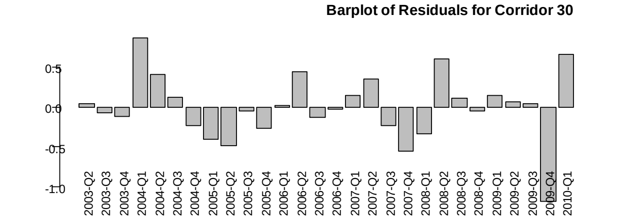

Partial Autocorrelation Function Plot for Co
Partial ACF
Lag

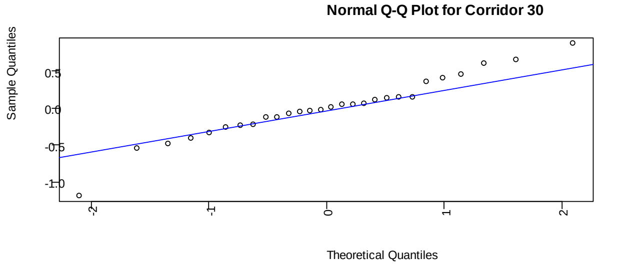

Barplot of Residuals for Corridor 21

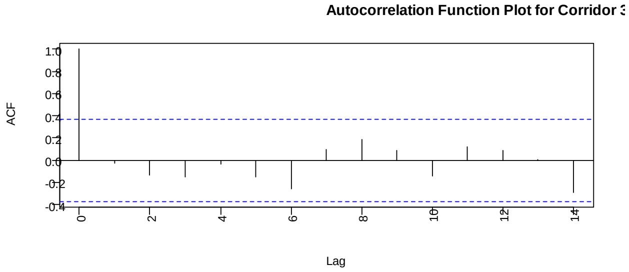

Normal Q-Q Plot for Corridor 21
Sample Quantiles
Theoretical Quantiles

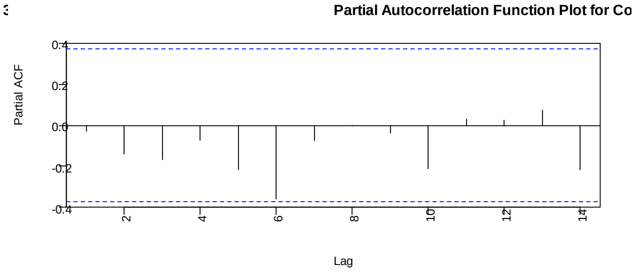

Autocorrelation Function Plot for Corridor 2
ACF
Lag

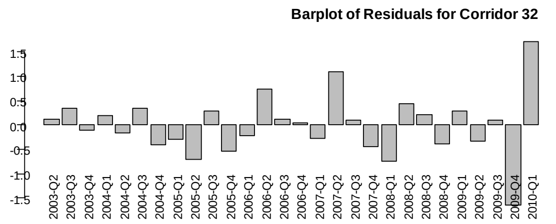

Partial Autocorrelation Function Plot for Co
Partial ACF
Lag

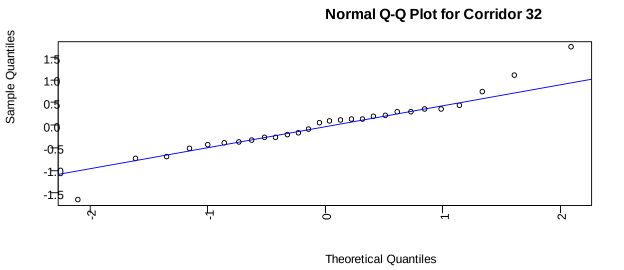

Barplot of Residuals for Corridor 30

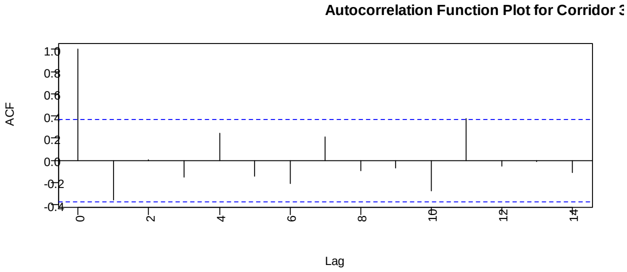

Normal Q-Q Plot for Corridor 30
Sample Quantiles
Theoretical Quantiles

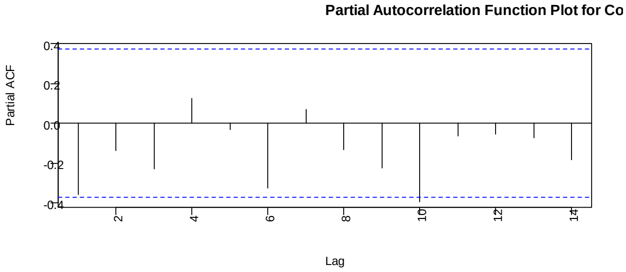

Autocorrelation Function Plot for Corridor 3
ACF
Lag

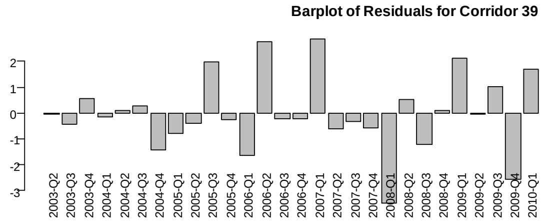

Partial Autocorrelation Function Plot for Co
Partial ACF
Lag

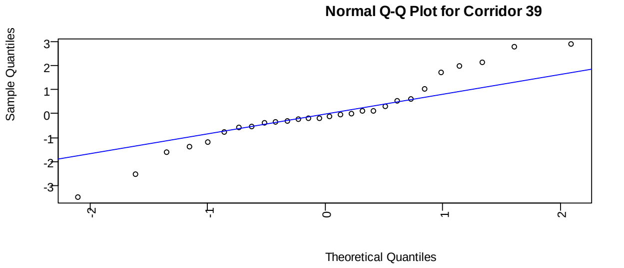

Barplot of Residuals for Corridor 32

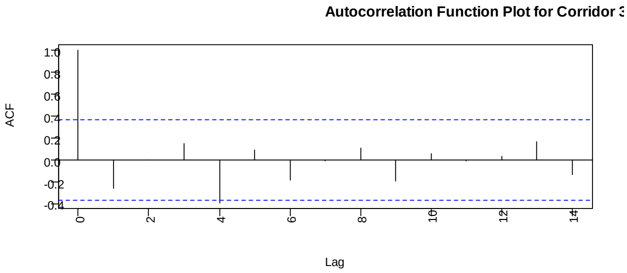

Normal Q-Q Plot for Corridor 32
Sample Quantiles
Theoretical Quantiles

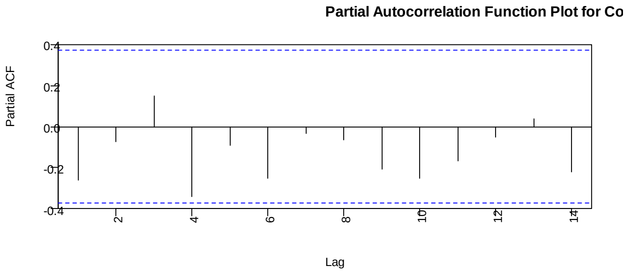

Autocorrelation Function Plot for Corridor 3
ACF
Lag

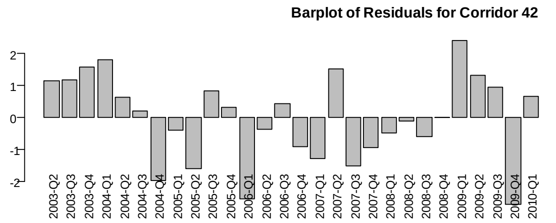

Partial Autocorrelation Function Plot for Co
Partial ACF
Lag

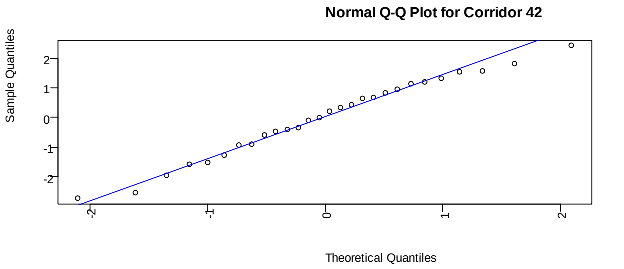

Barplot of Residuals for Corridor 39

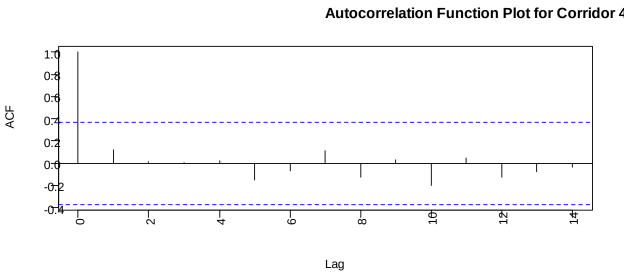

Normal Q-Q Plot for Corridor 39
Sample Quantiles
Theoretical Quantiles

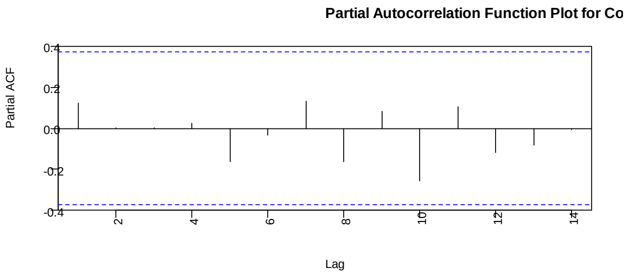

Autocorrelation Function Plot for Corridor 3
ACF
Lag

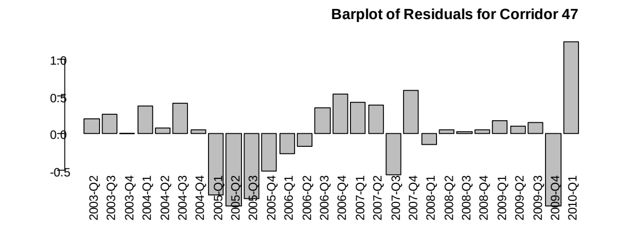

Partial Autocorrelation Function Plot for Co
Partial ACF
Lag

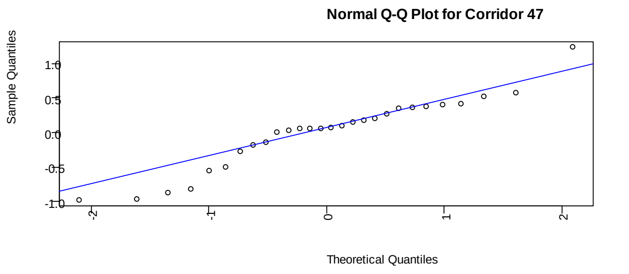

Barplot of Residuals for Corridor 42

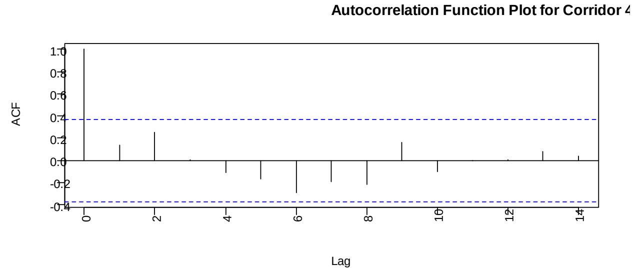

Normal Q-Q Plot for Corridor 42
Sample Quantiles
Theoretical Quantiles

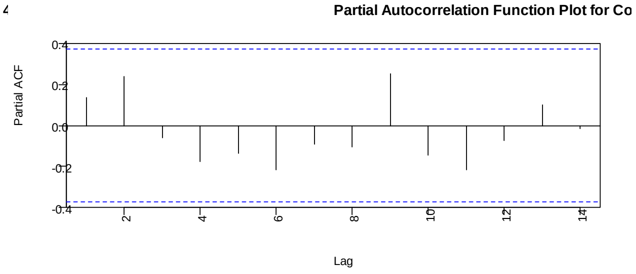

Autocorrelation Function Plot for Corridor 4
ACF
Lag

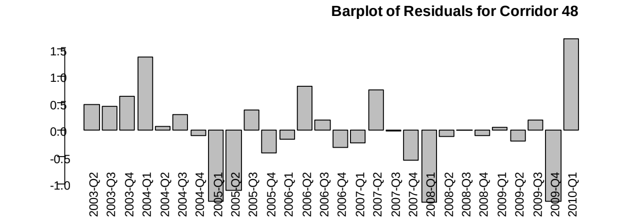

Partial Autocorrelation Function Plot for Co
Partial ACF
Lag

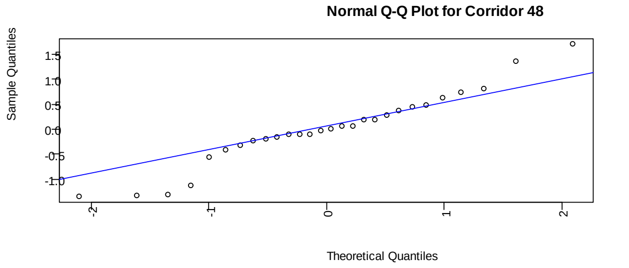

Barplot of Residuals for Corridor 47

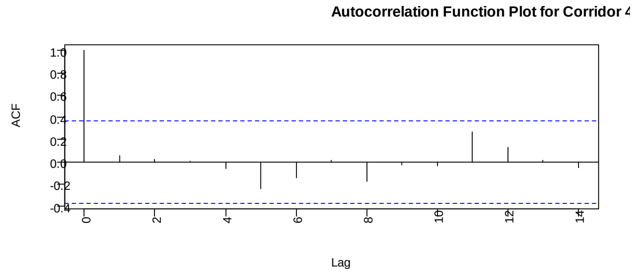

Normal Q-Q Plot for Corridor 47
Sample Quantiles
Theoretical Quantiles

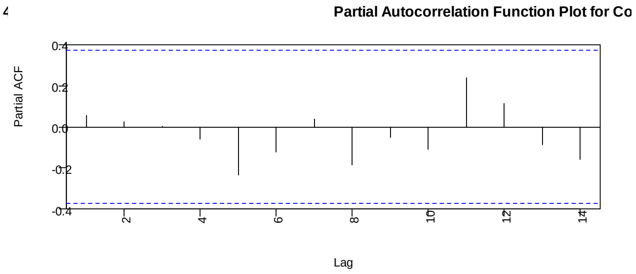

Autocorrelation Function Plot for Corridor 4
ACF
Lag

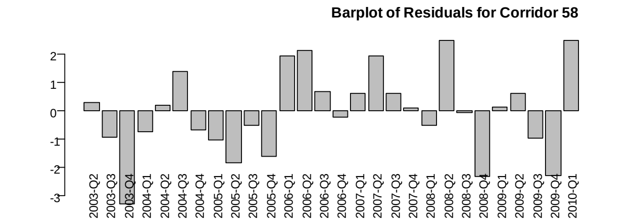

Partial Autocorrelation Function Plot for Co
Partial ACF
Lag

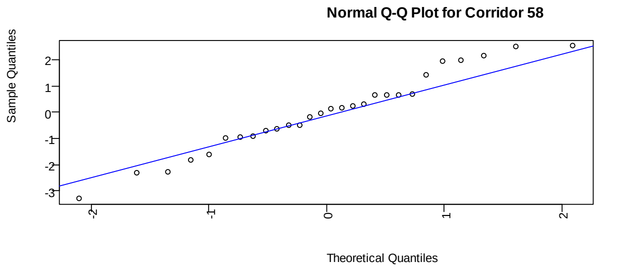

Barplot of Residuals for Corridor 48

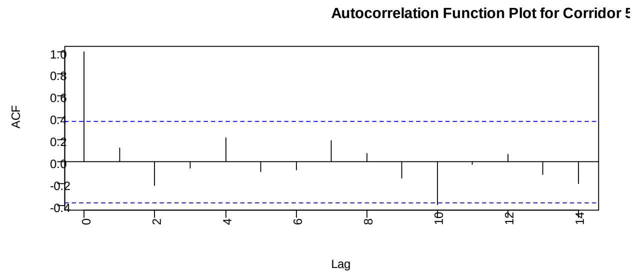

Normal Q-Q Plot for Corridor 48
Sample Quantiles
Theoretical Quantiles

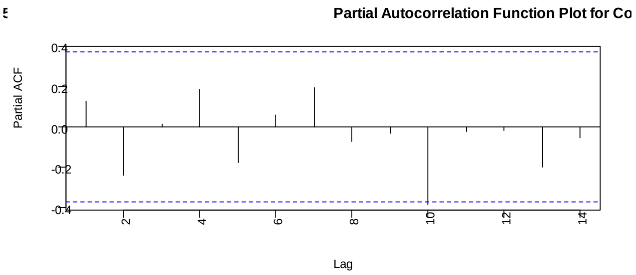

Autocorrelation Function Plot for Corridor 4
ACF
Lag


Partial Autocorrelation Function Plot for Co
Partial ACF
Lag

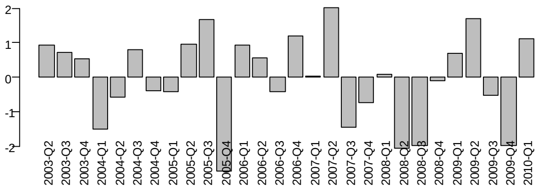

Barplot of Residuals for Corridor 58


Normal Q-Q Plot for Corridor 58
Sample Quantiles
Theoretical Quantiles

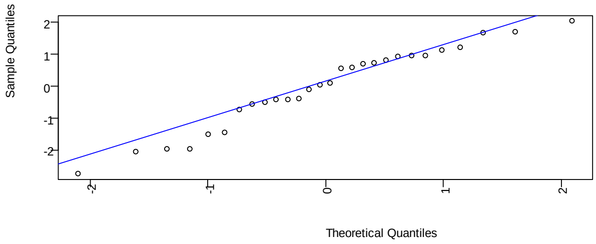

Autocorrelation Function Plot for Corridor 5
ACF
Lag


Partial Autocorrelation Function Plot for Co
Partial ACF
Lag

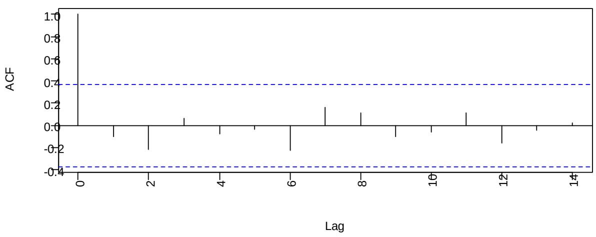
Barplot of Residuals for Corridor 74



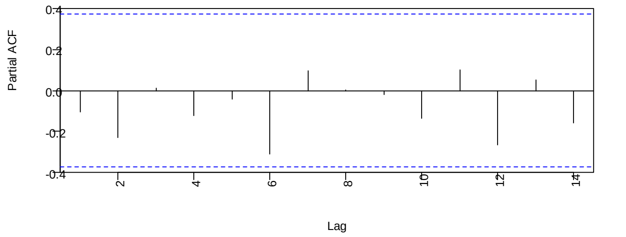
Normal Q-Q Plot for Corridor 74



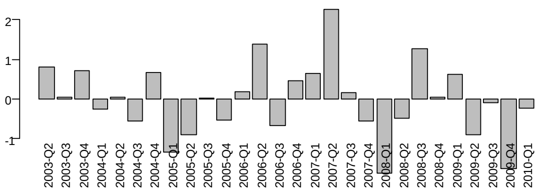
Autocorrelation Function Plot for Corridor 7



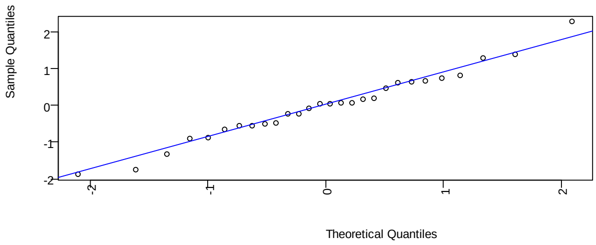
Partial Autocorrelation Function Plot for Co



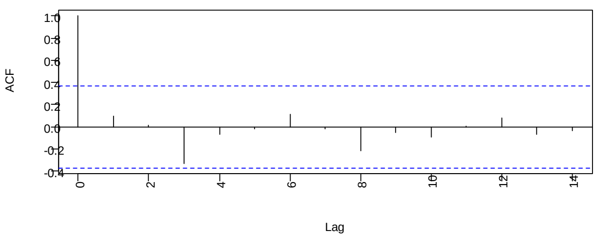
Barplot of Residuals for Corridor 81



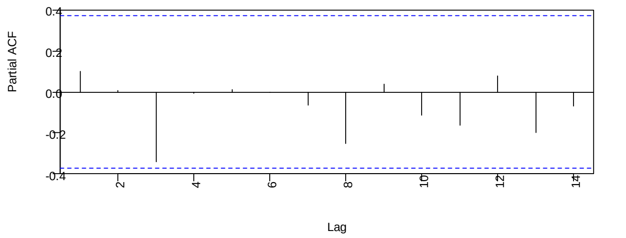
Normal Q-Q Plot for Corridor 81



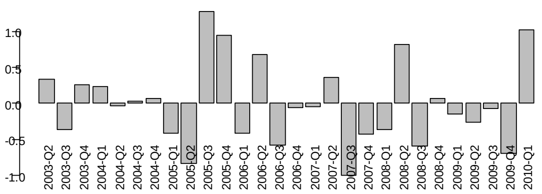
Autocorrelation Function Plot for Corridor 8



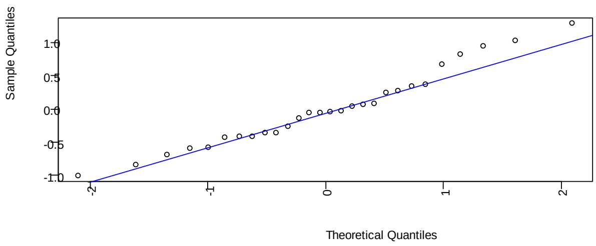
Partial Autocorrelation Function Plot for Co



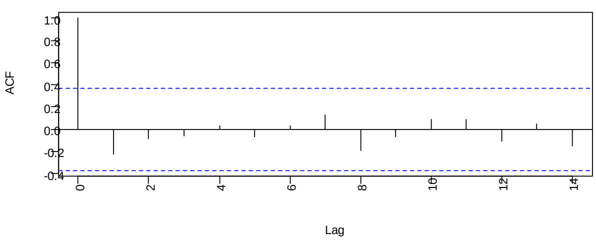
Barplot of Residuals for Corridor 83



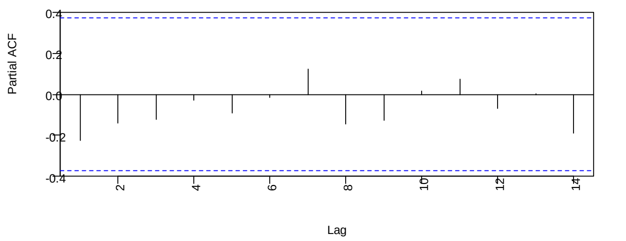
Normal Q-Q Plot for Corridor 83

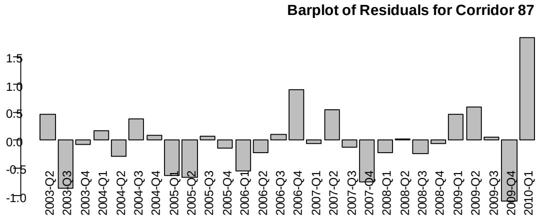


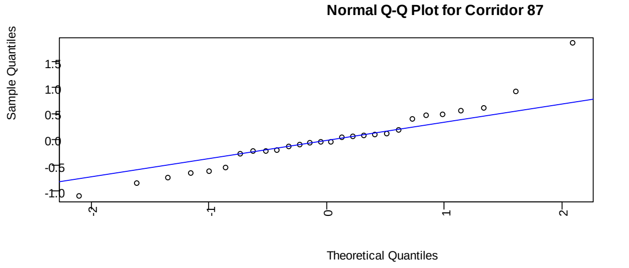
Autocorrelation Function Plot for Corridor 8

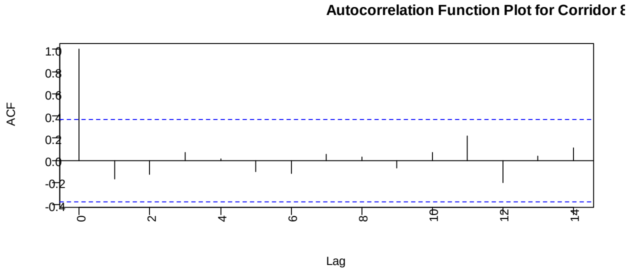


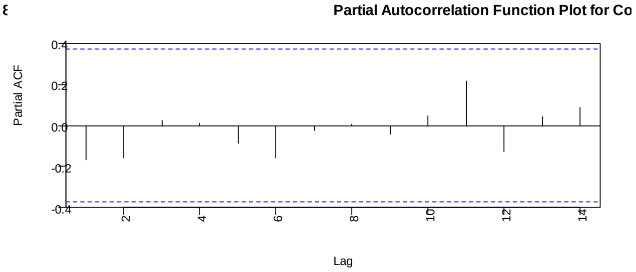
Partial Autocorrelation Function Plot for Co

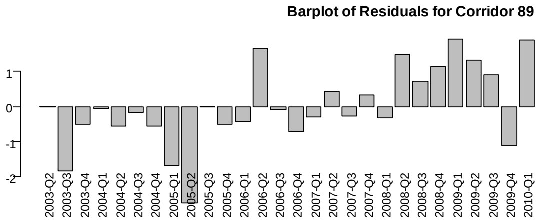


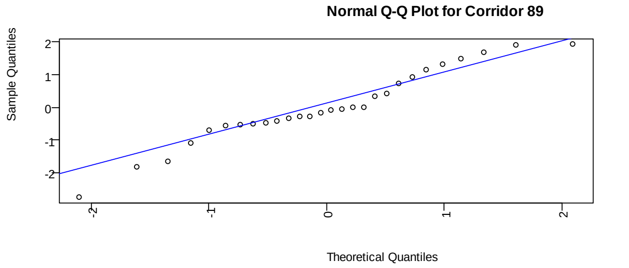

Barplot of Residuals for Corridor 87

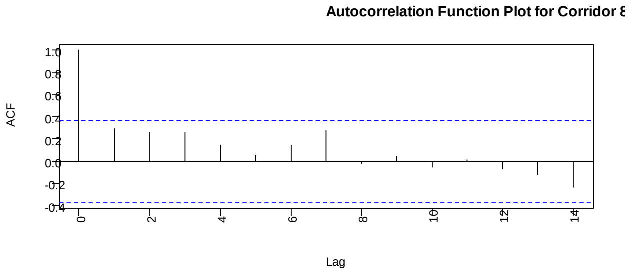

Normal Q-Q Plot for Corridor 87
Sample Quantiles
Theoretical Quantiles

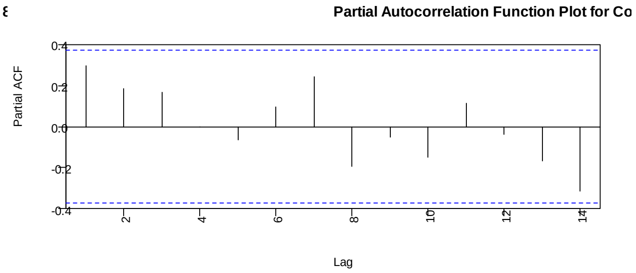

Autocorrelation Function Plot for Corridor 8
ACF
Lag

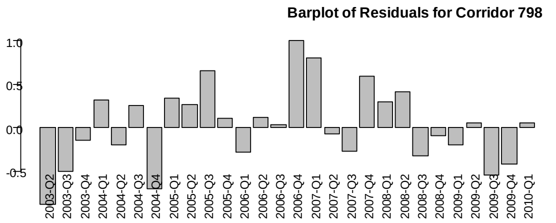

Partial Autocorrelation Function Plot for Co
Partial ACF
Lag

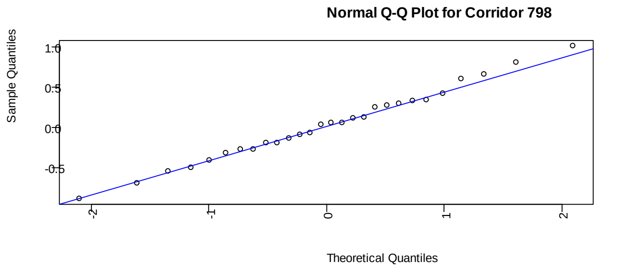

Barplot of Residuals for Corridor 89

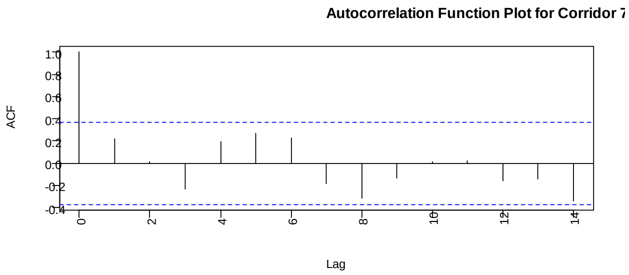

Normal Q-Q Plot for Corridor 89
Sample Quantiles
Theoretical Quantiles

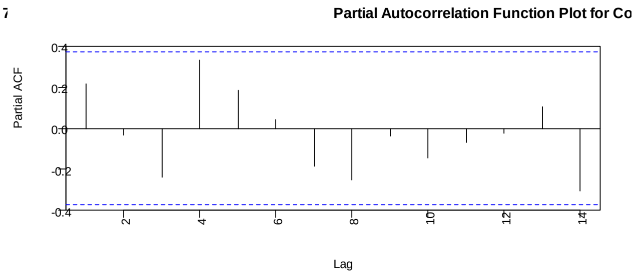

Autocorrelation Function Plot for Corridor 8
ACF
Lag


Partial Autocorrelation Function Plot for Co
Partial ACF
Lag


Barplot of Residuals for Corridor 798


Normal Q-Q Plot for Corridor 798
Sample Quantiles
Theoretical Quantiles


Autocorrelation Function Plot for Corridor 7
ACF
Lag


Partial Autocorrelation Function Plot for Co
Partial ACF
Lag

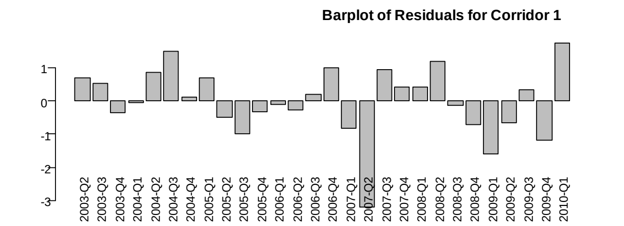
C6.3 Diagnostic analysis for the interpeak patronage model

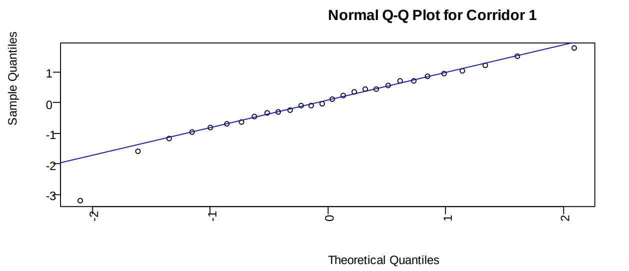
The figures below show diagnostic plots for the residuals from model 3 for interpeak patronage, as shown in table C.13.

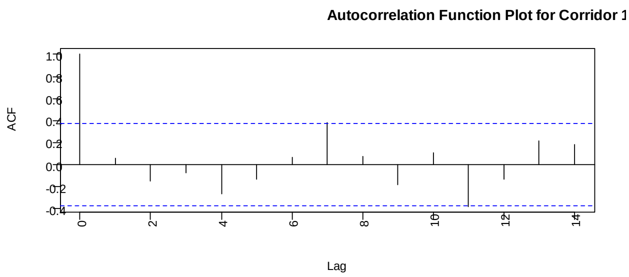
The diagnostic plots show that the residuals for most of the corridors are consistent with the assumption of normality and autocorrelation is generally low. Corridor 83 is a possible exception because it has 'heavy tails', but the deviation from the assumption of normality is not extreme.

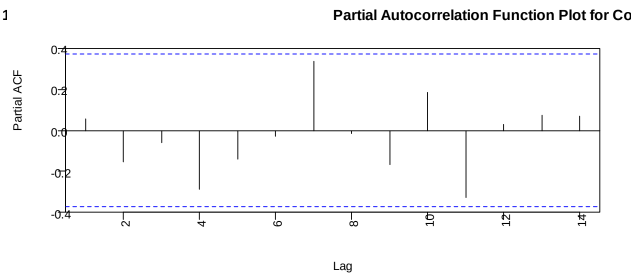
Corridor 89 shows evidence of a 'structural change' around 2008–Q1 onwards. The residuals are predominantly positive from this point onwards; this implies that we have omitted some unexplained event or factor that caused a burst in growth on this bus corridor.

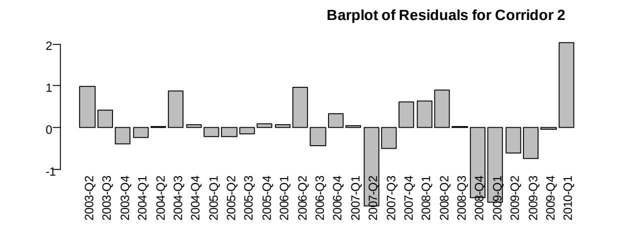
As noted in section C6.1, the deviations observed for bus corridor 89 were deemed serious enough for it to be omitted from the preferred model (along with bus corridors 14 and 21).

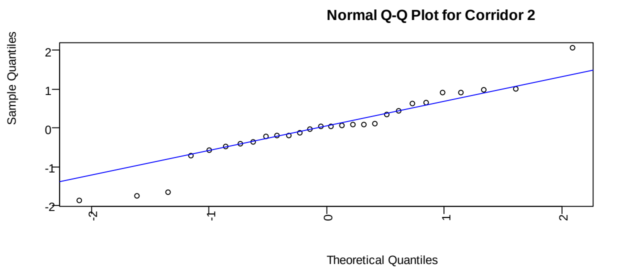


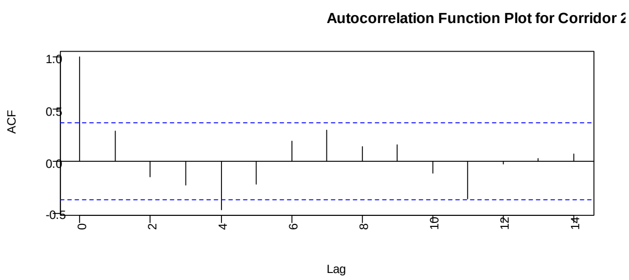


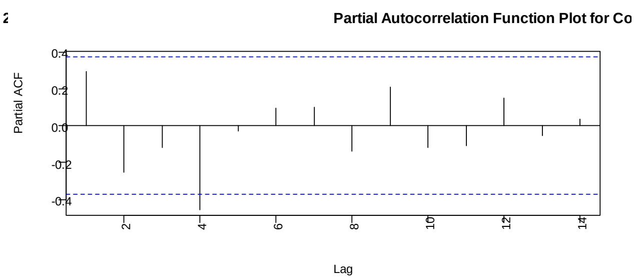


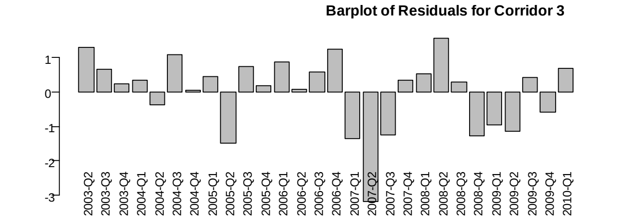


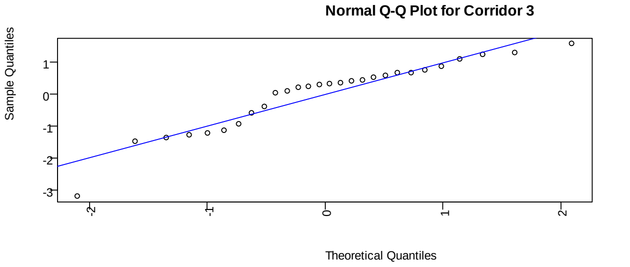


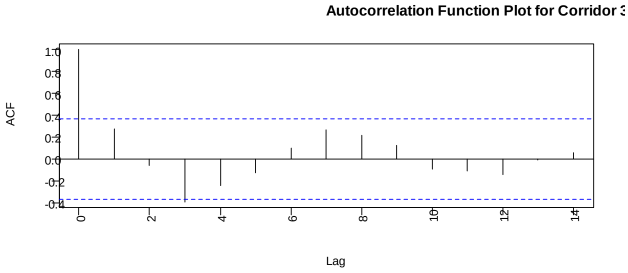


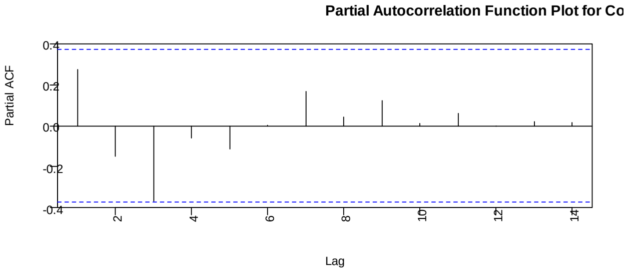


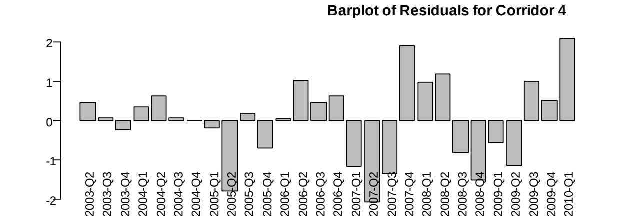


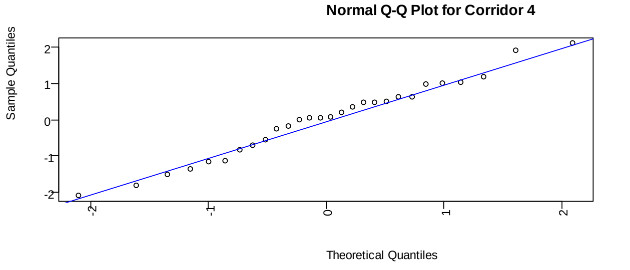

Barplot of Residuals for Corridor 3

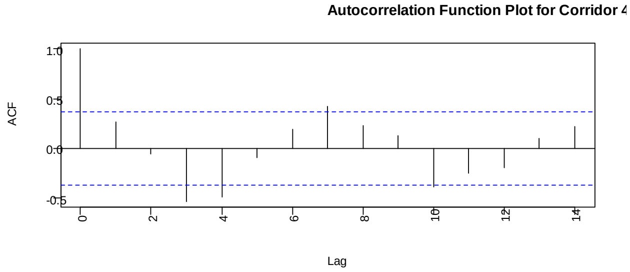

Normal Q-Q Plot for Corridor 3
Sample Quantiles
Theoretical Quantiles

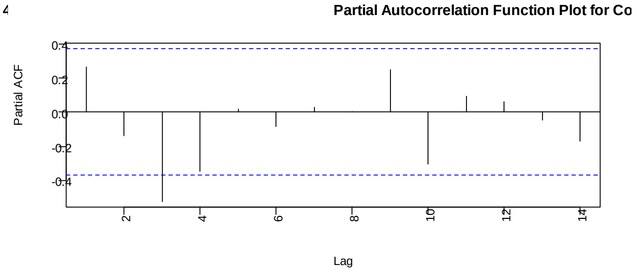

Autocorrelation Function Plot for Corridor 3
ACF
Lag

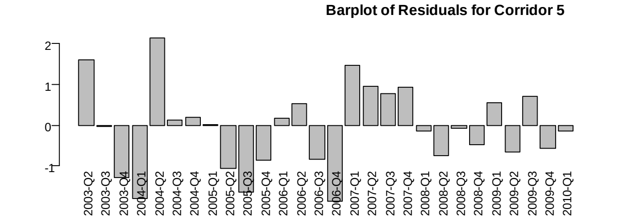

Partial Autocorrelation Function Plot for Co
Partial ACF
Lag

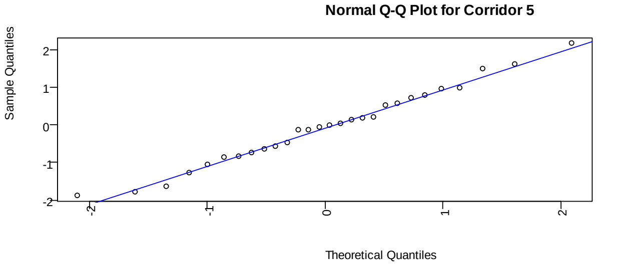

Barplot of Residuals for Corridor 4

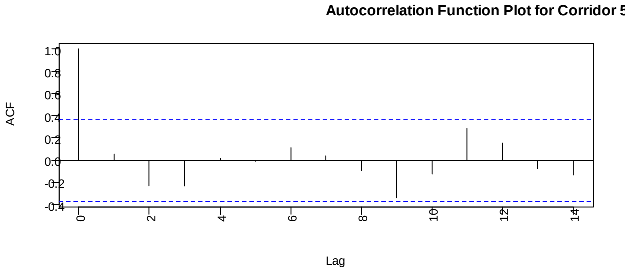

Normal Q-Q Plot for Corridor 4
Sample Quantiles
Theoretical Quantiles

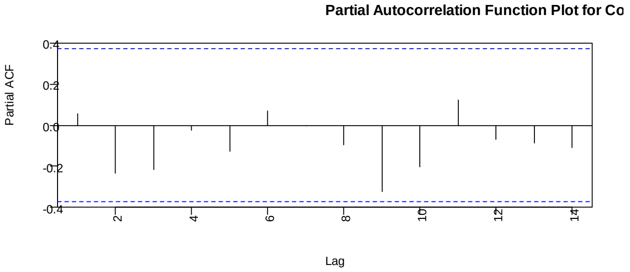

Autocorrelation Function Plot for Corridor 4
ACF
Lag

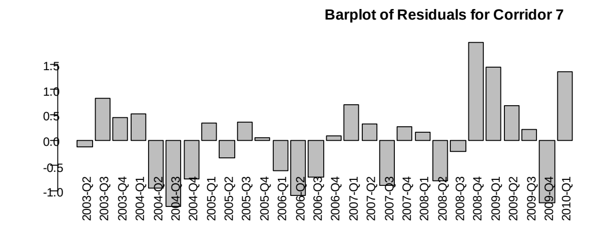

Partial Autocorrelation Function Plot for Co
Partial ACF
Lag

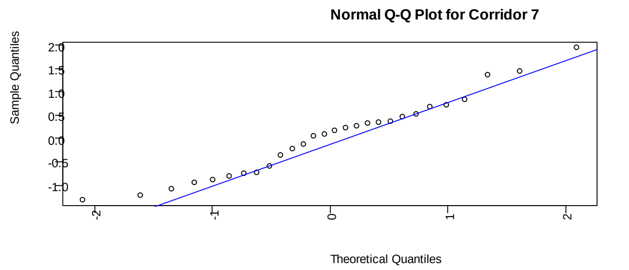

Barplot of Residuals for Corridor 5

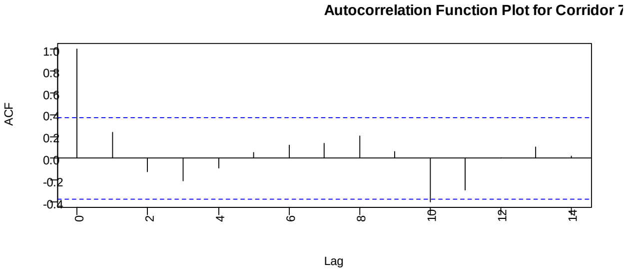

Normal Q-Q Plot for Corridor 5
Sample Quantiles
Theoretical Quantiles

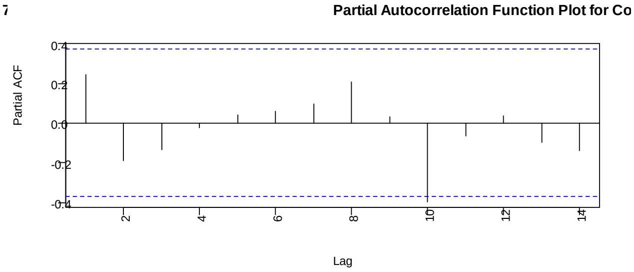

Autocorrelation Function Plot for Corridor 5
ACF
Lag

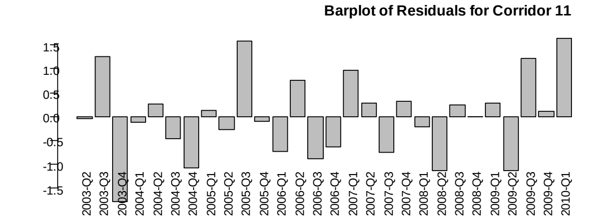

Partial Autocorrelation Function Plot for Co
Partial ACF
Lag

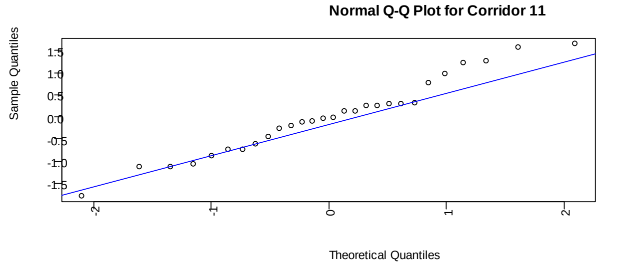

Barplot of Residuals for Corridor 7

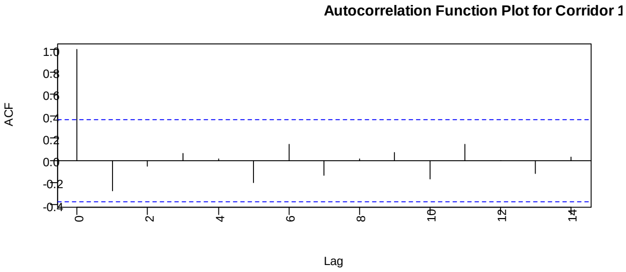

Normal Q-Q Plot for Corridor 7
Sample Quantiles
Theoretical Quantiles

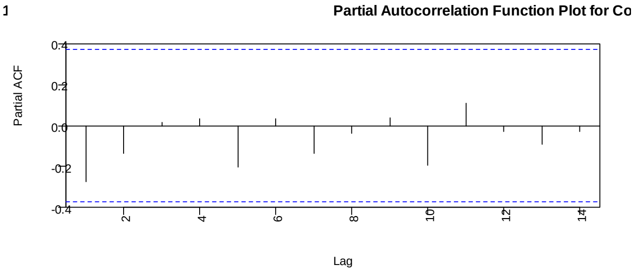

Autocorrelation Function Plot for Corridor 7
ACF
Lag

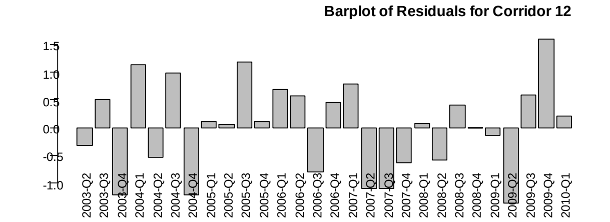

Partial Autocorrelation Function Plot for Co
Partial ACF
Lag

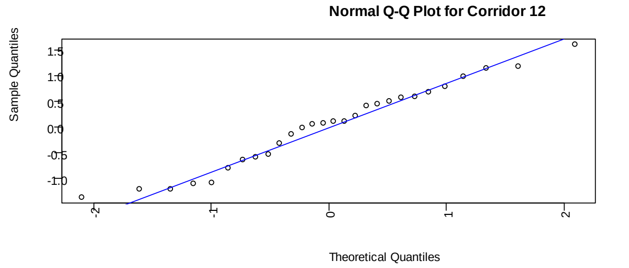

Barplot of Residuals for Corridor 11

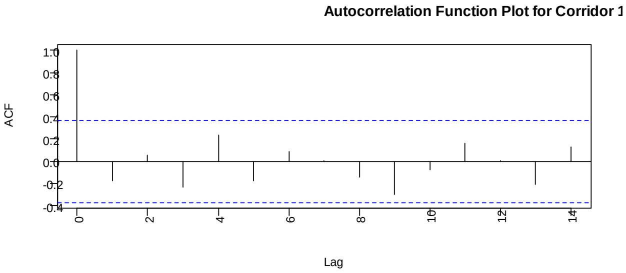

Normal Q-Q Plot for Corridor 11
Sample Quantiles
Theoretical Quantiles

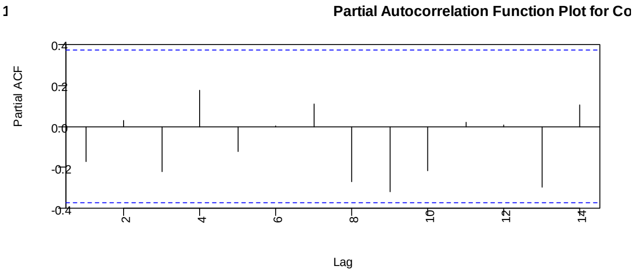

Autocorrelation Function Plot for Corridor 1
ACF
Lag

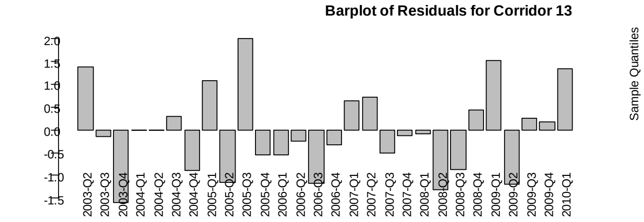

Partial Autocorrelation Function Plot for Co
Partial ACF
Lag

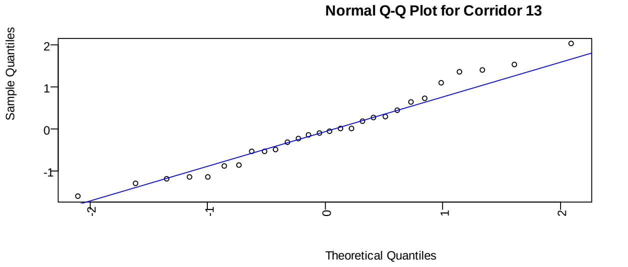

Barplot of Residuals for Corridor 12

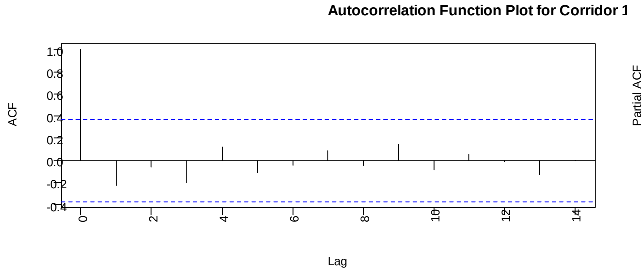

Normal Q-Q Plot for Corridor 12
Sample Quantiles
Theoretical Quantiles

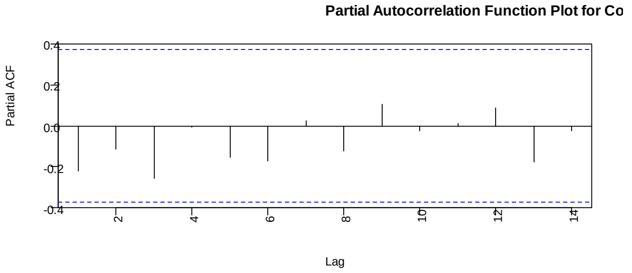

Autocorrelation Function Plot for Corridor 1
ACF
Lag

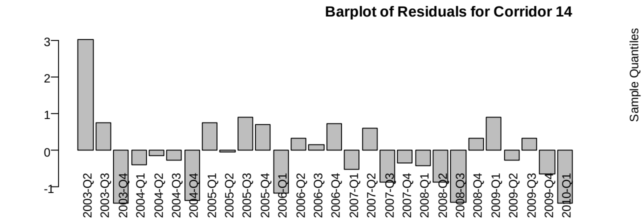

Partial Autocorrelation Function Plot for Co
Partial ACF
Lag

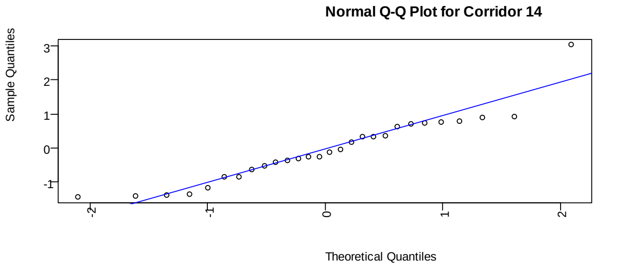

Barplot of Residuals for Corridor 13

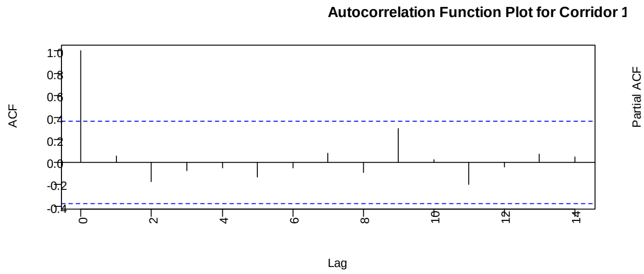

Normal Q-Q Plot for Corridor 13
Sample Quantiles
Theoretical Quantiles

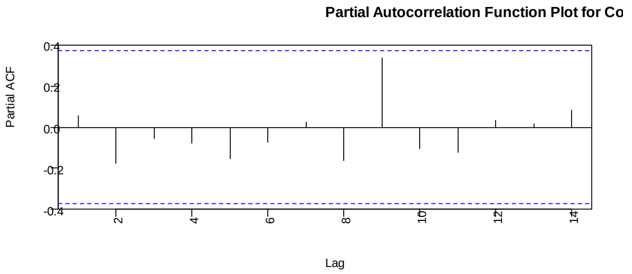

Autocorrelation Function Plot for Corridor 1
ACF
Lag

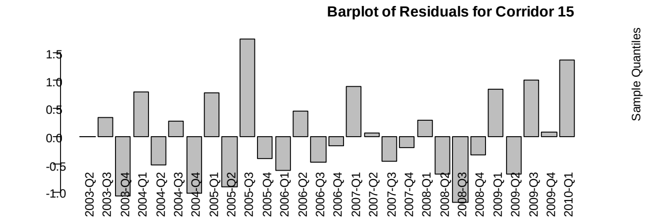

Partial Autocorrelation Function Plot for Co
Partial ACF
Lag

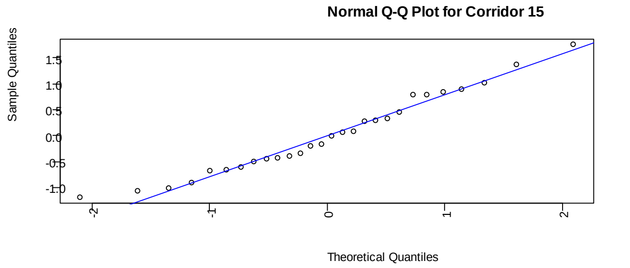

Barplot of Residuals for Corridor 14

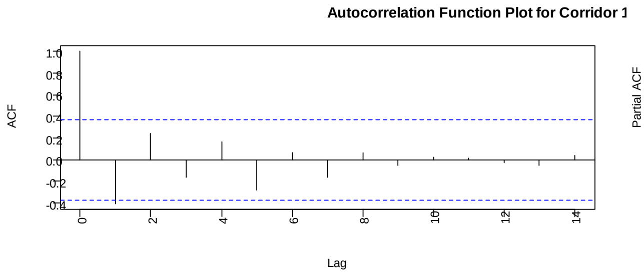

Normal Q-Q Plot for Corridor 14
Sample Quantiles
Theoretical Quantiles

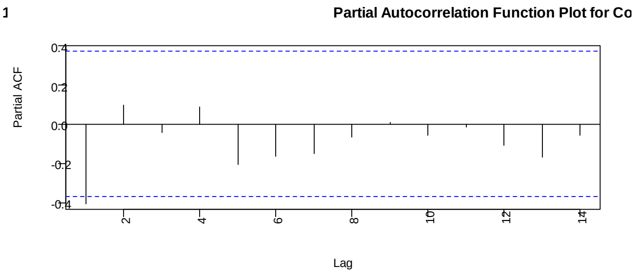

Autocorrelation Function Plot for Corridor 1
ACF
Lag

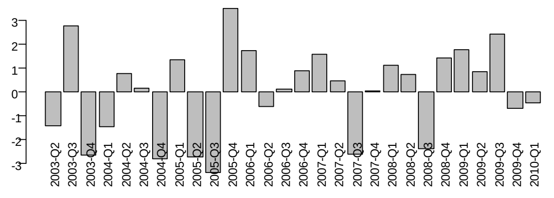

Partial Autocorrelation Function Plot for Co
Partial ACF
Lag

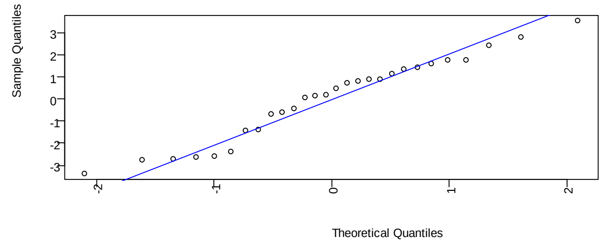

Barplot of Residuals for Corridor 15


Normal Q-Q Plot for Corridor 15
Sample Quantiles
Theoretical Quantiles

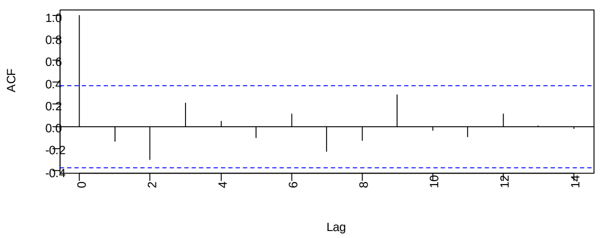

Autocorrelation Function Plot for Corridor 1
ACF
Lag


Partial Autocorrelation Function Plot for Co
Partial ACF
Lag

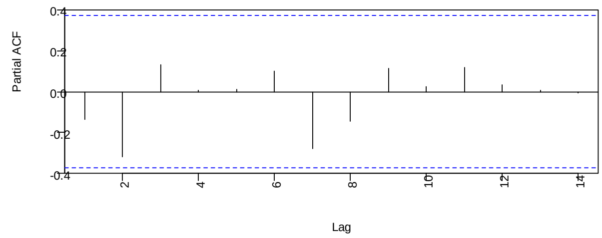

Barplot of Residuals for Corridor 17



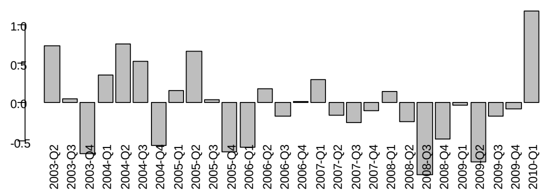
Normal Q-Q Plot for Corridor 17

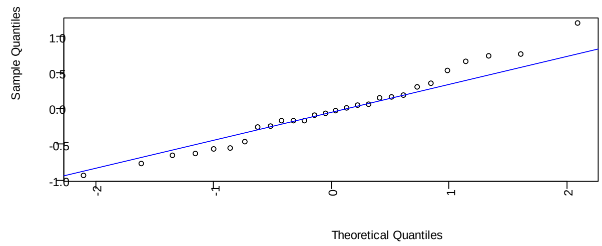


Autocorrelation Function Plot for Corridor 1

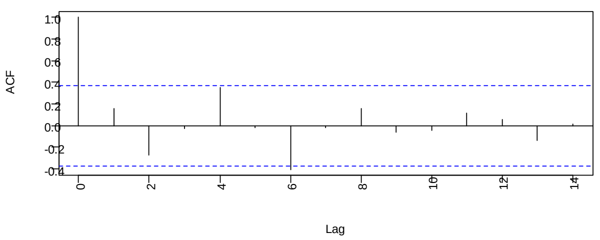


Partial Autocorrelation Function Plot for Co

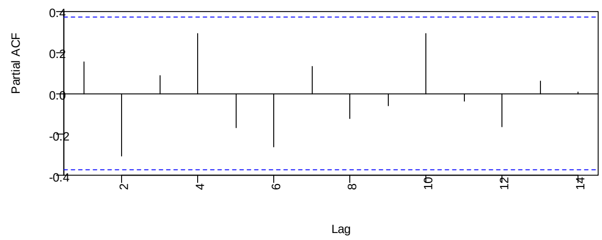

Barplot of Residuals for Corridor 21



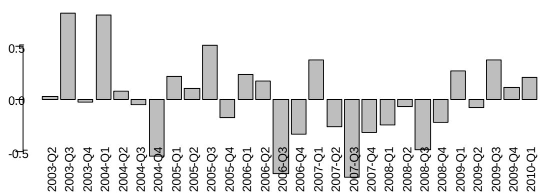
Normal Q-Q Plot for Corridor 21

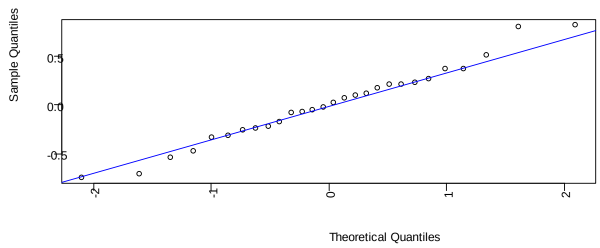


Autocorrelation Function Plot for Corridor 2

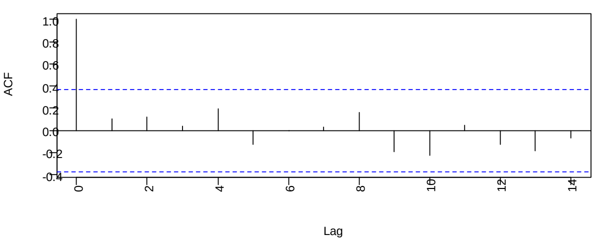


Partial Autocorrelation Function Plot for Co

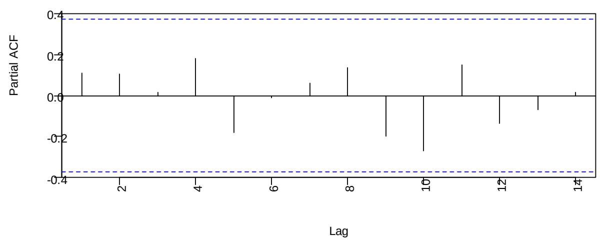

Barplot of Residuals for Corridor 30



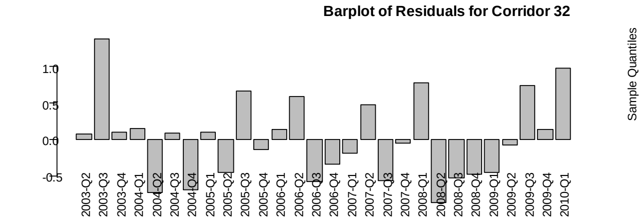
Normal Q-Q Plot for Corridor 30

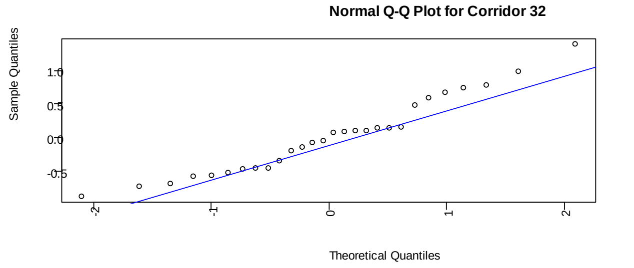


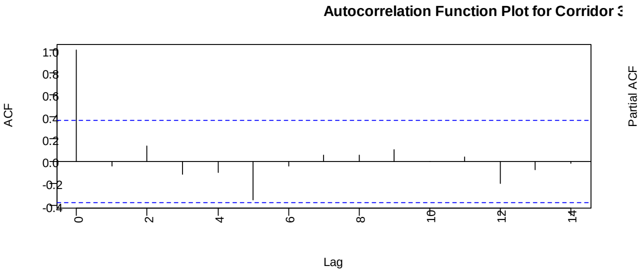
Autocorrelation Function Plot for Corridor 3

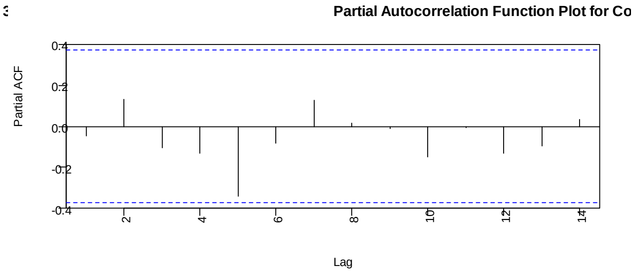


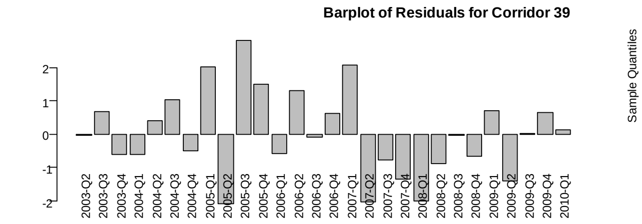
Partial Autocorrelation Function Plot for Co

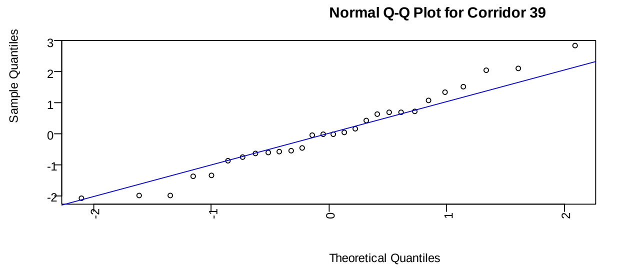

Barplot of Residuals for Corridor 32

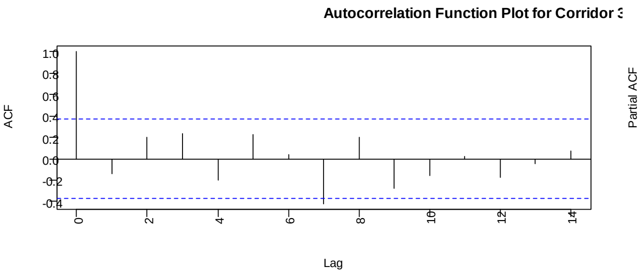

Normal Q-Q Plot for Corridor 32
Sample Quantiles
Theoretical Quantiles

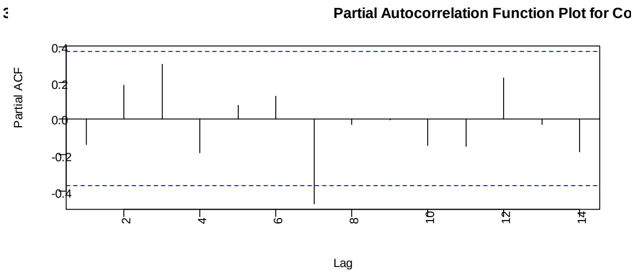

Autocorrelation Function Plot for Corridor 3
ACF
Lag

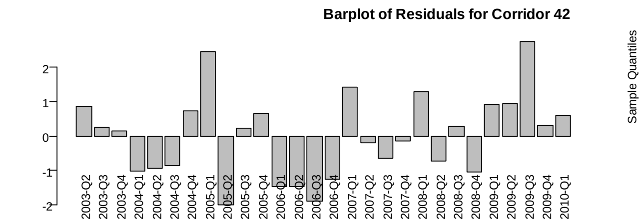

Partial Autocorrelation Function Plot for Co
Partial ACF
Lag

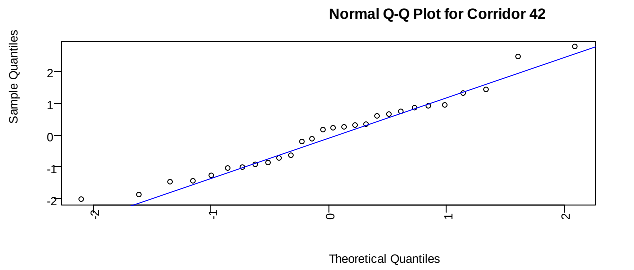

Barplot of Residuals for Corridor 39

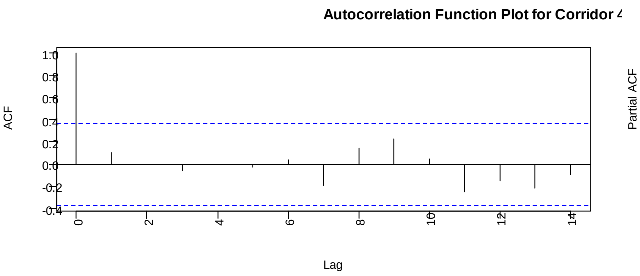

Normal Q-Q Plot for Corridor 39
Sample Quantiles
Theoretical Quantiles

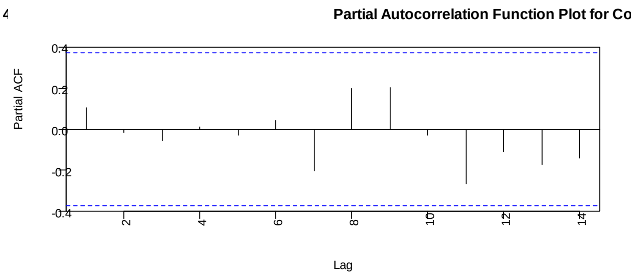

Autocorrelation Function Plot for Corridor 3
ACF
Lag

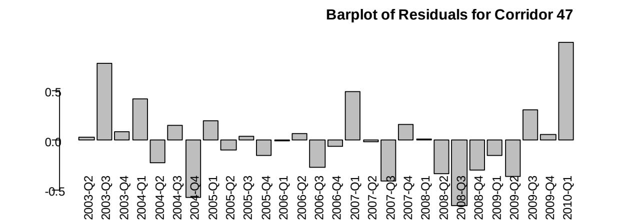

Partial Autocorrelation Function Plot for Co
Partial ACF
Lag

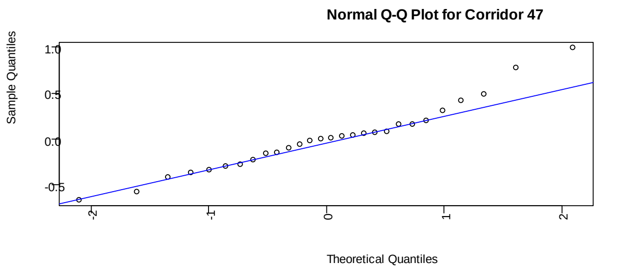

Barplot of Residuals for Corridor 42

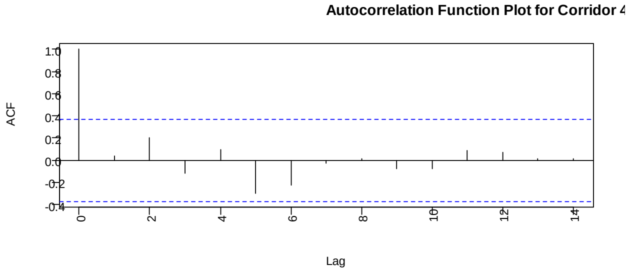

Normal Q-Q Plot for Corridor 42
Sample Quantiles
Theoretical Quantiles

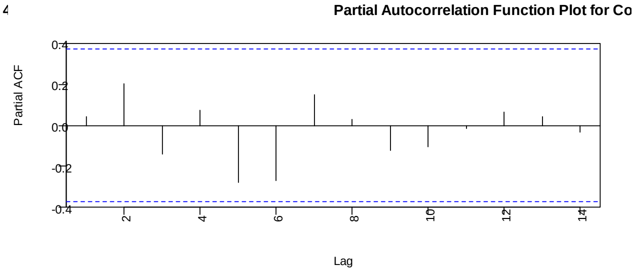

Autocorrelation Function Plot for Corridor 4
ACF
Lag

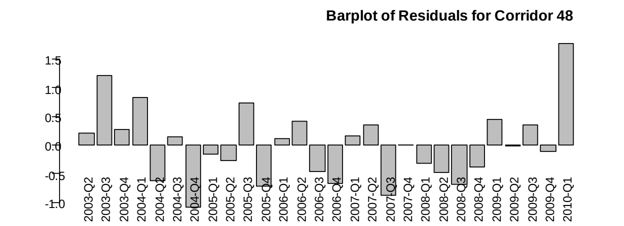

Partial Autocorrelation Function Plot for Co
Partial ACF
Lag

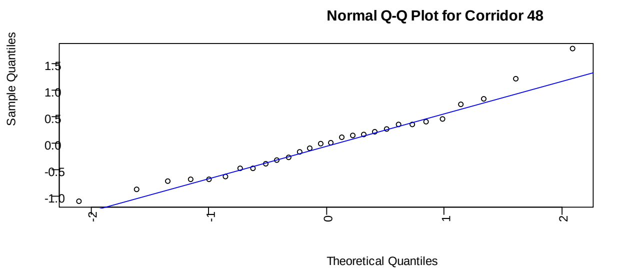

Barplot of Residuals for Corridor 47

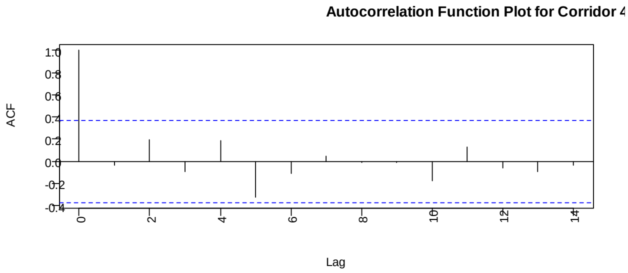

Normal Q-Q Plot for Corridor 47
Sample Quantiles
Theoretical Quantiles

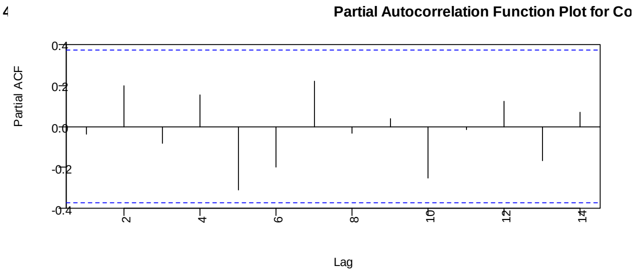

Autocorrelation Function Plot for Corridor 4
ACF
Lag

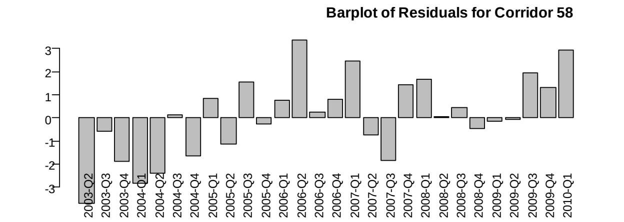

Partial Autocorrelation Function Plot for Co
Partial ACF
Lag

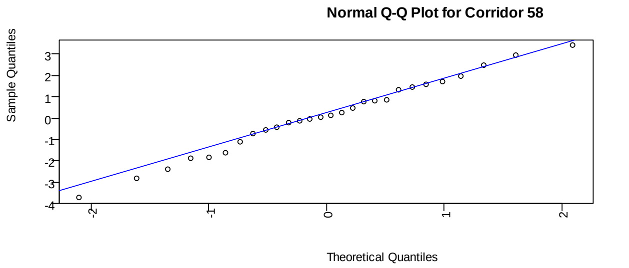

Barplot of Residuals for Corridor 48

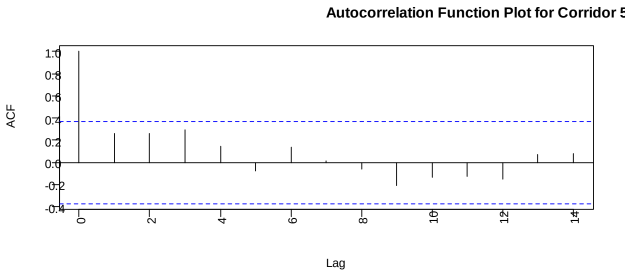

Normal Q-Q Plot for Corridor 48
Sample Quantiles
Theoretical Quantiles

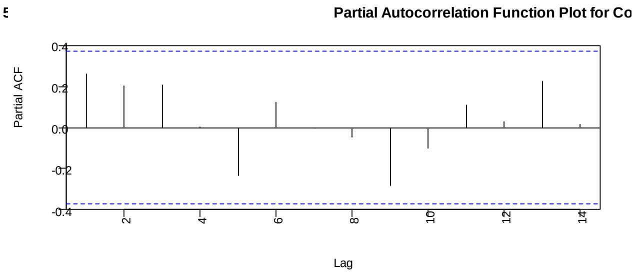

Autocorrelation Function Plot for Corridor 4
ACF
Lag

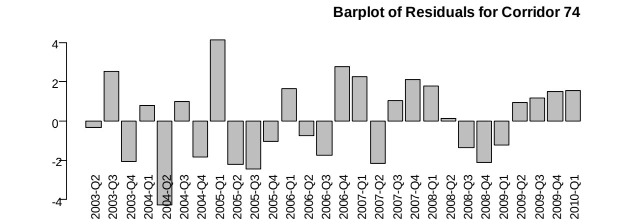

Partial Autocorrelation Function Plot for Co
Partial ACF
Lag

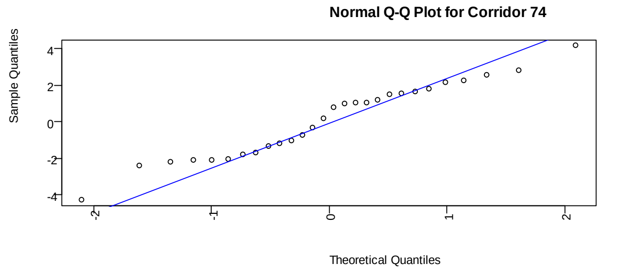

Barplot of Residuals for Corridor 58

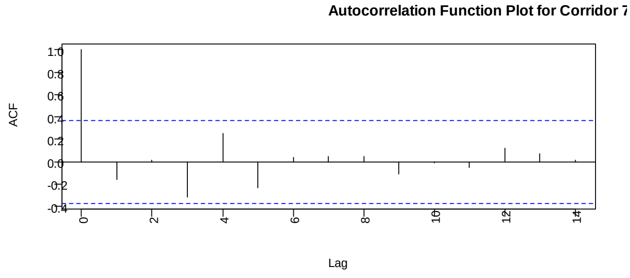

Normal Q-Q Plot for Corridor 58
Sample Quantiles
Theoretical Quantiles

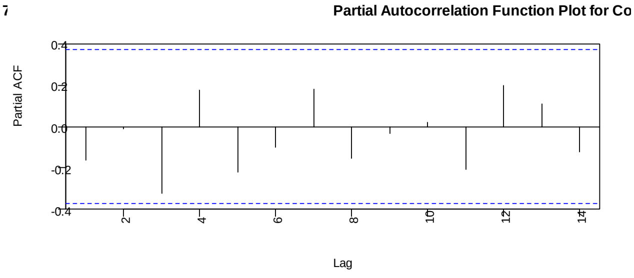

Autocorrelation Function Plot for Corridor 5
ACF
Lag

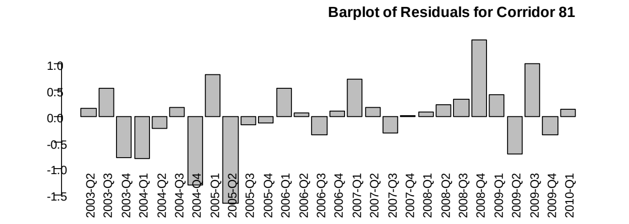

Partial Autocorrelation Function Plot for Co
Partial ACF
Lag

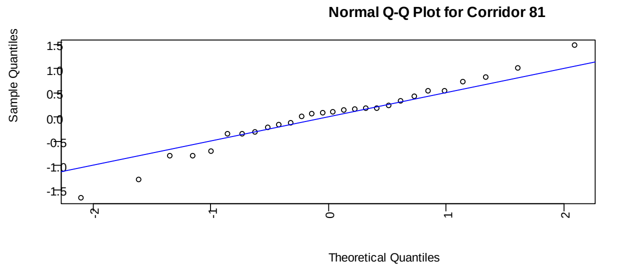

Barplot of Residuals for Corridor 74

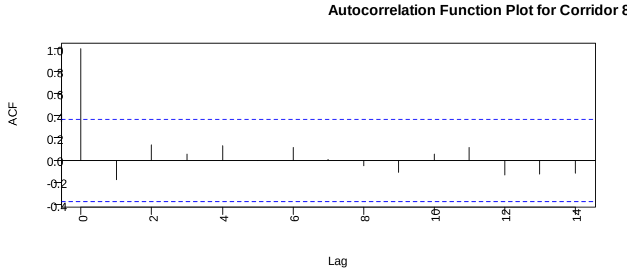

Normal Q-Q Plot for Corridor 74
Sample Quantiles
Theoretical Quantiles

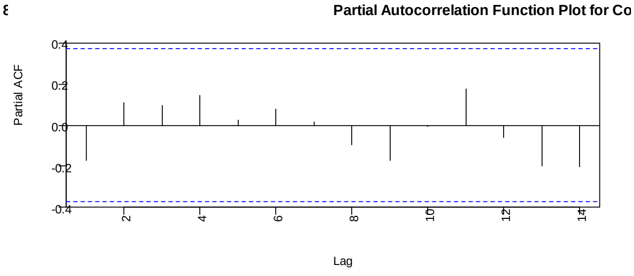

Autocorrelation Function Plot for Corridor 7
ACF
Lag

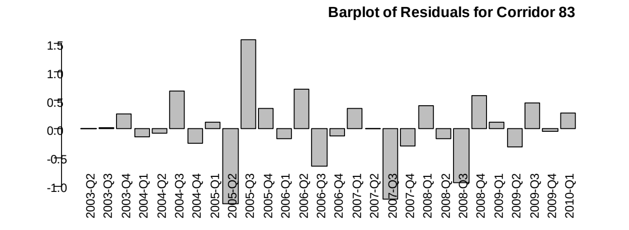

Partial Autocorrelation Function Plot for Co
Partial ACF
Lag

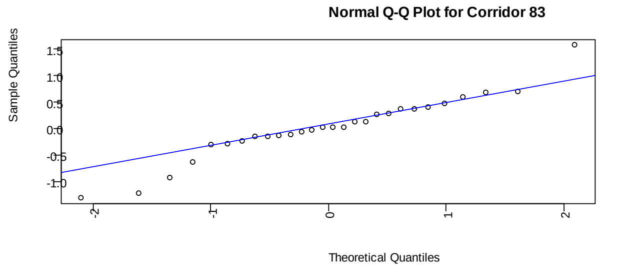

Barplot of Residuals for Corridor 81

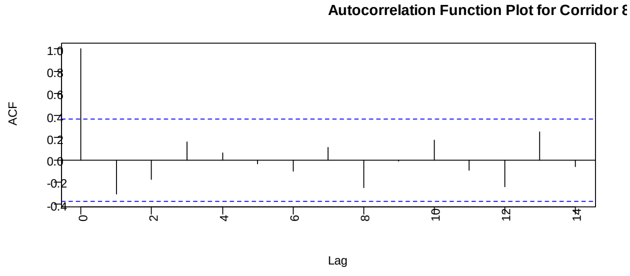

Normal Q-Q Plot for Corridor 81
Sample Quantiles
Theoretical Quantiles

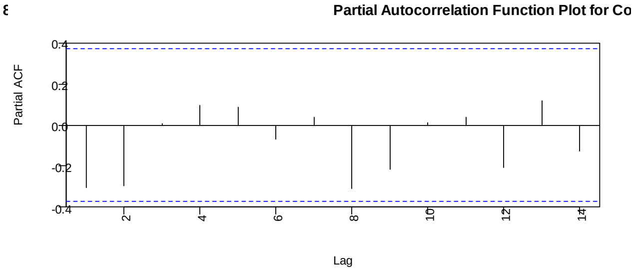

Autocorrelation Function Plot for Corridor 8
ACF
Lag

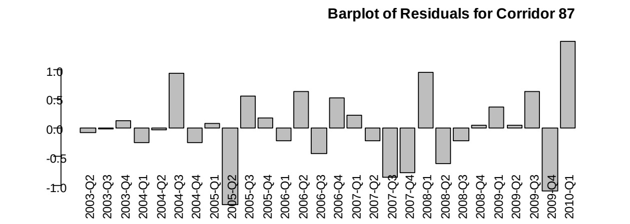

Partial Autocorrelation Function Plot for Co
Partial ACF
Lag

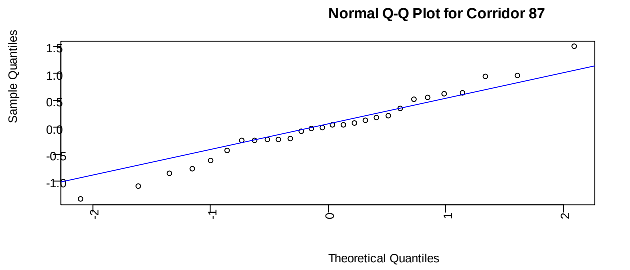

Barplot of Residuals for Corridor 83

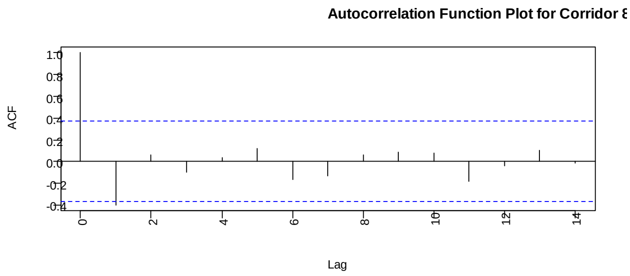

Normal Q-Q Plot for Corridor 83
Sample Quantiles
Theoretical Quantiles

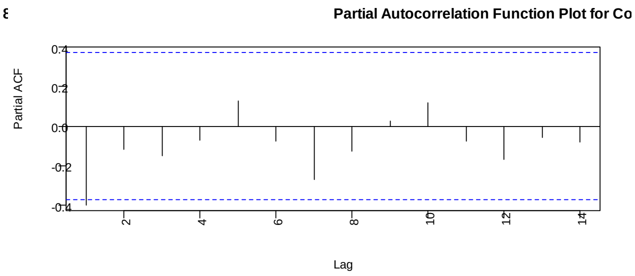

Autocorrelation Function Plot for Corridor 8
ACF
Lag

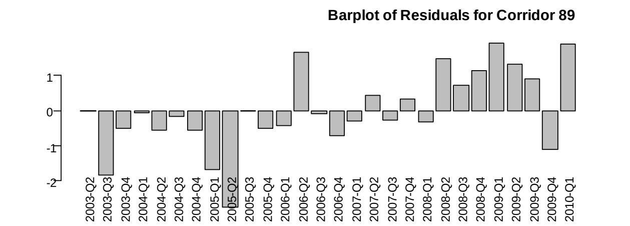

Partial Autocorrelation Function Plot for Co
Partial ACF
Lag

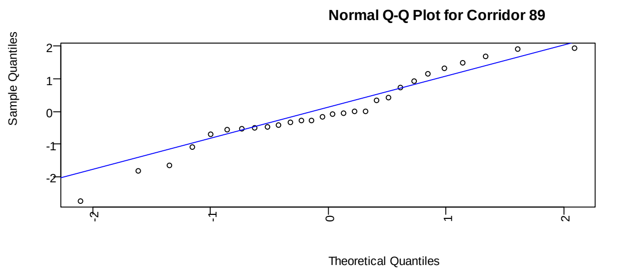

Barplot of Residuals for Corridor 87

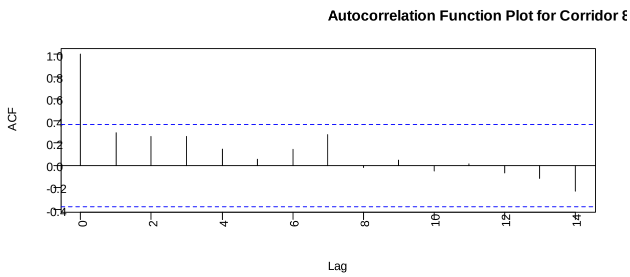

Normal Q-Q Plot for Corridor 87
Sample Quantiles
Theoretical Quantiles

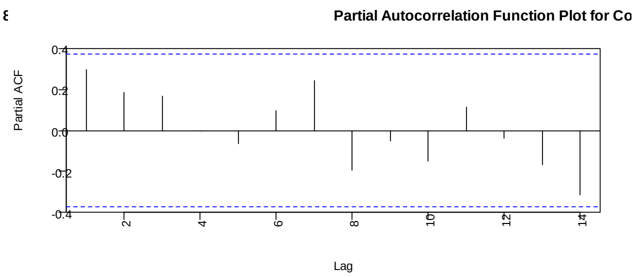

Autocorrelation Function Plot for Corridor 8
ACF
Lag

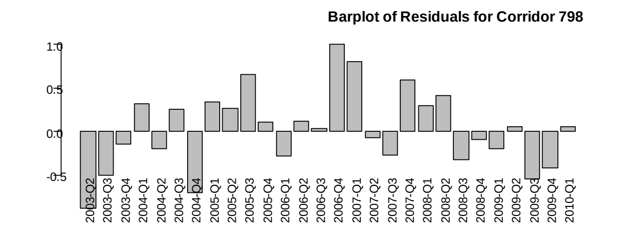

Partial Autocorrelation Function Plot for Co
Partial ACF
Lag

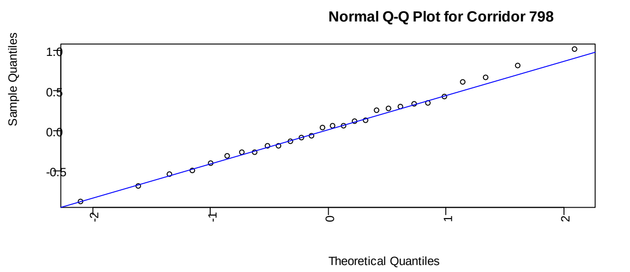

Barplot of Residuals for Corridor 89

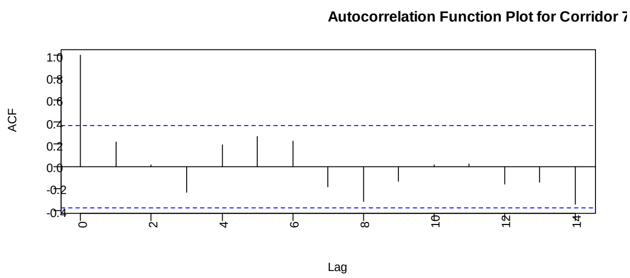

Normal Q-Q Plot for Corridor 89
Sample Quantiles
Theoretical Quantiles

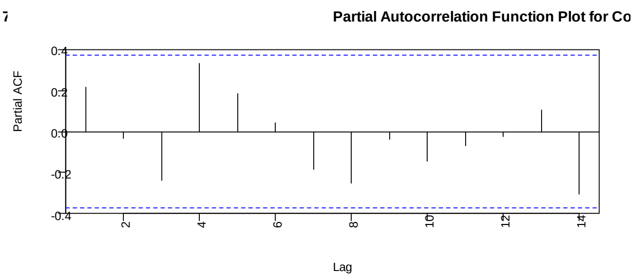

Autocorrelation Function Plot for Corridor 8
ACF
Lag


Partial Autocorrelation Function Plot for Co
Partial ACF
Lag


Barplot of Residuals for Corridor 798


Normal Q-Q Plot for Corridor 798
Sample Quantiles
Theoretical Quantiles


Autocorrelation Function Plot for Corridor 7
ACF
Lag


Partial Autocorrelation Function Plot for Co
Partial ACF
Lag

C6.4 Diagnostic analysis for the evening patronage model

The figures below show diagnostic plots for the residuals from model 3 for evening patronage, as shown in table C.14.

The diagnostic plots show that the residuals for most of the corridors are consistent with the assumption of normality and that autocorrelation is generally low.

Corridors 1, 2, 3 and 4 show negative autocorrelation, particularly at the 4th lag. This could be due to seasonality patterns in the data. The data for this model was transformed using seasonal differencing but this approach may be inadequate at picking up on seasonal patterns that are stochastic, ie they change through time[42]. We regard this as a relatively minor problem for the purposes of this research project, but note that future research could attempt to address this issue via corridor-specific seasonal autoregressive (AR)(1) or seasonal moving average (MA)(1) terms.

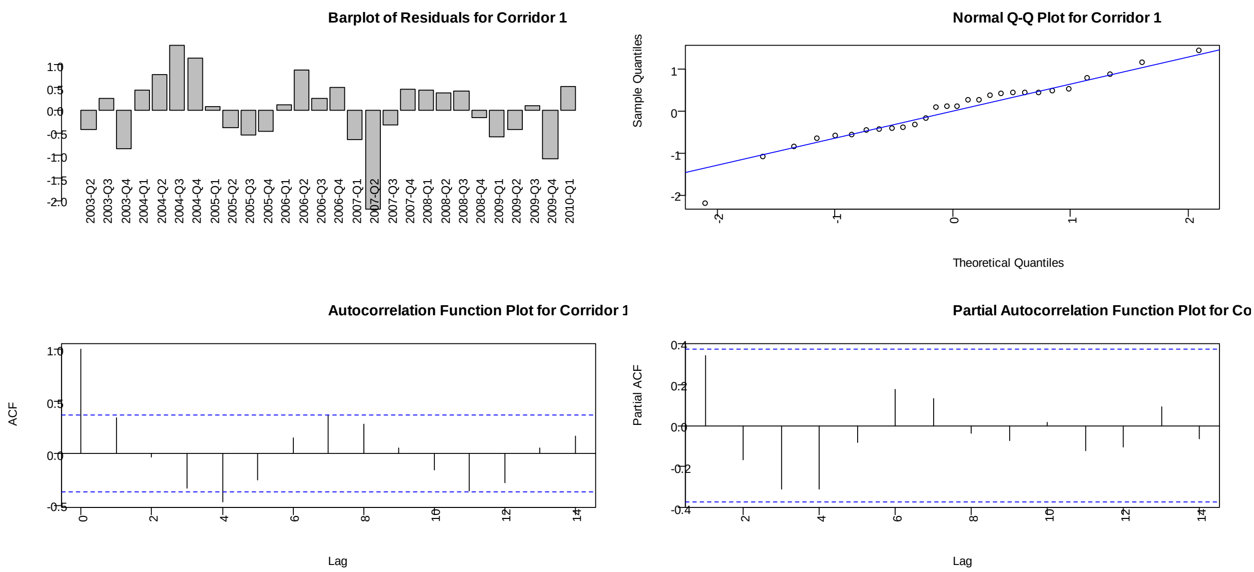
Corridors 12, 14 and 21 show evidence of a 'structural change' around 2007–Q3. The residuals were predominantly negative from this point onwards; this implies that we have omitted some unexplained event or factor which caused a drop-off in growth rates on these bus corridors.

Corridor 39 exhibited an outlier in 2007–Q1, when there was an unexplained jump in patronage. Given that most of the other bus corridors were consistent with normality, a single outlier on one bus corridor is regarded as not serious enough to justify the corridor's exclusion.

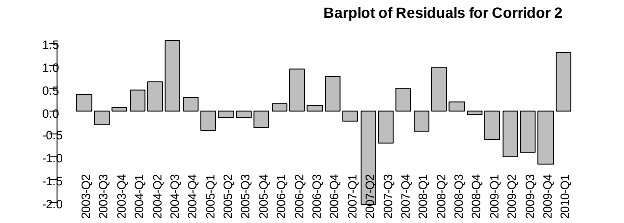
Corridor 83 exhibits a few concerning characteristics. In particular, the barplot of residuals shows 'clusters' of positive and negative residuals (even though this does not show up as autocorrelation in the ACF or PACF plots). However, on balance, we decided to retain corridor 83.

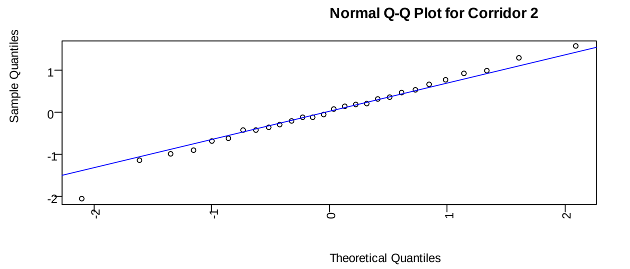
Corridor 89 shows evidence of a 'structural change' around 2008–Q1 onwards. The residuals are predominantly positive from this point onwards; this implies that we have omitted some unexplained event or factor which caused a burst in growth on this bus corridor.

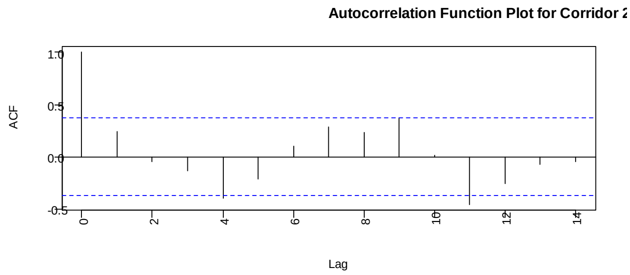
As noted in section C6.1, the deviations observed for bus corridors 14, 21 and 89 were deemed serious enough to be omitted from the preferred model.

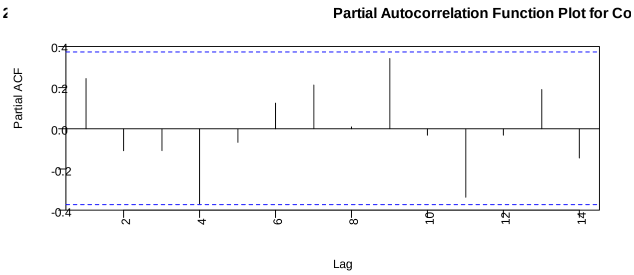


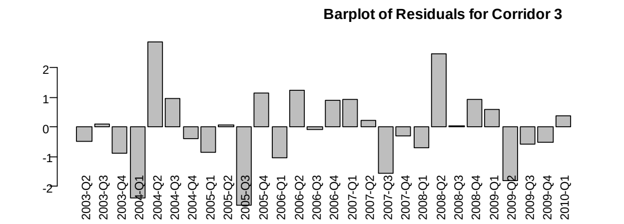
[42] It would seem plausible that seasonality could have a notable influence on evening patronage growth, given that weather and hours of daylight will affect the relative appeal of evening trips.

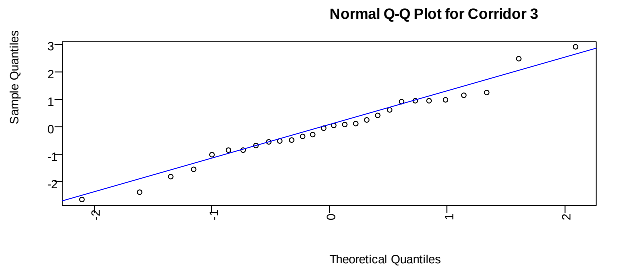

Barplot of Residuals for Corridor 2

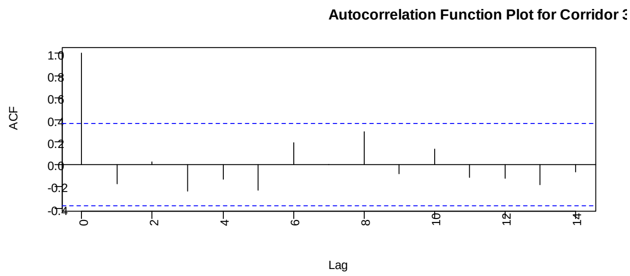

Normal Q-Q Plot for Corridor 2
Sample Quantiles
Theoretical Quantiles

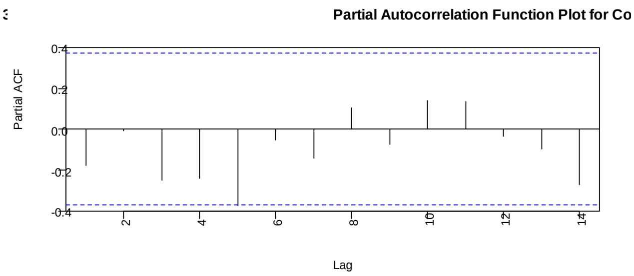

Autocorrelation Function Plot for Corridor
ACF
Lag

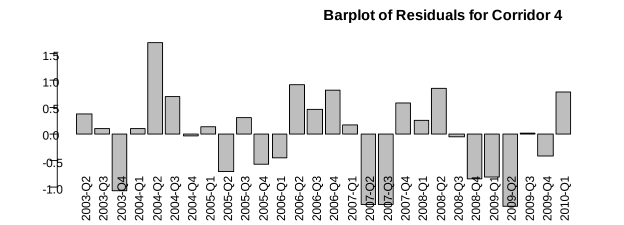

Partial Autocorrelation Function Plot for Co
Partial ACF
Lag

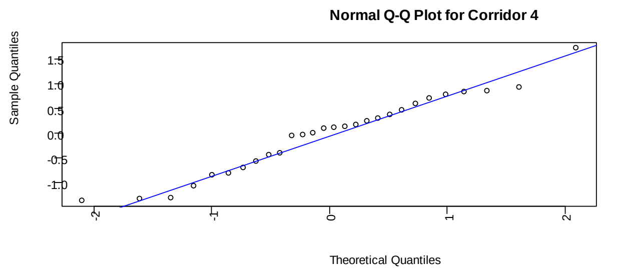

Barplot of Residuals for Corridor 3

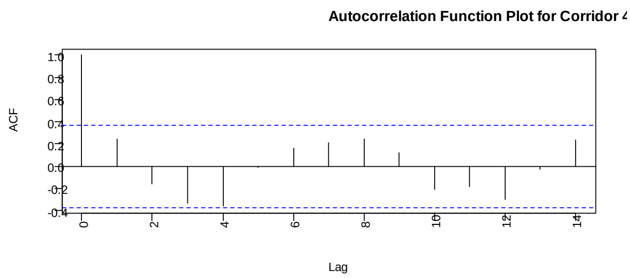

Normal Q-Q Plot for Corridor 3
Sample Quantiles
Theoretical Quantiles

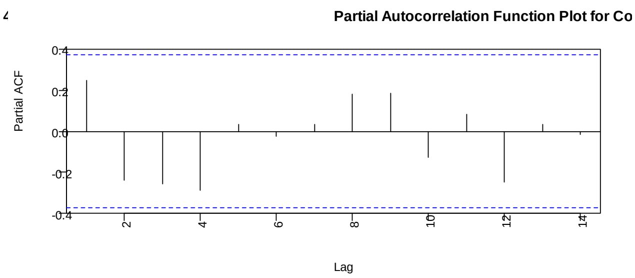

Autocorrelation Function Plot for Corridor
ACF
Lag

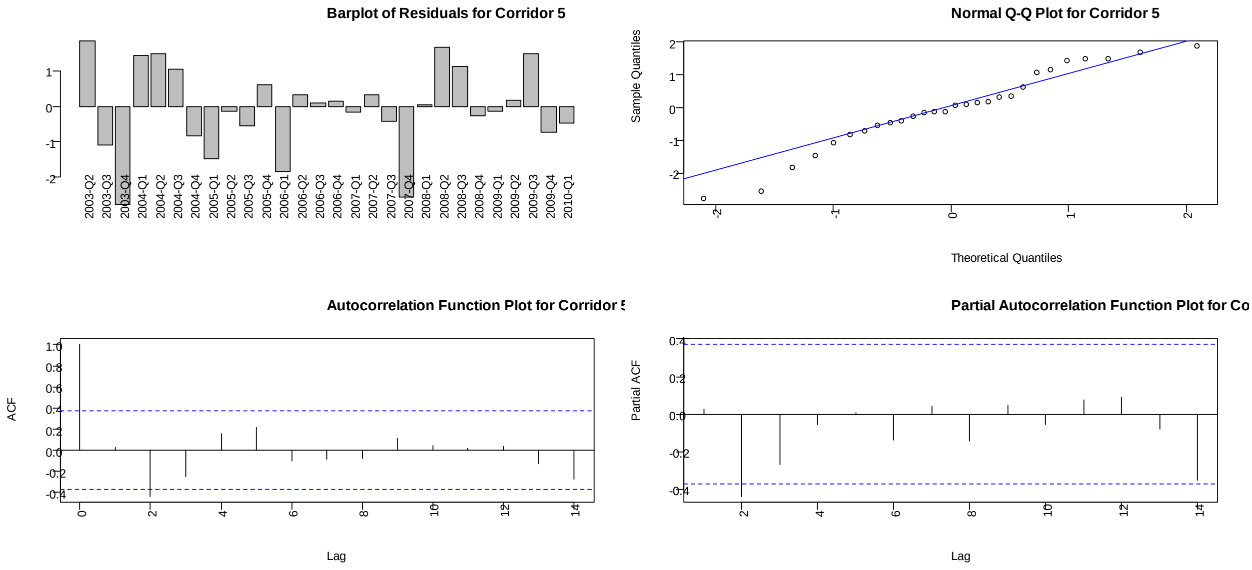

Partial Autocorrelation Function Plot for Co
Partial ACF
Lag

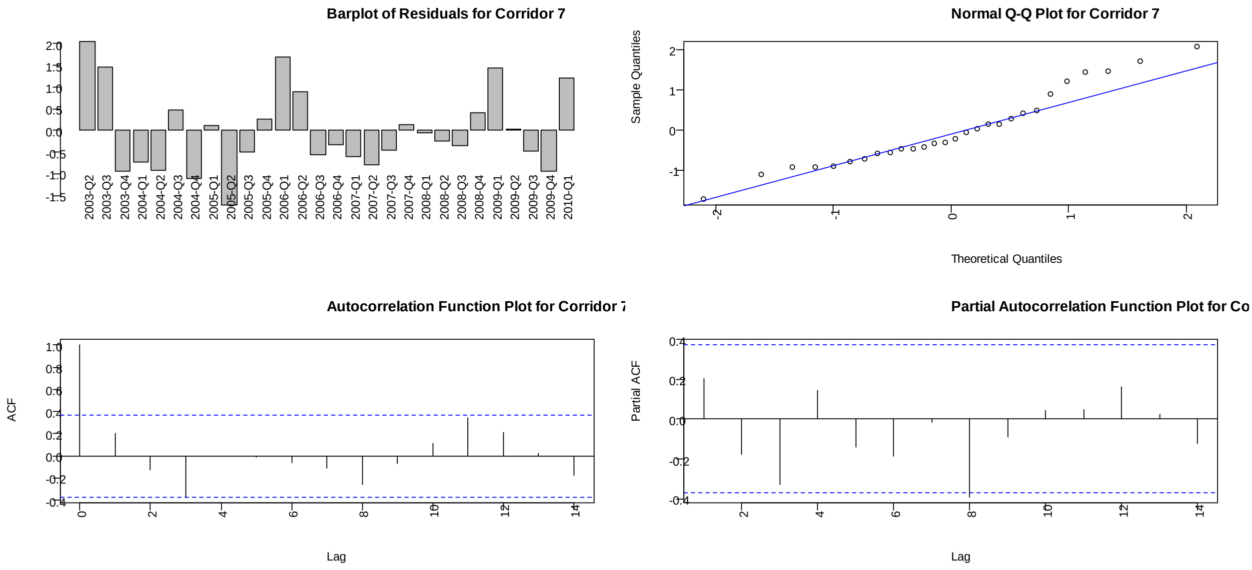

Barplot of Residuals for Corridor 4

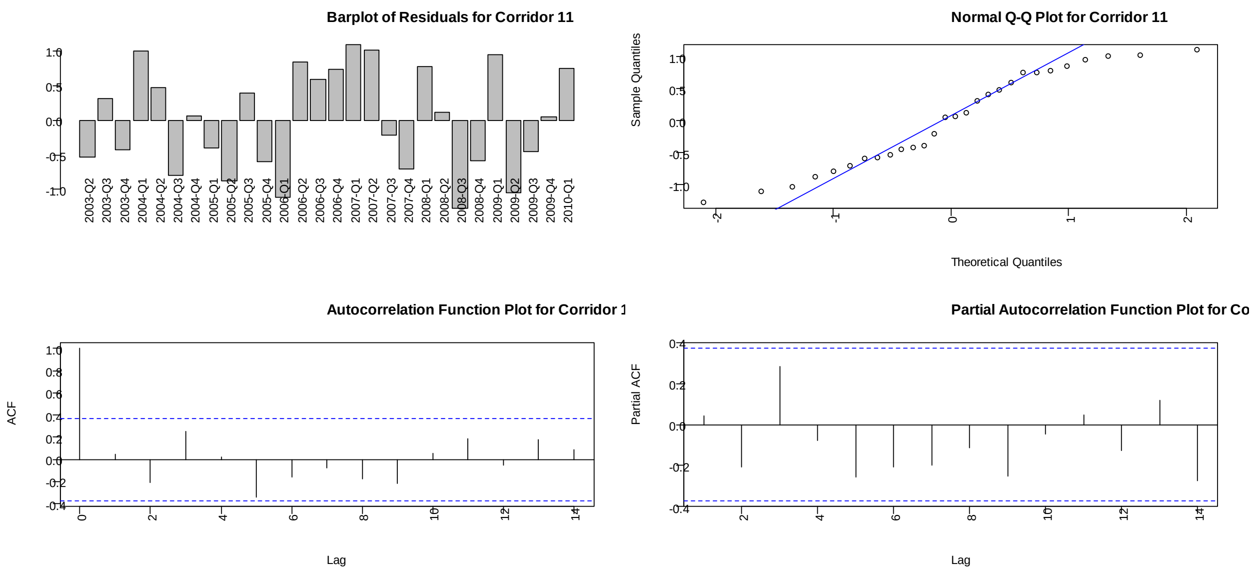

Normal Q-Q Plot for Corridor 4
Sample Quantiles
Theoretical Quantiles


Autocorrelation Function Plot for Corridor
ACF
Lag

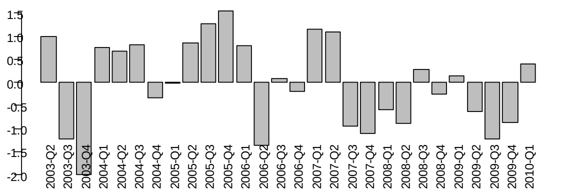

Partial Autocorrelation Function Plot for Co
Partial ACF
Lag


Barplot of Residuals for Corridor 5
Normal Q-Q Plot for Corridor 5
Sample Quantiles
Theoretical Quantiles
Autocorrelation Function Plot for Corridor 5
Partial Autocorrelation Function Plot for Co
ACF
Partial ACF
Lag
Lag

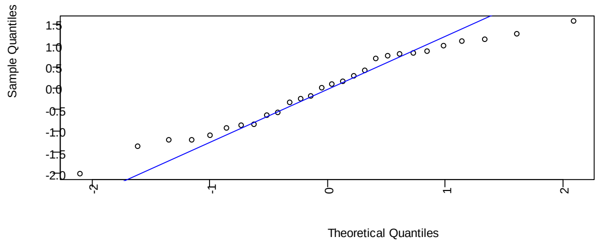

Barplot of Residuals for Corridor 7
Normal Q-Q Plot for Corridor 7
Sample Quantiles
Theoretical Quantiles
Autocorrelation Function Plot for Corridor 7
Partial Autocorrelation Function Plot for Co
ACF
Partial ACF
Lag
Lag


Barplot of Residuals for Corridor 11
Normal Q-Q Plot for Corridor 11
Sample Quantiles
Theoretical Quantiles
Autocorrelation Function Plot for Corridor 1
Partial Autocorrelation Function Plot for Co
ACF
Partial ACF
Lag
Lag

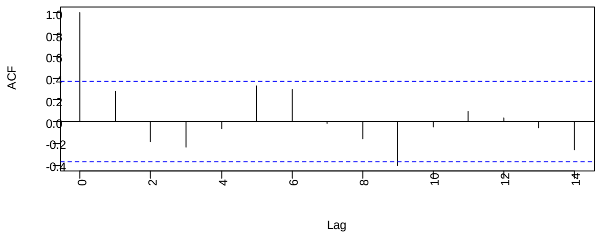
Barplot of Residuals for Corridor 12



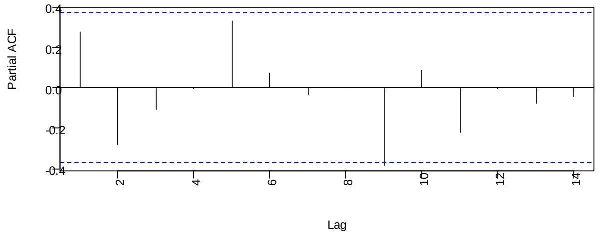
Normal Q-Q Plot for Corridor 12



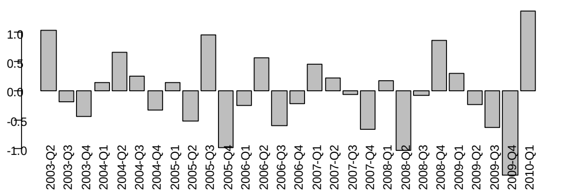
Autocorrelation Function Plot for Corridor 1



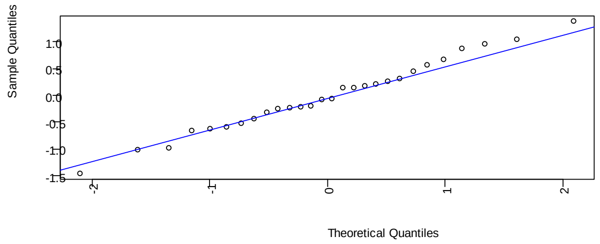
Partial Autocorrelation Function Plot for Co



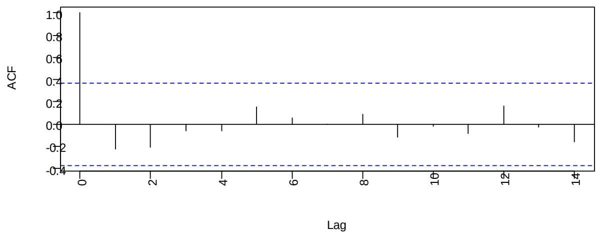
Barplot of Residuals for Corridor 13



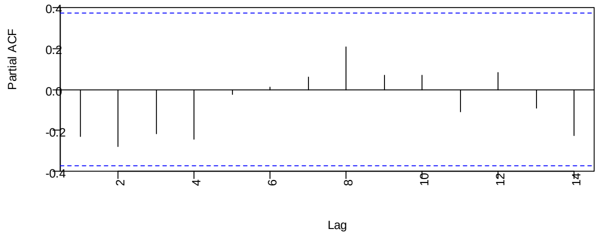
Normal Q-Q Plot for Corridor 13



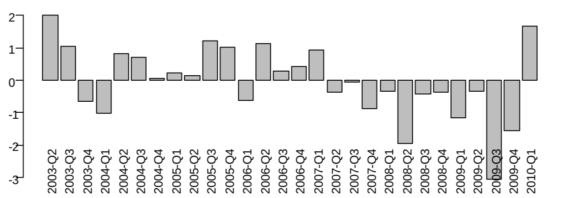
Autocorrelation Function Plot for Corridor 1



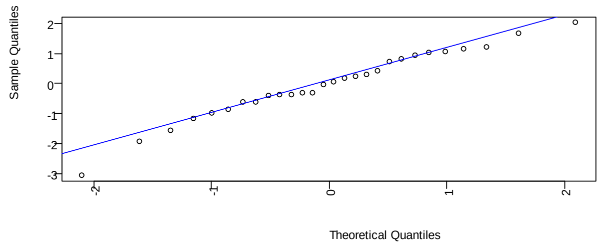
Partial Autocorrelation Function Plot for Co



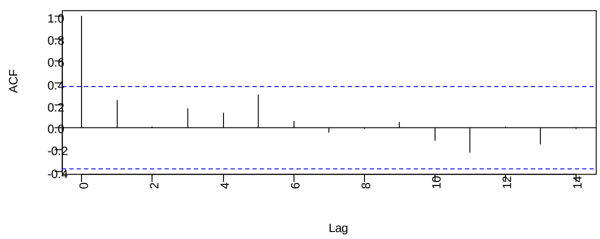
Barplot of Residuals for Corridor 14



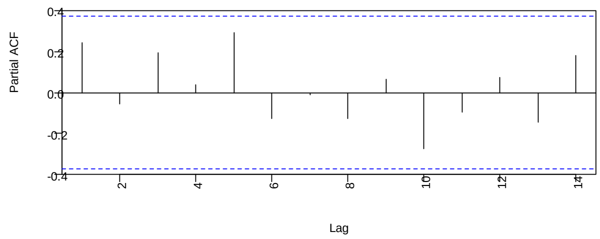
Normal Q-Q Plot for Corridor 14

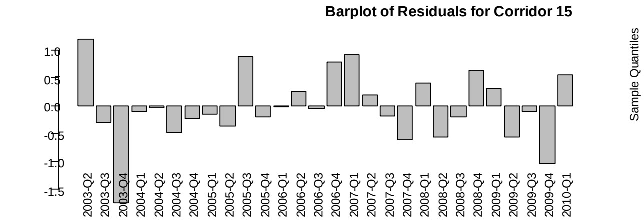


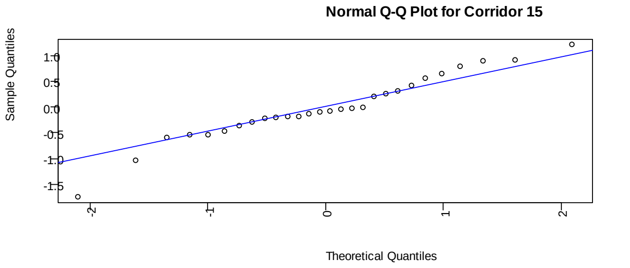
Autocorrelation Function Plot for Corridor 1

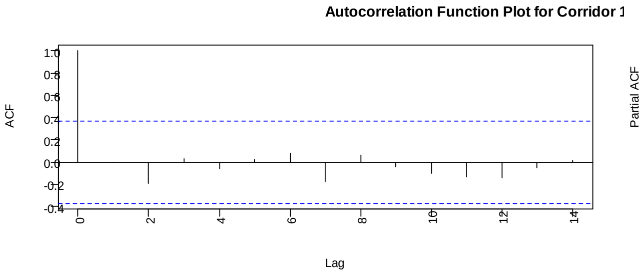


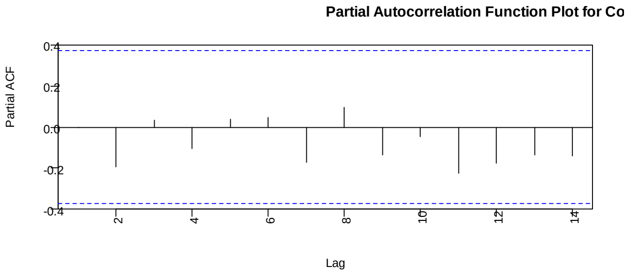
Partial Autocorrelation Function Plot for Co

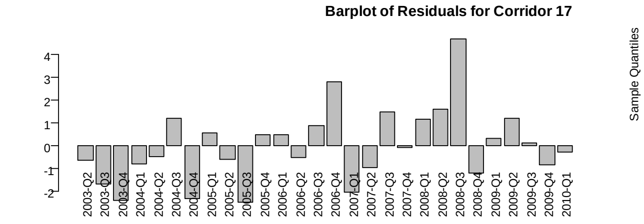


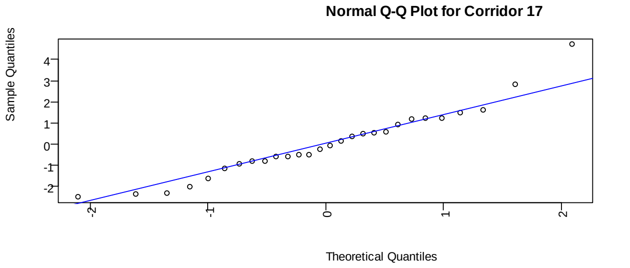

Barplot of Residuals for Corridor 15

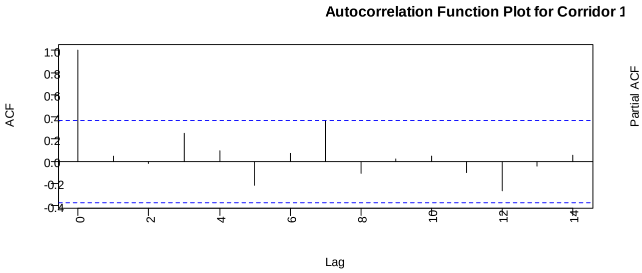

Normal Q-Q Plot for Corridor 15
Sample Quantiles
Theoretical Quantiles

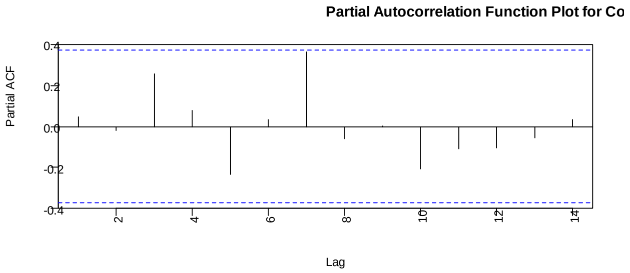

Autocorrelation Function Plot for Corridor 1
ACF
Lag

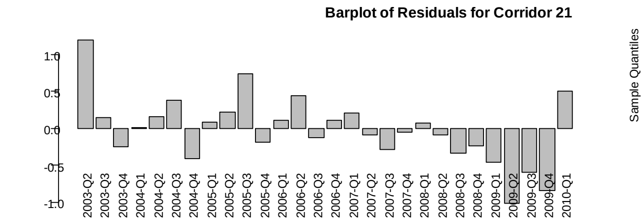

Partial Autocorrelation Function Plot for Co
Partial ACF
Lag

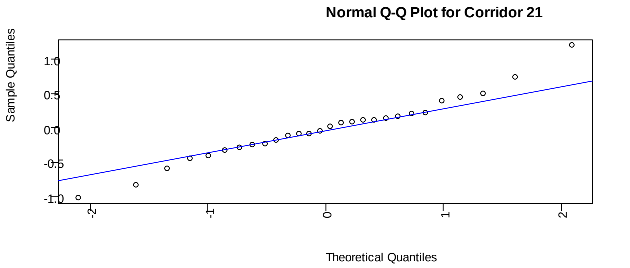

Barplot of Residuals for Corridor 17

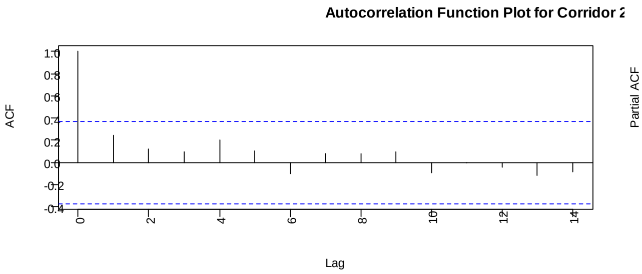

Normal Q-Q Plot for Corridor 17
Sample Quantiles
Theoretical Quantiles

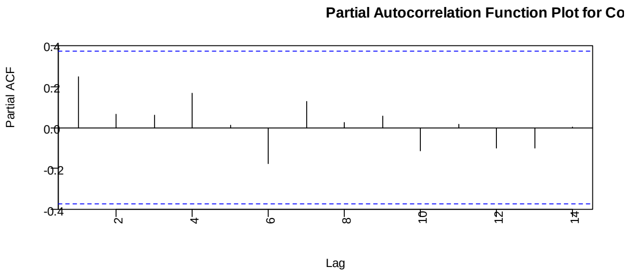

Autocorrelation Function Plot for Corridor 1
ACF
Lag


Partial Autocorrelation Function Plot for Co
Partial ACF
Lag

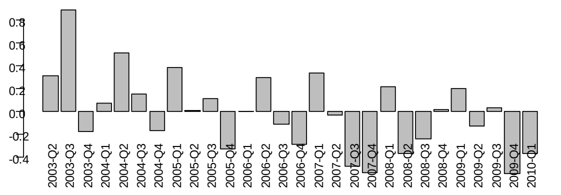

Barplot of Residuals for Corridor 21


Normal Q-Q Plot for Corridor 21
Sample Quantiles
Theoretical Quantiles

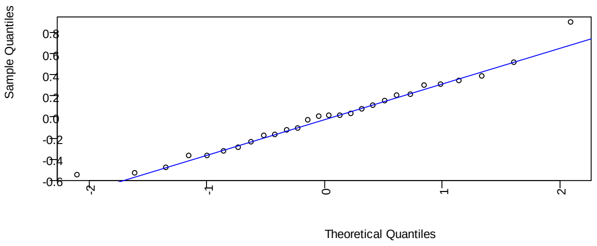

Autocorrelation Function Plot for Corridor 2
ACF
Lag


Partial Autocorrelation Function Plot for Co
Partial ACF
Lag

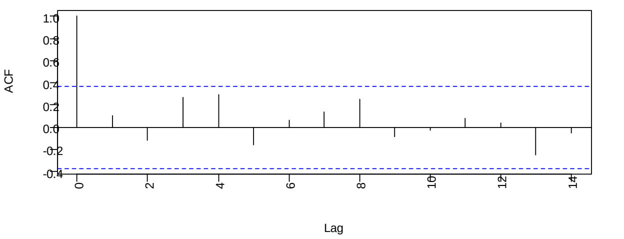
Barplot of Residuals for Corridor 30



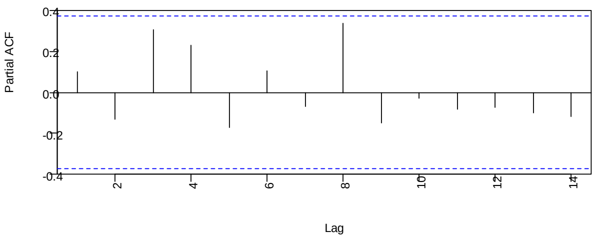
Normal Q-Q Plot for Corridor 30



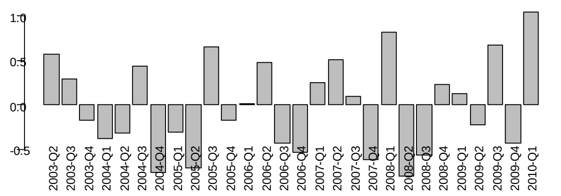
Autocorrelation Function Plot for Corridor 3



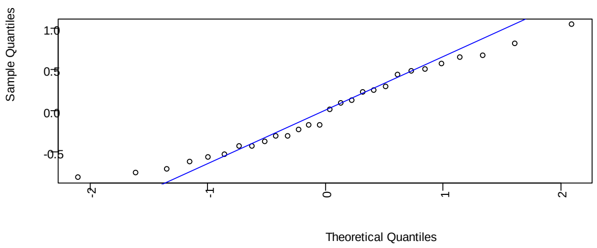
Partial Autocorrelation Function Plot for Co



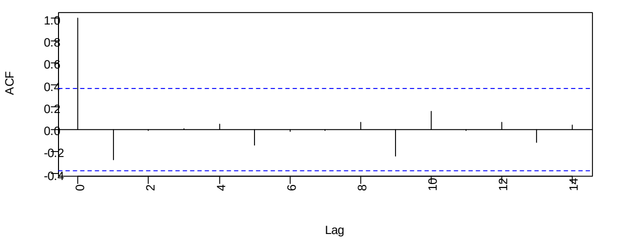
Barplot of Residuals for Corridor 32



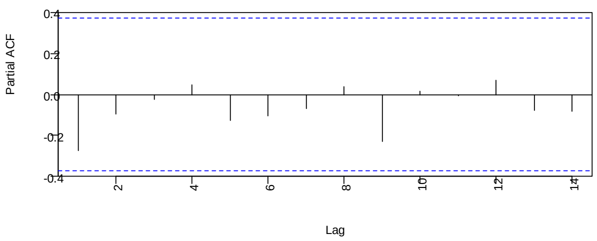
Normal Q-Q Plot for Corridor 32



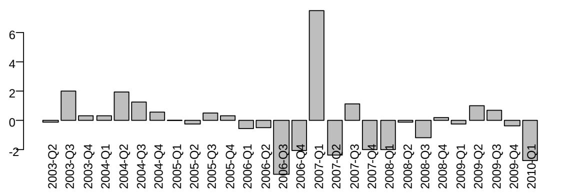
Autocorrelation Function Plot for Corridor 3



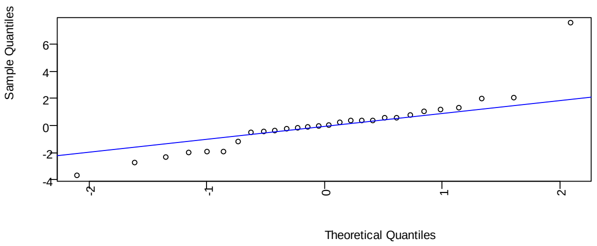
Partial Autocorrelation Function Plot for Co



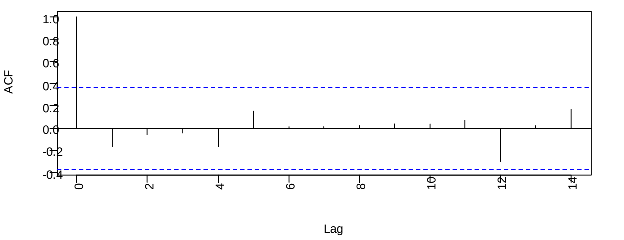
Barplot of Residuals for Corridor 39



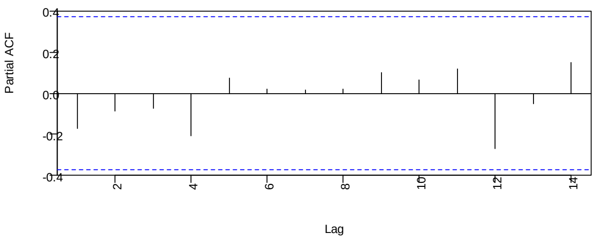
Normal Q-Q Plot for Corridor 39

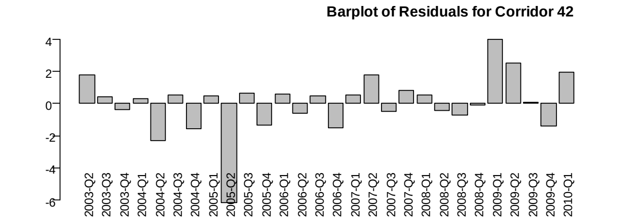


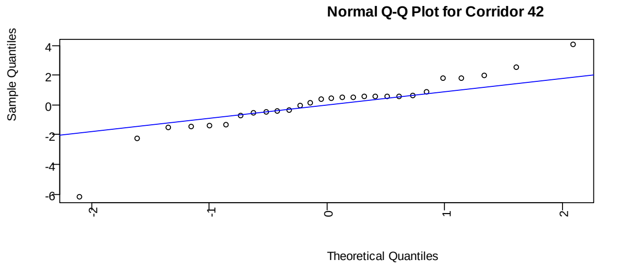
Autocorrelation Function Plot for Corridor 3

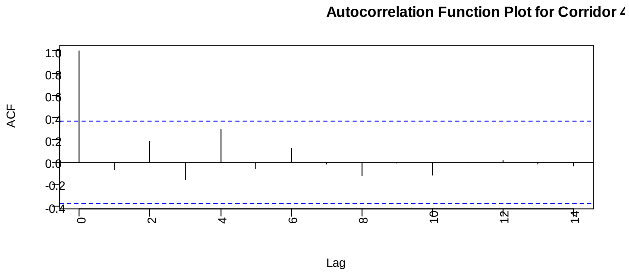


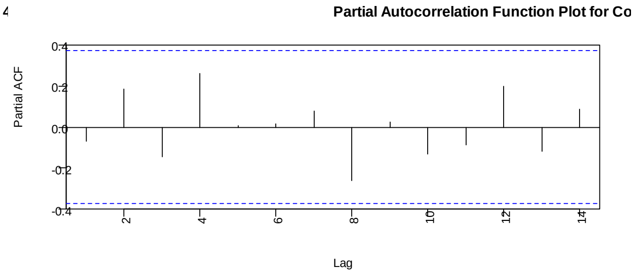
Partial Autocorrelation Function Plot for Co

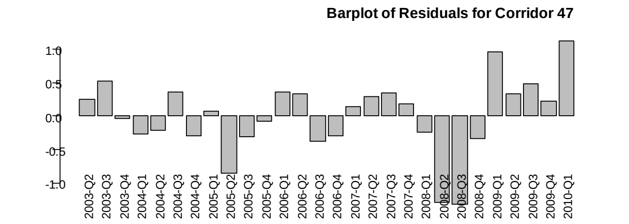


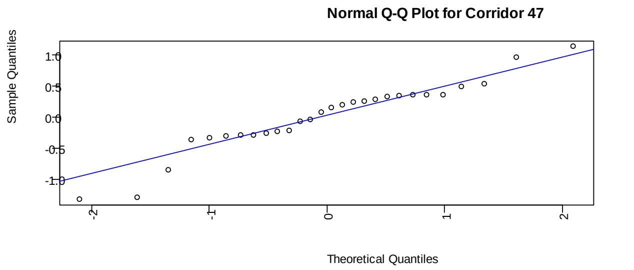

Barplot of Residuals for Corridor 42

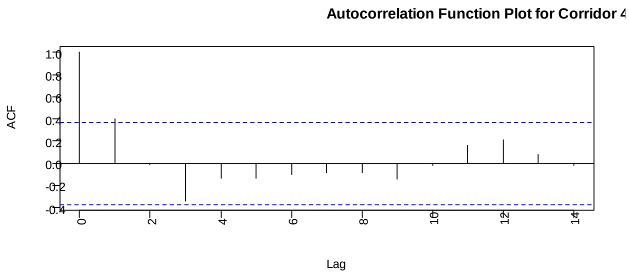

Normal Q-Q Plot for Corridor 42
Sample Quantiles
Theoretical Quantiles

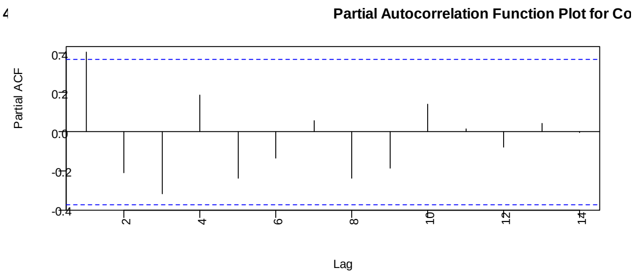

Autocorrelation Function Plot for Corridor 4
ACF
Lag

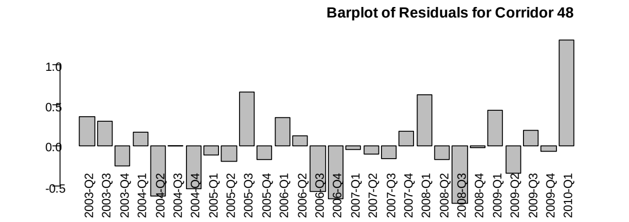

Partial Autocorrelation Function Plot for Co
Partial ACF
Lag

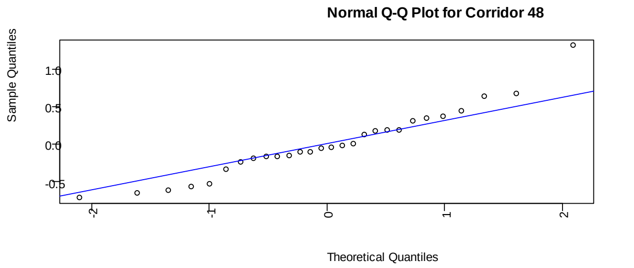

Barplot of Residuals for Corridor 47

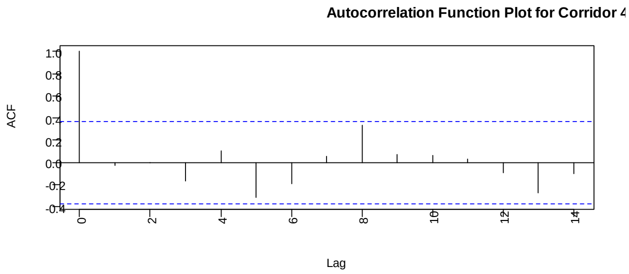

Normal Q-Q Plot for Corridor 47
Sample Quantiles
Theoretical Quantiles

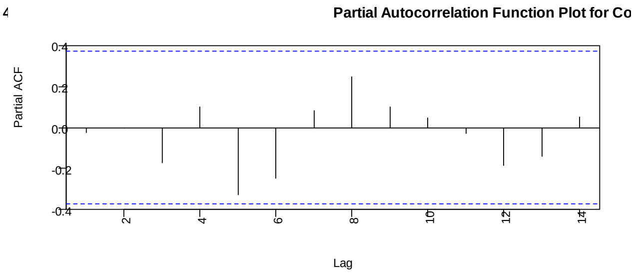

Autocorrelation Function Plot for Corridor 4
ACF
Lag

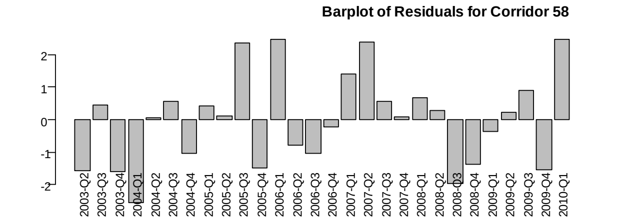

Partial Autocorrelation Function Plot for Co
Partial ACF
Lag

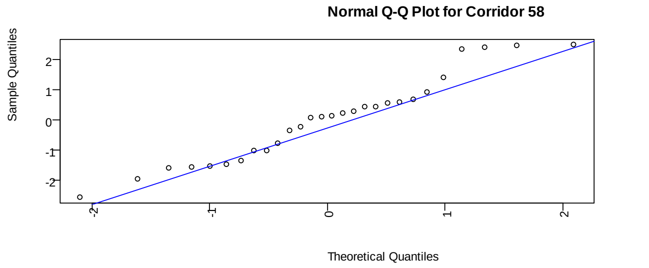

Barplot of Residuals for Corridor 48

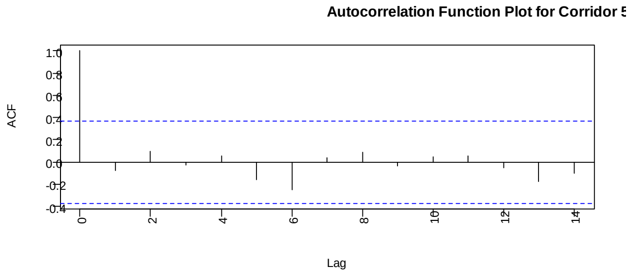

Normal Q-Q Plot for Corridor 48
Sample Quantiles
Theoretical Quantiles

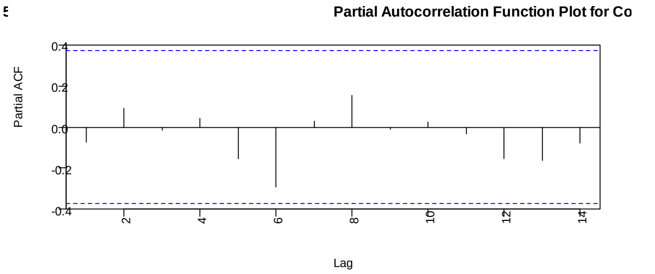

Autocorrelation Function Plot for Corridor 4
ACF
Lag

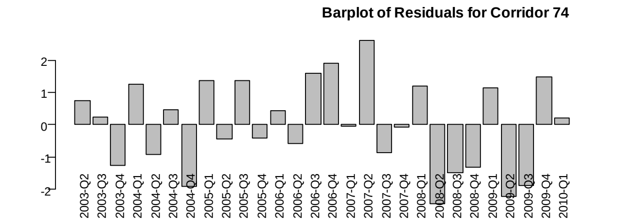

Partial Autocorrelation Function Plot for Co
Partial ACF
Lag

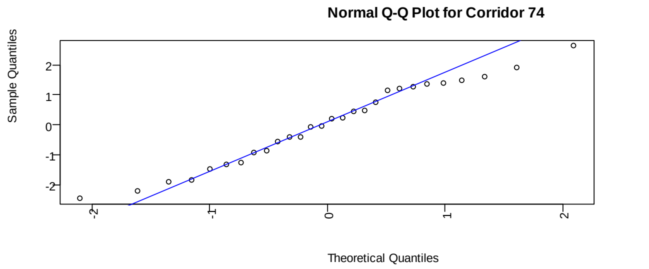

Barplot of Residuals for Corridor 58

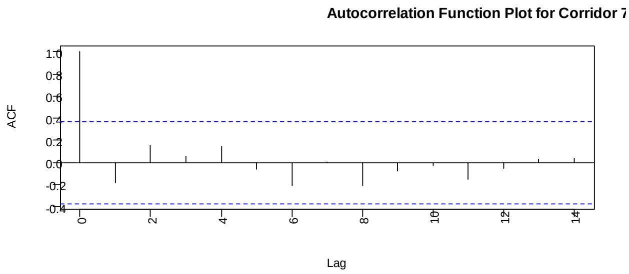

Normal Q-Q Plot for Corridor 58
Sample Quantiles
Theoretical Quantiles

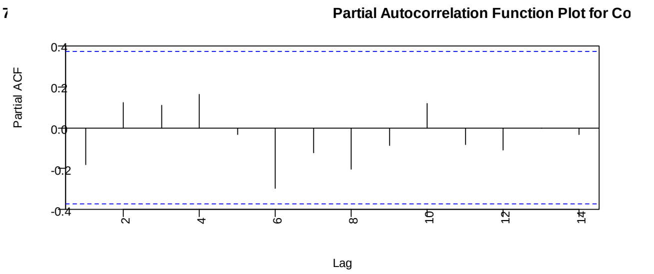

Autocorrelation Function Plot for Corridor 5
ACF
Lag

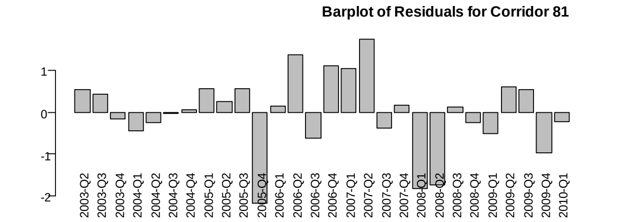

Partial Autocorrelation Function Plot for Co
Partial ACF
Lag

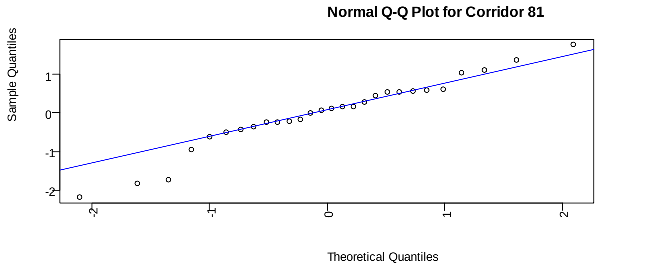

Barplot of Residuals for Corridor 74

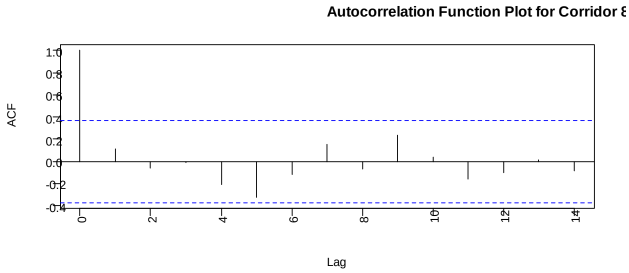

Normal Q-Q Plot for Corridor 74
Sample Quantiles
Theoretical Quantiles

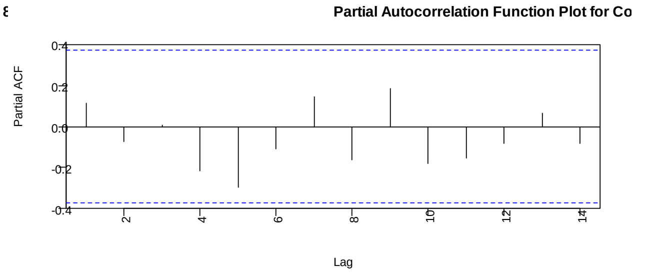

Autocorrelation Function Plot for Corridor 7
ACF
Lag

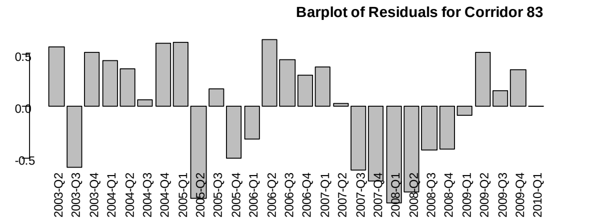

Partial Autocorrelation Function Plot for Co
Partial ACF
Lag

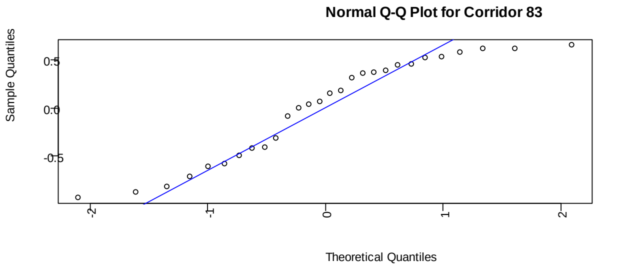

Barplot of Residuals for Corridor 81

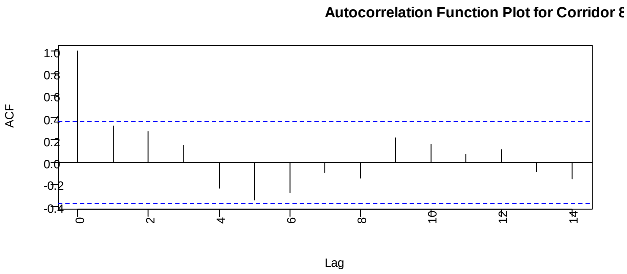

Normal Q-Q Plot for Corridor 81
Sample Quantiles
Theoretical Quantiles

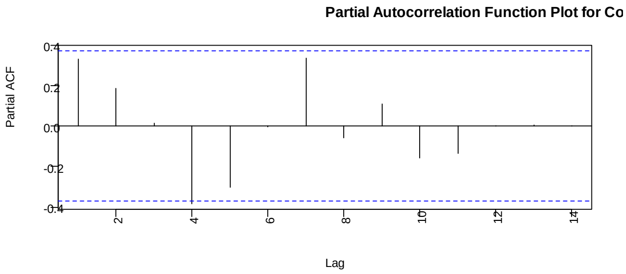

Autocorrelation Function Plot for Corridor 8
ACF
Lag

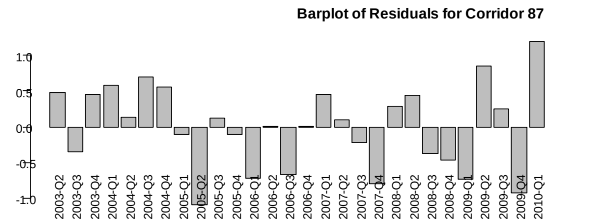

Partial Autocorrelation Function Plot for Co
Partial ACF
Lag

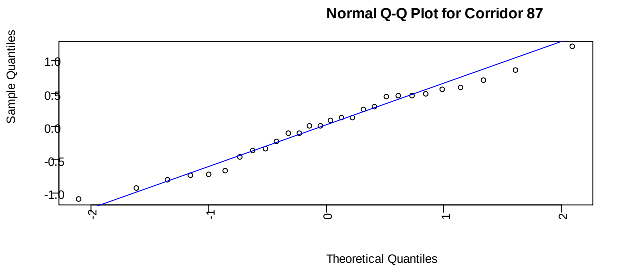

Barplot of Residuals for Corridor 83

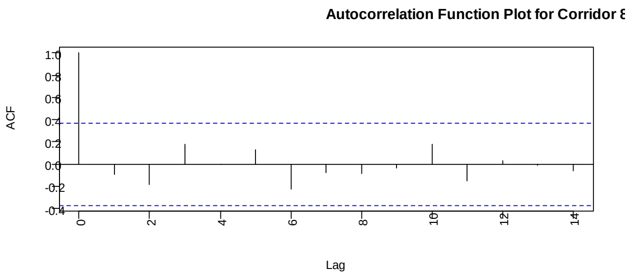

Normal Q-Q Plot for Corridor 83
Sample Quantiles
Theoretical Quantiles

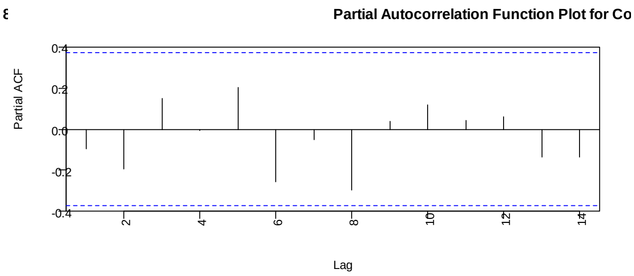

Autocorrelation Function Plot for Corridor 8
ACF
Lag

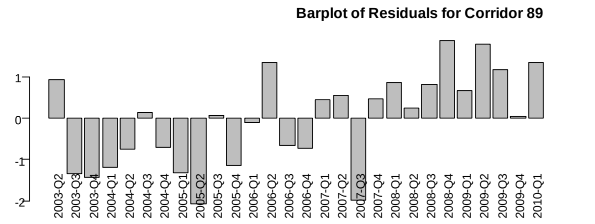

Partial Autocorrelation Function Plot for Co
Partial ACF
Lag

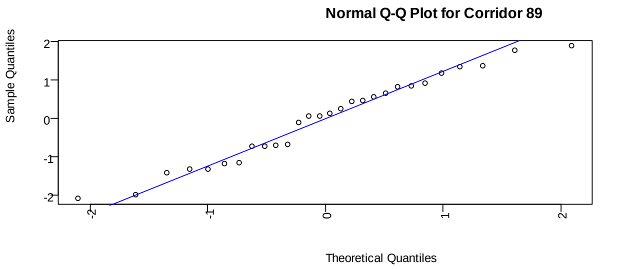

Barplot of Residuals for Corridor 87

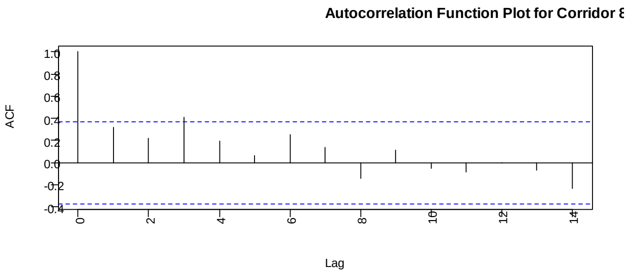

Normal Q-Q Plot for Corridor 87
Sample Quantiles
Theoretical Quantiles

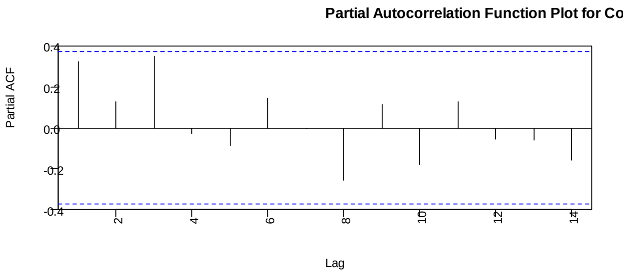

Autocorrelation Function Plot for Corridor 8
ACF
Lag


Partial Autocorrelation Function Plot for Co
Partial ACF
Lag


Barplot of Residuals for Corridor 89


Normal Q-Q Plot for Corridor 89
Sample Quantiles
Theoretical Quantiles


Autocorrelation Function Plot for Corridor 8
ACF
Lag


Partial Autocorrelation Function Plot for Co
Partial ACF
Lag

C6.5 Diagnostic analysis for the weekend patronage model

The figures below show diagnostic plots for the residuals from model 3 for evening patronage, as shown in table C.15.

The diagnostic plots show that the residuals for most of the corridors are consistent with the assumption of normality and autocorrelation is generally low. Corridor 83 shows some non-normality.

As with the diagnostic analysis of evening patronage (see section C6.4) corridors 1, 2, 3 and 4 show negative autocorrelation at the 4th lag. This could be due to seasonality patterns in the data. The data for this model was transformed using seasonal differencing but this approach may be inadequate for picking up on seasonal patterns that are stochastic, ie they change through time[43]. We regard this as a relatively minor problem for the purposes of this research project, but note that future research could attempt to address this issue via corridor-specific seasonal AR(1) or seasonal MA(1) terms.

Corridor 17 shows evidence of a 'structural change' from 2008–Q4 onwards. The residuals are predominantly positive from this point onwards; this implies we have omitted some unexplained event or factor that caused a burst in growth on this bus corridor.

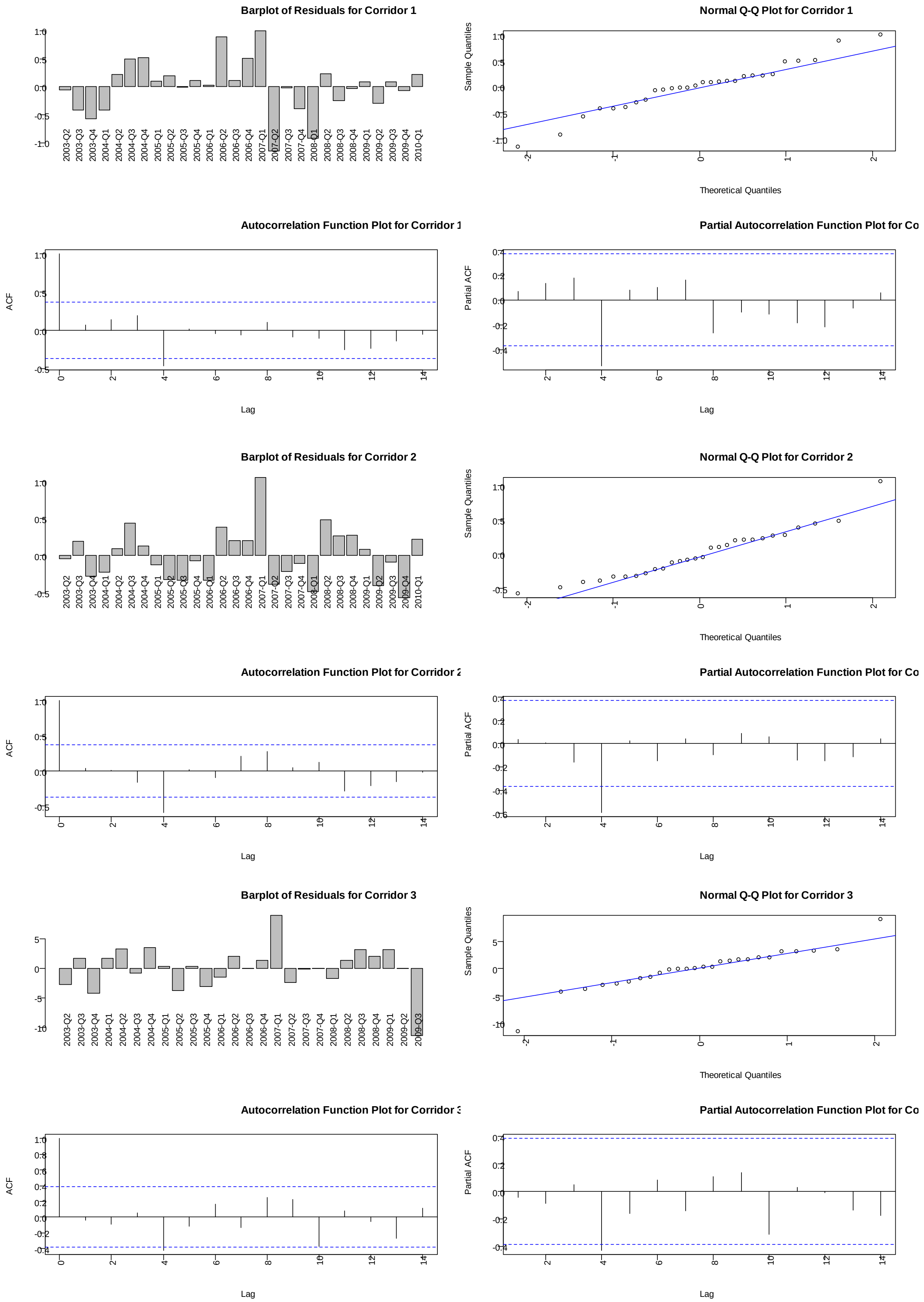
The barplot of residuals for corridor 58 shows 'clusters' of positive and negative residuals. There is also evidence of mild autocorrelation in the ACF or PACF plots.

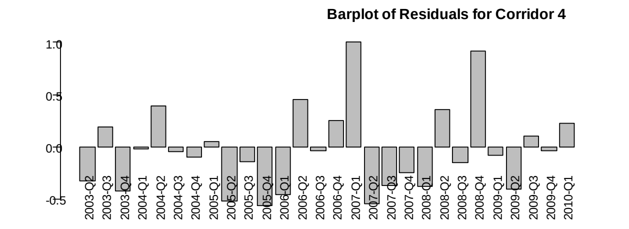
Corridor 89 shows evidence of a 'structural change' around 2008–Q2 onwards. The residuals are predominantly positive from this point onwards; this implies we have omitted some unexplained event or factor that caused a burst in growth on this bus corridor.

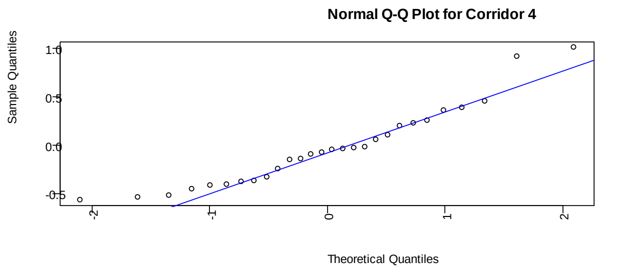
The barplot of residuals for corridor 798 shows 'clusters' of positive and negative residuals. There is also evidence of mild autocorrelation in the ACF or PACF plots.

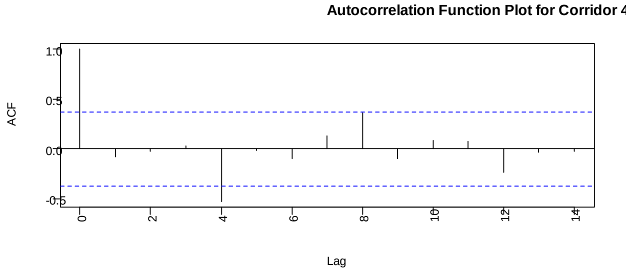
As noted in section C6.1, the deviations observed for bus corridor 89 were deemed serious enough for it to be omitted from the preferred model (along with bus corridors 14 and 21). We decided in favour of retaining bus corridors 17, 58 and 798 for the weekend model despite the anomalous patterns observed above; however, any findings for the weekend model have to be regarded with some caution because the weekend data seems less predictable than the weekday data.

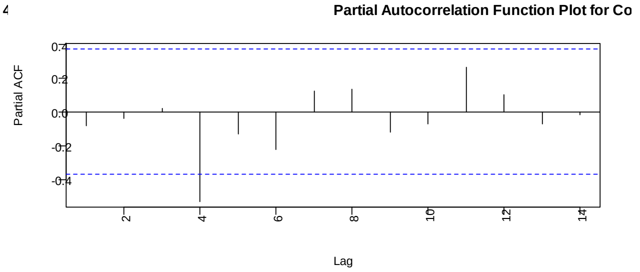
[43] It would seem plausible that seasonality could have a notable influence on weekend patronage growth, given that weather and hours of daylight will affect the relative appeal of weekend trips.

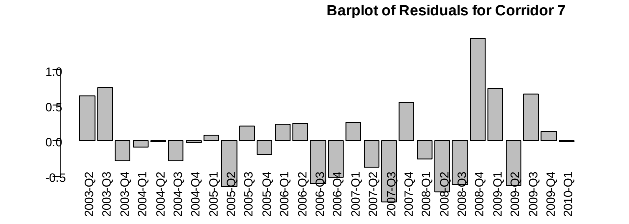

Barplot of Residuals for Corridor 1
Normal Q-Q Plot for Corridor 1
Sample Quantiles
Theoretical Quantiles
Autocorrelation Function Plot for Corridor 1
ACF
Lag
Partial Autocorrelation Function Plot for Co
Partial ACF
Lag
Barplot of Residuals for Corridor 2
Normal Q-Q Plot for Corridor 2
Sample Quantiles
Theoretical Quantiles
Autocorrelation Function Plot for Corridor 2
ACF
Lag
Partial Autocorrelation Function Plot for Co
Partial ACF
Lag
Barplot of Residuals for Corridor 3
Normal Q-Q Plot for Corridor 3
Sample Quantiles
Theoretical Quantiles
Autocorrelation Function Plot for Corridor 3
ACF
Lag
Partial Autocorrelation Function Plot for Co
Partial ACF
Lag

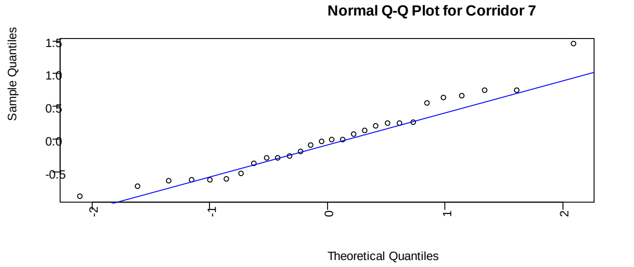

Barplot of Residuals for Corridor 4

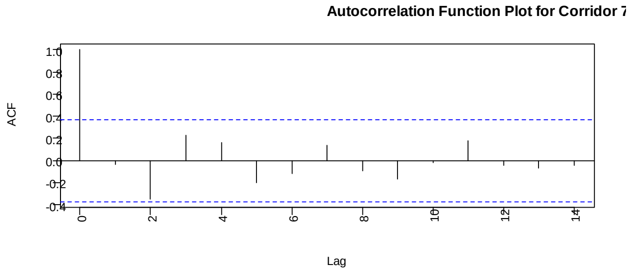

Normal Q-Q Plot for Corridor 4
Sample Quantiles
Theoretical Quantiles

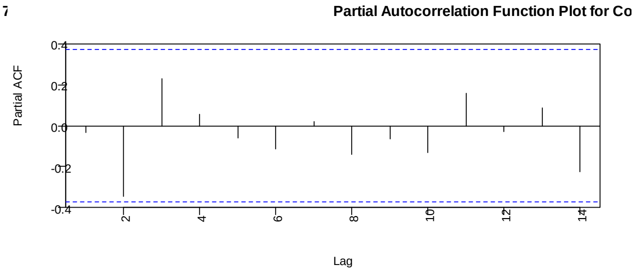

Autocorrelation Function Plot for Corridor 4
ACF
Lag

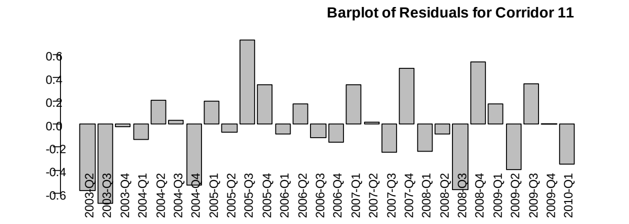

Partial Autocorrelation Function Plot for Co
Partial ACF
Lag

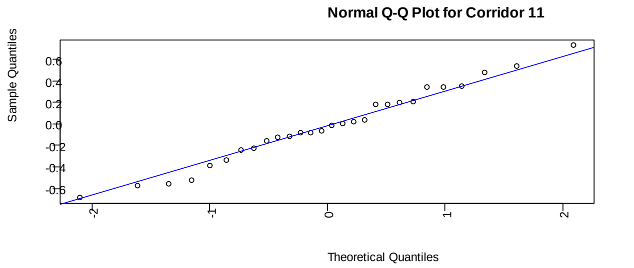

Barplot of Residuals for Corridor 7

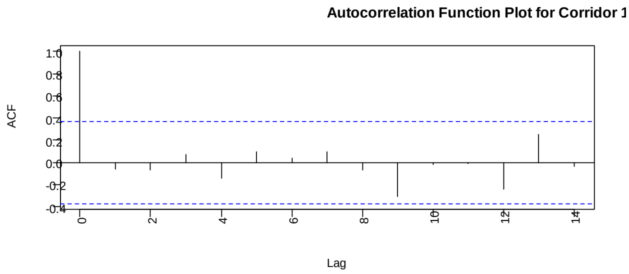

Normal Q-Q Plot for Corridor 7
Sample Quantiles
Theoretical Quantiles

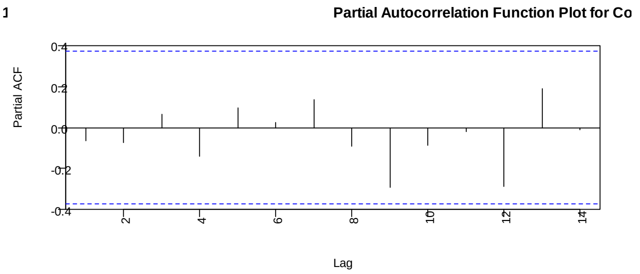

Autocorrelation Function Plot for Corridor 7
ACF
Lag

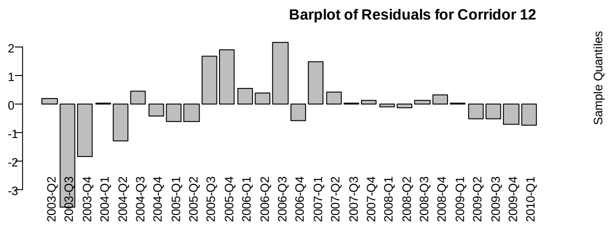

Partial Autocorrelation Function Plot for Co
Partial ACF
Lag

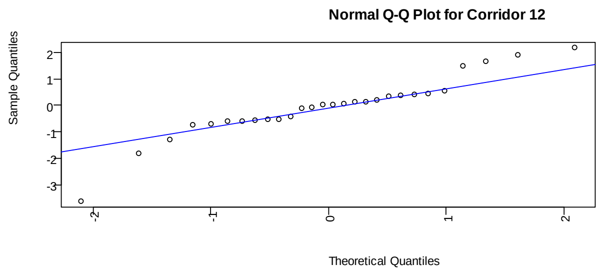

Barplot of Residuals for Corridor 11

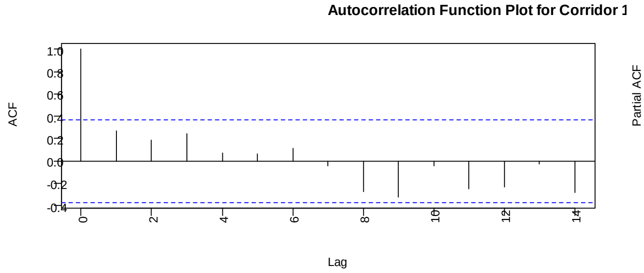

Normal Q-Q Plot for Corridor 11
Sample Quantiles
Theoretical Quantiles

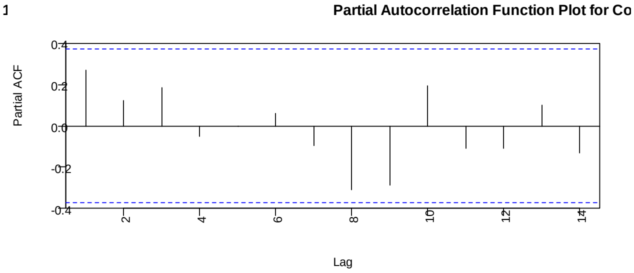

Autocorrelation Function Plot for Corridor 1
ACF
Lag

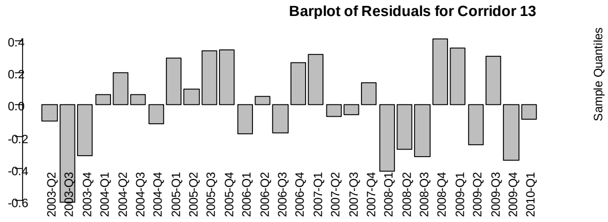

Partial Autocorrelation Function Plot for Co
Partial ACF
Lag

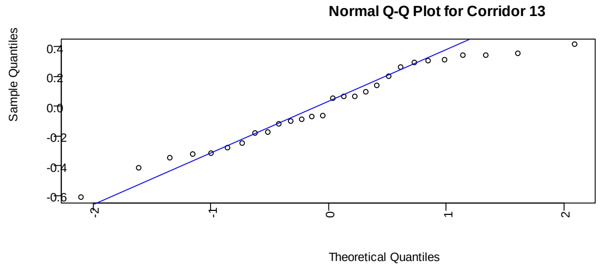

Barplot of Residuals for Corridor 12

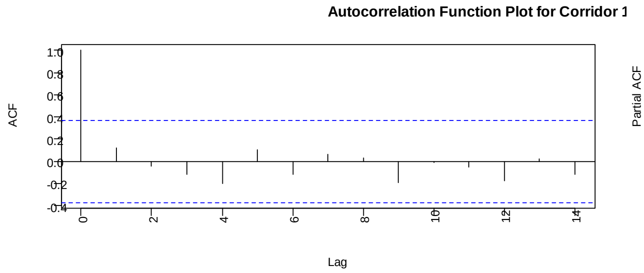

Normal Q-Q Plot for Corridor 12
Sample Quantiles
Theoretical Quantiles

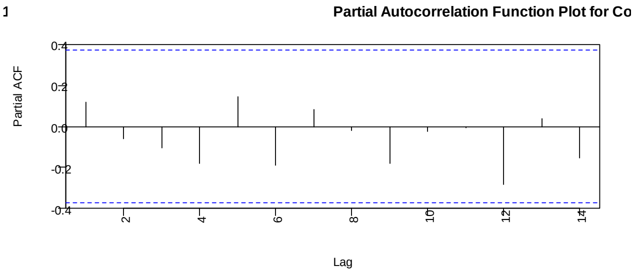

Autocorrelation Function Plot for Corridor 1
ACF
Lag

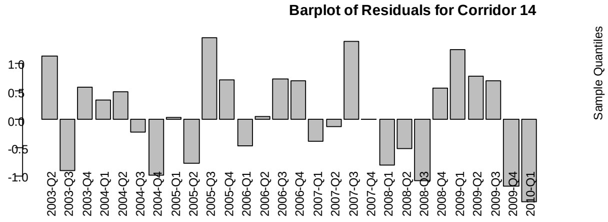

Partial Autocorrelation Function Plot for Co
Partial ACF
Lag

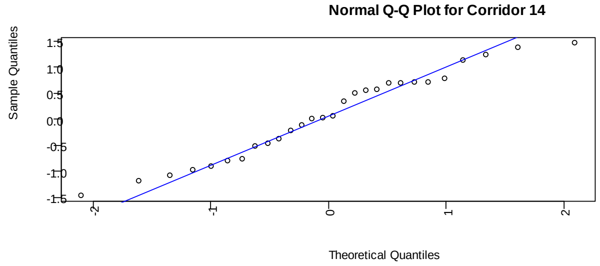

Barplot of Residuals for Corridor 13

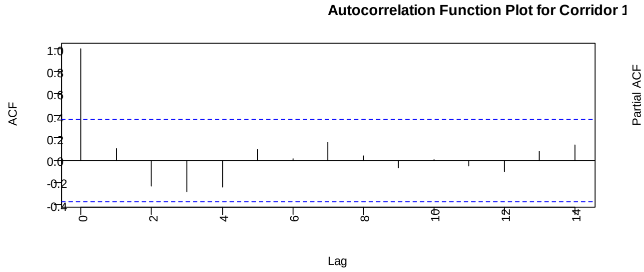

Normal Q-Q Plot for Corridor 13
Sample Quantiles
Theoretical Quantiles

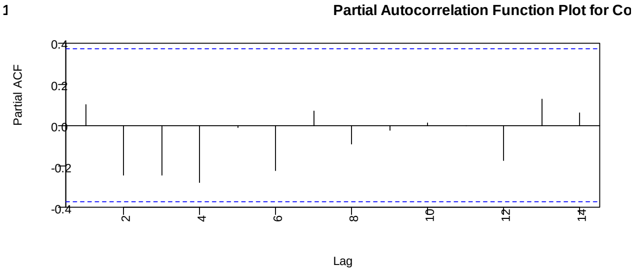

Autocorrelation Function Plot for Corridor 1
ACF
Lag

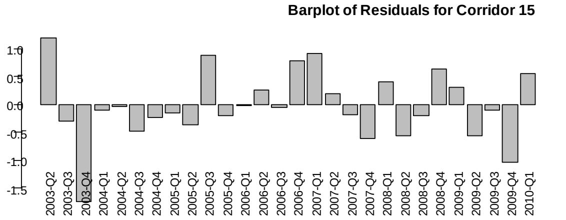

Partial Autocorrelation Function Plot for Co
Partial ACF
Lag

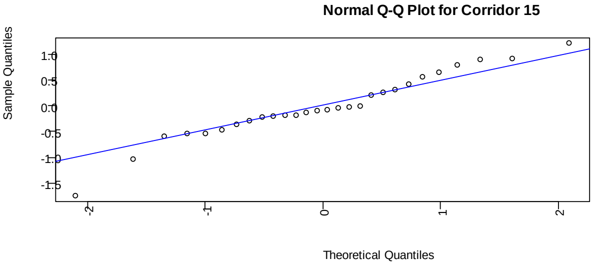

Barplot of Residuals for Corridor 14

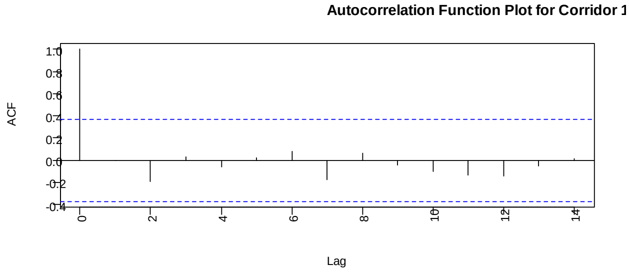

Normal Q-Q Plot for Corridor 14
Sample Quantiles
Theoretical Quantiles

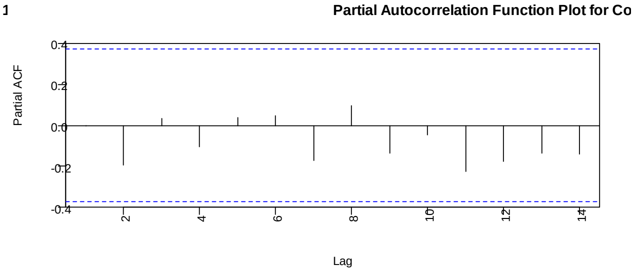

Autocorrelation Function Plot for Corridor 1
ACF
Lag

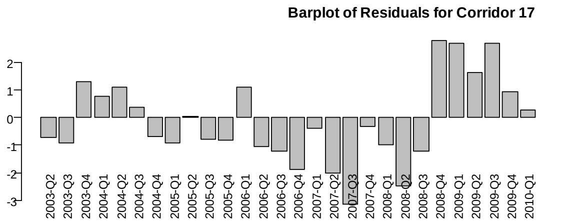

Partial Autocorrelation Function Plot for Co
Partial ACF
Lag

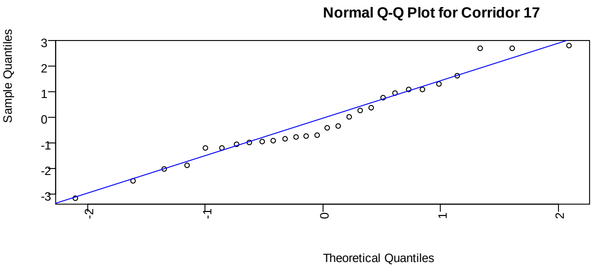

Barplot of Residuals for Corridor 15

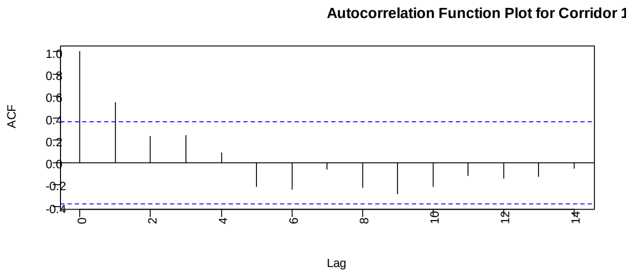

Normal Q-Q Plot for Corridor 15
Sample Quantiles
Theoretical Quantiles

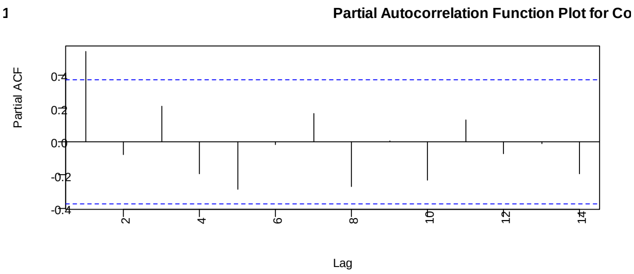

Autocorrelation Function Plot for Corridor 1
ACF
Lag

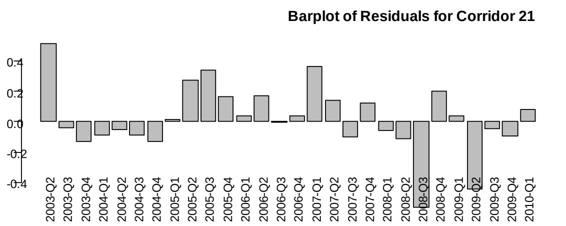

Partial Autocorrelation Function Plot for Co
Partial ACF
Lag

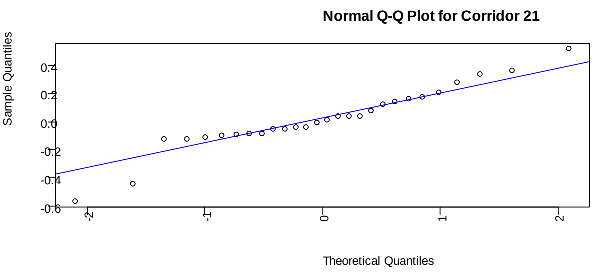

Barplot of Residuals for Corridor 17

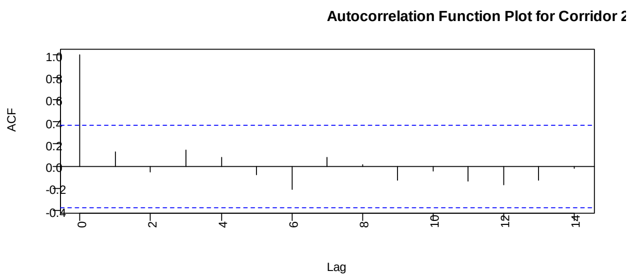

Normal Q-Q Plot for Corridor 17
Sample Quantiles
Theoretical Quantiles

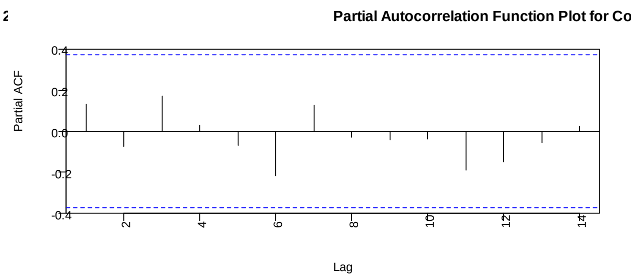

Autocorrelation Function Plot for Corridor 1
ACF
Lag


Partial Autocorrelation Function Plot for Co
Partial ACF
Lag

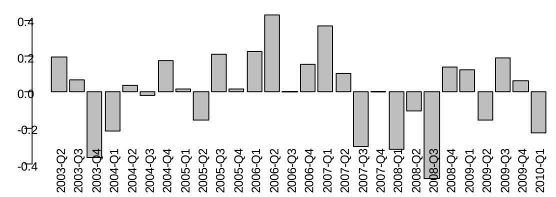

Barplot of Residuals for Corridor 21


Normal Q-Q Plot for Corridor 21
Sample Quantiles
Theoretical Quantiles

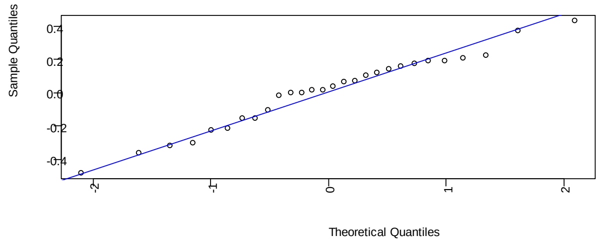

Autocorrelation Function Plot for Corridor 2
ACF
Lag


Partial Autocorrelation Function Plot for Co
Partial ACF
Lag

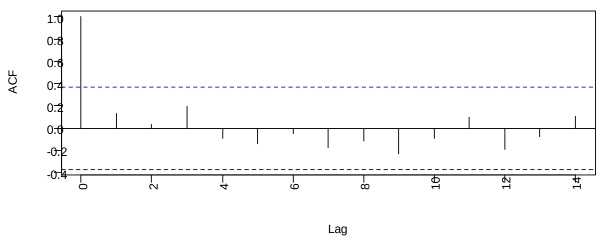
Barplot of Residuals for Corridor 30



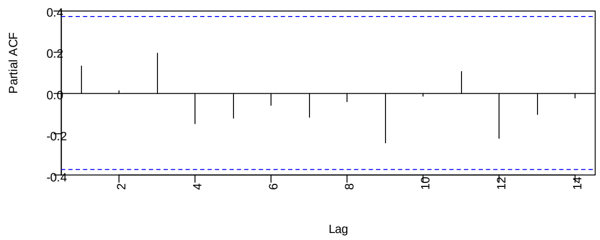
Normal Q-Q Plot for Corridor 30



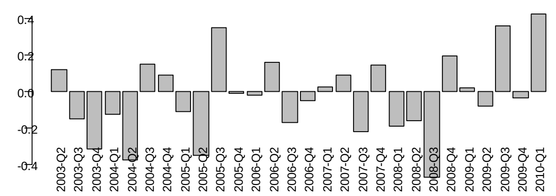
Autocorrelation Function Plot for Corridor 3



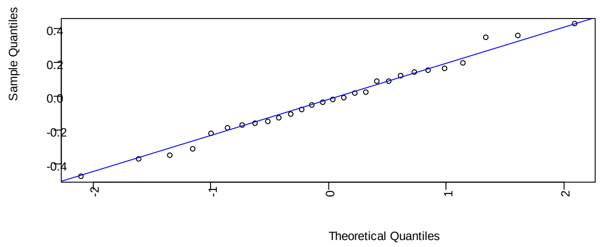
Partial Autocorrelation Function Plot for Co



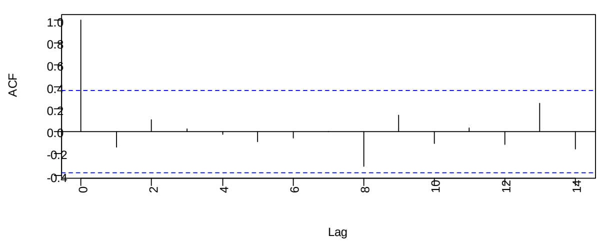
Barplot of Residuals for Corridor 32



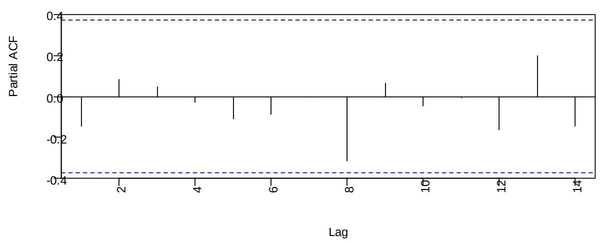
Normal Q-Q Plot for Corridor 32



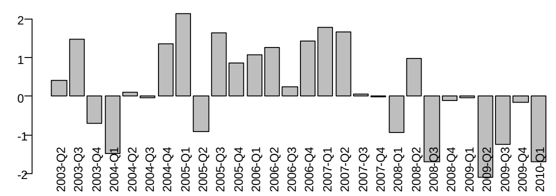
Autocorrelation Function Plot for Corridor 3



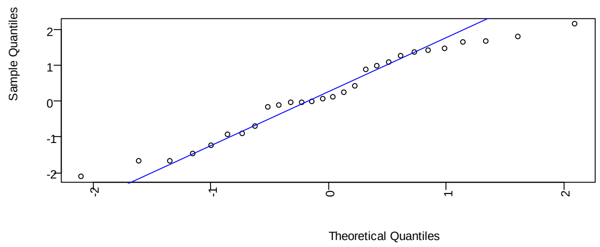
Partial Autocorrelation Function Plot for Co



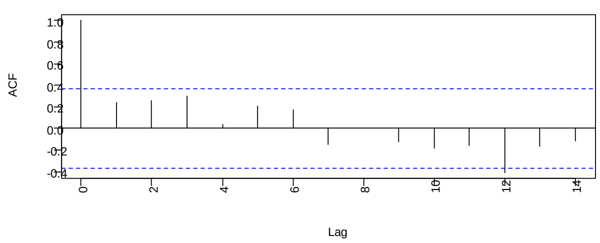
Barplot of Residuals for Corridor 39



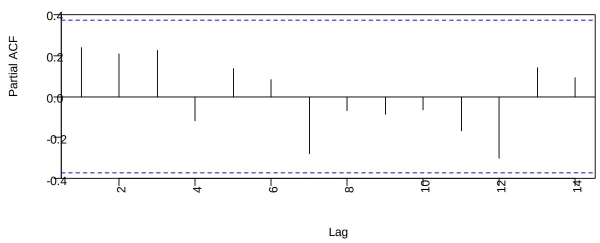
Normal Q-Q Plot for Corridor 39

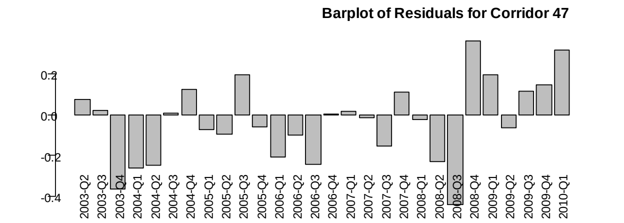


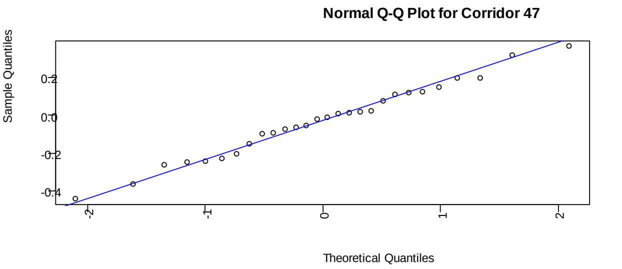
Autocorrelation Function Plot for Corridor 3

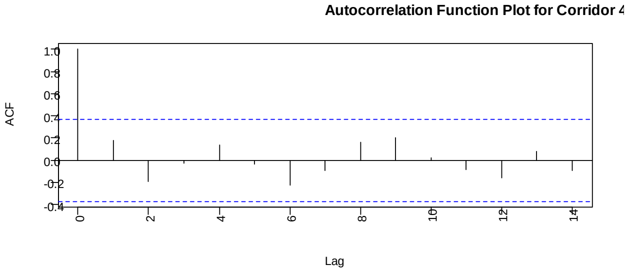


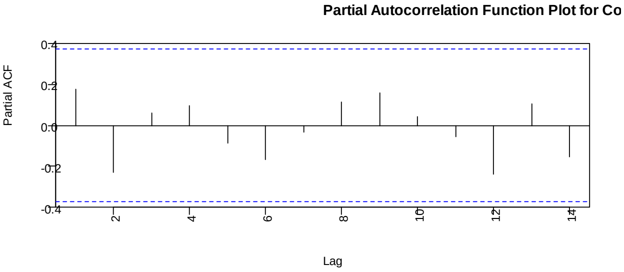
Partial Autocorrelation Function Plot for Co

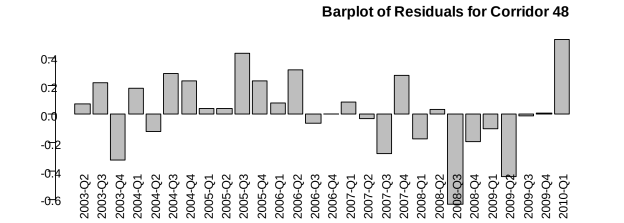


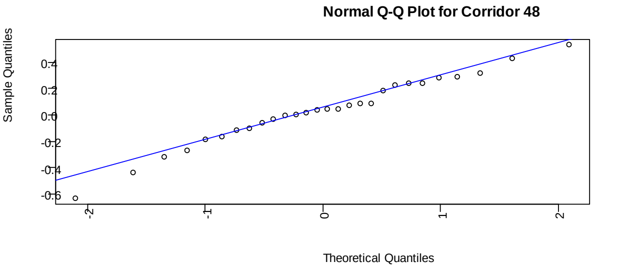

Barplot of Residuals for Corridor 47

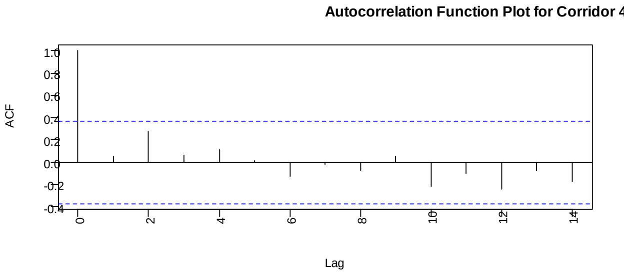

Normal Q-Q Plot for Corridor 47
Sample Quantiles
Theoretical Quantiles

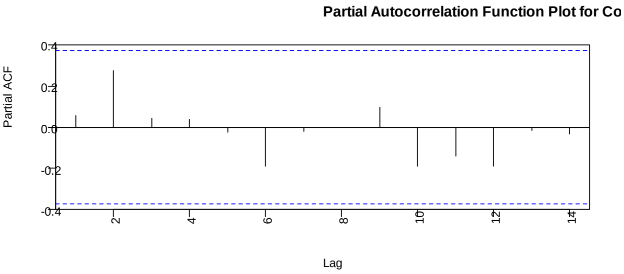

Autocorrelation Function Plot for Corridor 4
ACF
Lag


Partial Autocorrelation Function Plot for Co
Partial ACF
Lag


Barplot of Residuals for Corridor 48


Normal Q-Q Plot for Corridor 48
Sample Quantiles
Theoretical Quantiles


Autocorrelation Function Plot for Corridor 4
ACF
Lag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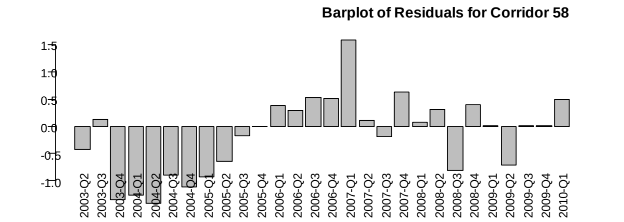
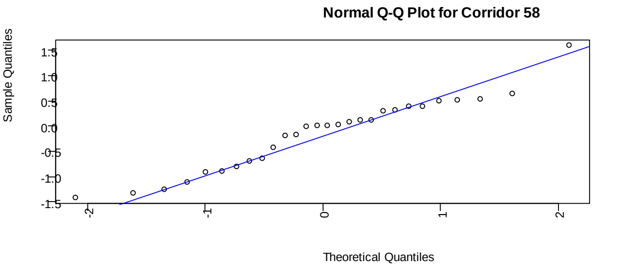
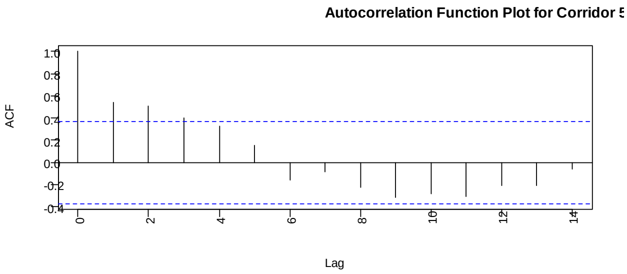
Partial ACF
Lag


Barplot of Residuals for Corridor 58


Normal Q-Q Plot for Corridor 58
Sample Quantiles
Theoretical Quantiles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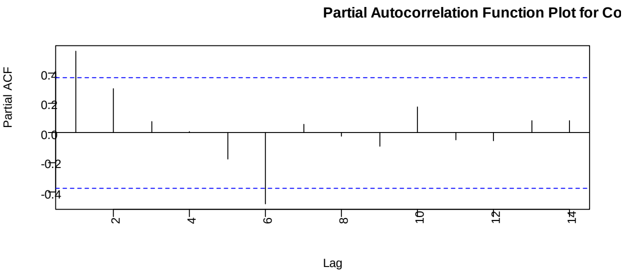
ACF
Lag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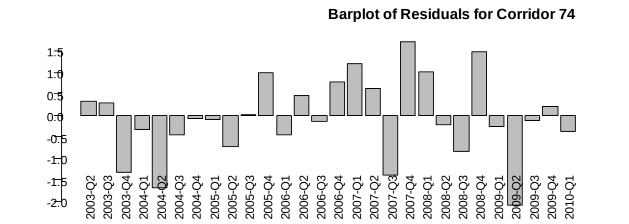
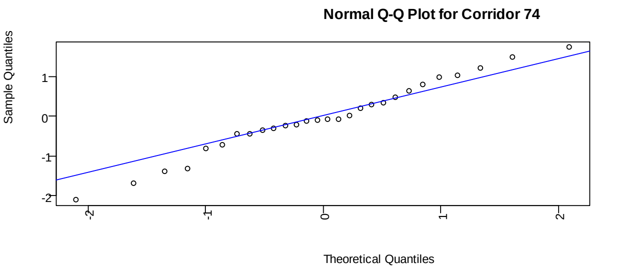
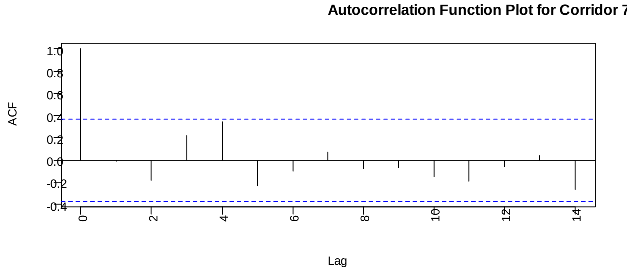
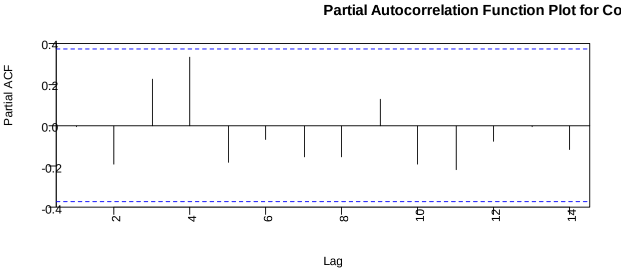
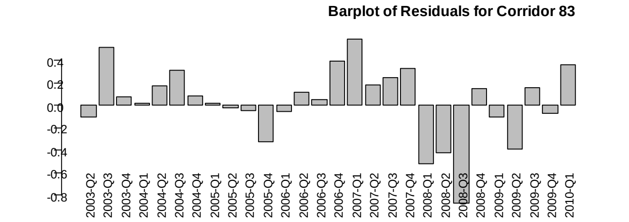
Partial ACF
Lag

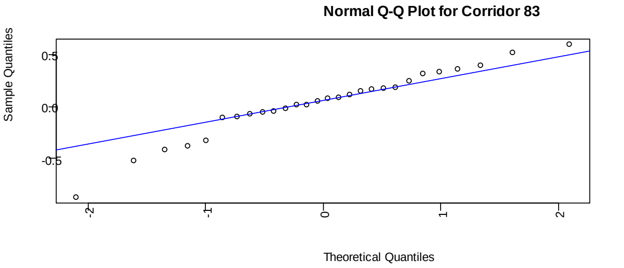

Barplot of Residuals for Corridor 74

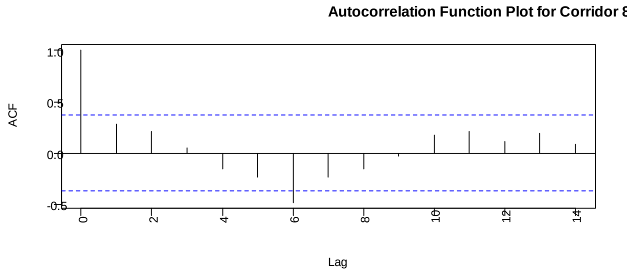

Normal Q-Q Plot for Corridor 74
Sample Quantiles
Theoretical Quantiles

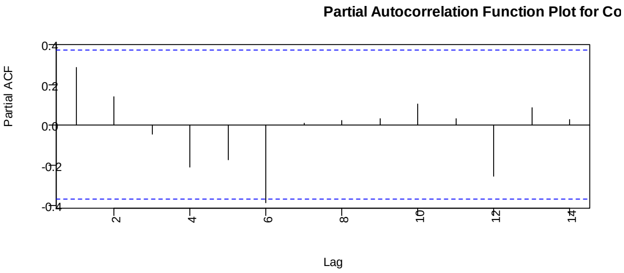

Autocorrelation Function Plot for Corridor 7
ACF
Lag

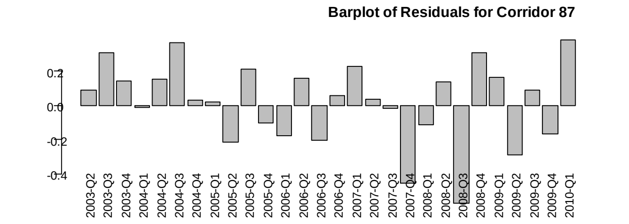

Partial Autocorrelation Function Plot for Co
Partial ACF
Lag

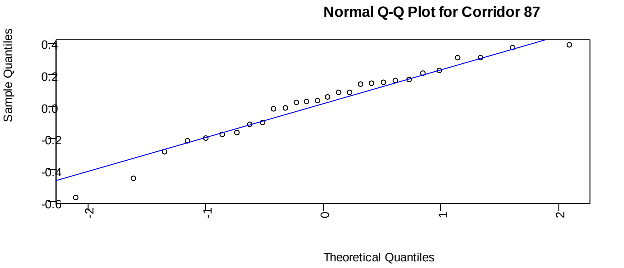

Barplot of Residuals for Corridor 83

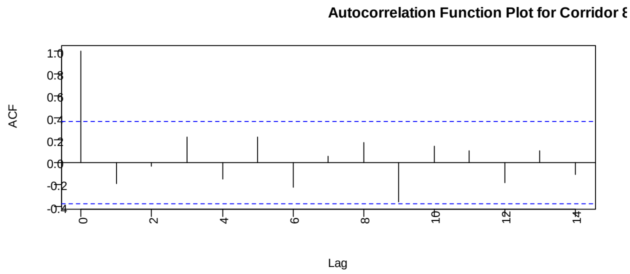

Normal Q-Q Plot for Corridor 83
Sample Quantiles
Theoretical Quantiles


Autocorrelation Function Plot for Corridor 8
ACF
Lag


Partial Autocorrelation Function Plot for Co
Partial ACF
Lag


Barplot of Residuals for Corridor 87


Normal Q-Q Plot for Corridor 87
Sample Quantiles
Theoretical Quantiles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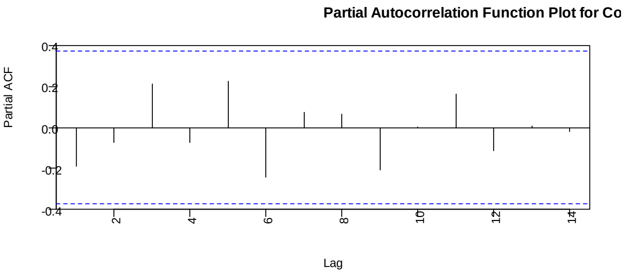
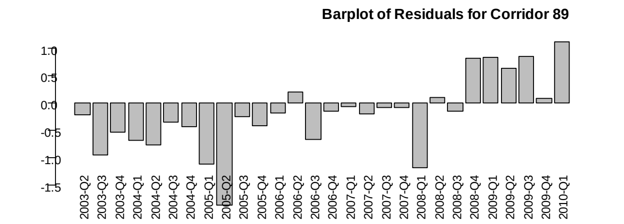
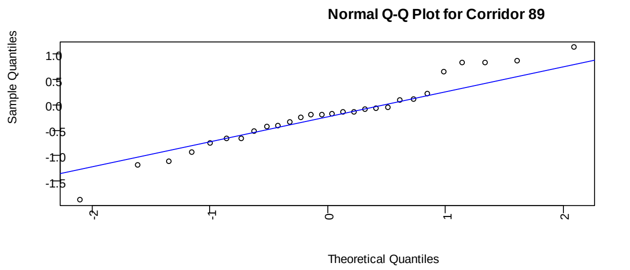
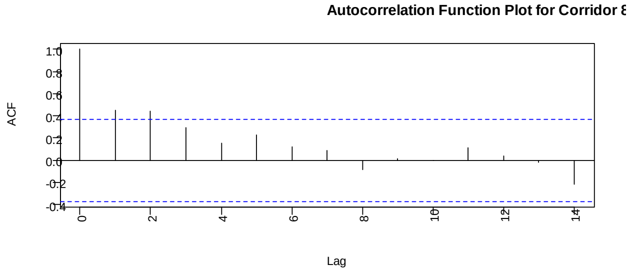
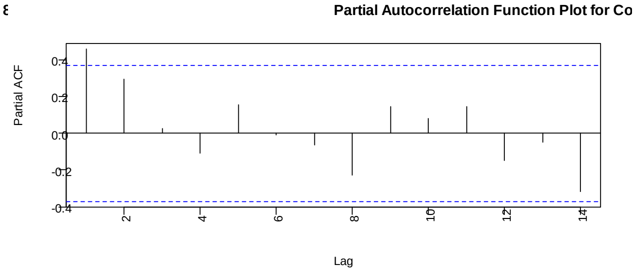
ACF
Lag

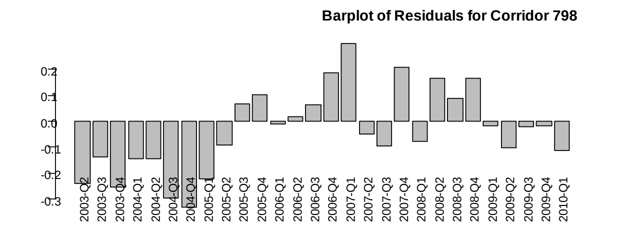

Partial Autocorrelation Function Plot for Co
Partial ACF
Lag

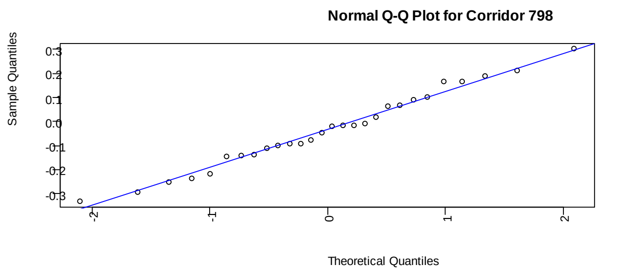


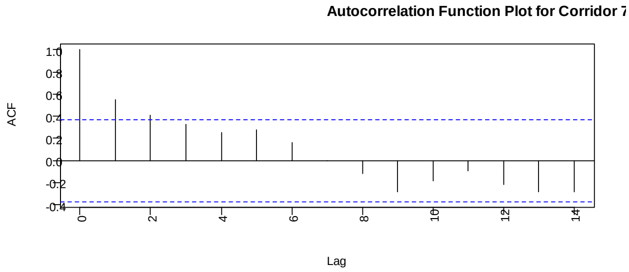


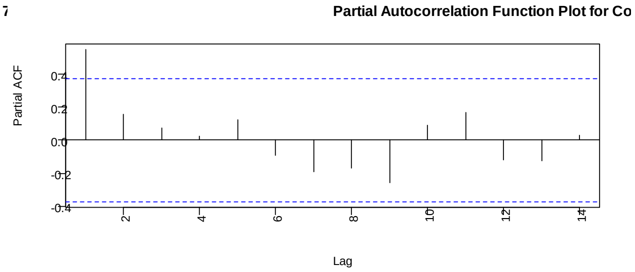












C7 Estimates and findings

This section presents the coefficients estimated using our econometric panel data model.

Table C.16 below shows our estimates for the impact of economic variables.

Table C.16 Estimates of coefficients for economic variables

Economic variables	Weekday			
	Peak	Interpeak	Evening	Weekend
Real adult bus fare	-0.30*** (-0.43, -0.16)	-0.24*** (-0.38, -0.11)	-0.12 (-0.31, 0.06)	-0.42*** (-0.65, -0.18)
Real petrol price	0.03 (-0.03, 0.10)	0.02 (-0.04, 0.09)	Removed due to implausible sign	Removed due to implausible sign
$2.00 nominal petrol price threshold	3% (-1%, 6%)	Removed due to implausible sign	5% (-1%, 11%)	Removed due to implausible sign

Economic variables	Weekday			Weekend
	Peak	Interpeak	Evening	
Real retail sales	-0.19** (-0.31, -0.07)	-0.27*** (-0.40, -0.13)	-0.09 (-0.27, 0.09)	-0.21* (-0.42, -0.01)
Employment	0.79*** (0.50, 1.07)	-0.08 (-0.36, 0.19)	0.52** (0.19, 0.86)	0.07 (-0.37, 0.51)
SuperGold Card introduction		11%*** (9%, 13%)	2% (-2%, 6%)	Removed due to implausible sign

Note for symbols of statistical significance: *** → 0.1%, ** → 1%, * → 5%, ‘ →10%

Key findings from table C.16 are:

- The fare elasticity is highest during the weekday peak and weekend. This is perhaps because many of the patrons who dominate use during the weekday off-peak are more dependent on public transport.
- The petrol price cross-elasticity is close to zero, but still feasible and consistent with findings elsewhere.
- The petrol price $2.00 thresholds have an impact during the evening and the weekend but are not statistically significant.
- Real retail sales have a negative impact on patronage; this pattern was observed across all periods.
- The coefficients for the employment elasticities were highest during the peak and then the evenings. The employment elasticities were close to zero during the interpeak and the weekends.

Table C.17 shows the impact of miscellaneous events on patronage growth. The most important events in the period covered relate to improvements on the Auckland train system.

In section C3.2 we concluded that the Auckland train system has gained patronage in recent years at the expense, at least in part, of competing NZ Bus corridors:

- For bus corridors that compete with the southern train line there was a long period of patronage loss but the losses were greatest during two periods:
  - immediately following the completion of Britomart in 2003–Q3
  - again in 2005–Q2.
- For bus corridors that compete with the western train line there were modest initial impacts, but there was a distinct loss of patronage when double-tracking was completed between Mount Eden and Morningside.

Table C.17 Impacts of miscellaneous events on patronage growth

Impact of miscellaneous events		Weekday			Weekend
		Peak	Interpeak	Evening	
Impact of Britomart (Jul 03) on bus corridors that had previously transferred passengers into the CBD:	01	-42%*** (-50%, -33%)	-26%*** (-35%, -18%)	-10%* (-21%, 0%)	-2% (-18%, 13%)
	02	-16%*** (-24%, -8%)	-16%*** (-24%, -8%)	-6% (-16%, 3%)	Removed due to implausible sign
	03	-14%** (-22%, -5%)	-5% (-13%, 3%)	-2% (-12%, 7%)	-6% (-23%, 12%)
	04	-14%** (-22%, -6%)	-1% (-9%, 7%)	-6% (-15%, 3%)	-11% (-28%, 7%)
Impact of Britomart (Jul 03) on bus corridors that 'compete' with the southern and eastern train lines:	Immediate impact	-8%*** (-11%, -5%)	-9%*** (-11%, -6%)	-8%*** (-12%, -5%)	-6%* (-10%, -1%)
	Impact in second year	-6%*** (-8%, -3%)	-3%* (-5%, 0%)	-6%*** (-9%, -3%)	-8%*** (-13%, -4%)
	Impact in third year	Removed due to implausible sign	Removed due to implausible sign	Removed due to implausible sign	-2% (-9%, 5%)
Impact of double tracking (Feb 05) on bus corridors that 'compete' with the western train line:		-16%*** (-20%, -12%)	-6%** (-10%, -3%)	-8%** (-12%, -3%)	-15%*** (-23%, -7%)
Impact of the Stagecoach bus 6-day labour strike (May 05) on bus corridors that 'compete' with the western, southern and eastern train lines:		-4%** (-7%, -2%)	-8%*** (-10%, -5%)	-10%*** (-13%, -7%)	-10%** (-18%, -3%)
Impact of Easter		Removed due to implausible sign	Removed due to implausible sign	Removed due to implausible sign	-1% (-3%, 0%)
Impact of Grafton Bridge		Removed due to implausible sign	1% (-12%, 15%)	Removed due to implausible sign	Removed due to implausible sign

As section C3.3.1 notes, there was a drop off in peak and interpeak patronage on corridors 01, 02, 03 and 04 in 2003–Q3. We attribute this to the extension of the train line through to the Britomart station in the Auckland CBD. This extension drew away passengers that would otherwise have transferred from the previous (Bridge Road) train station through to the CBD.

Table C.17 also shows that we were unable to estimate any discernible impact of Grafton Bridge on patronage, other than for a small impact on interpeak patronage. We note in section C2.3, table C.3, that the only NZ Bus corridors we could identify that used Grafton Bridge were the Link and 028.

Tables C.18 to C.21 show estimates of service elasticities for various periods. The general theme is that most service elasticities are around +0.3 on average. The exception to this theme is evening services which have an average service elasticity of around +0.6.

Table C.18 Corridor and date-specific service elasticities for peak-time service timetable improvements

Corridor		Date	Peak service elasticity
005	Herne Bay	Jul 04	0.28
13	Ranui – Swanson	Aug 03	-0.33
15	Glen Eden	Aug 03	0.00
47	Papakura	Dec 09	0.32
		Feb 09	0.09
81	Devonport	Jul 05	0.42***
83	Beach Road	Nov 02	0.22
		Feb 08	0.85**
87	East Coast Rd	Oct 02	0.61*
		Jul 05	-0.10
	Weighted average		**0.27**

Note for symbols of statistical significance: *** → 0.1%, ** → 1%, * → 5%, ‘ →10%

Table C.19 Corridor and date-specific service elasticities for interpeak service timetable improvements

Corridor		Date	Interpeak service elasticity
17	Titirangi	Aug 03	1.40***
47	Papakura	Aug 05	0.34
		Oct 06	-0.17
81	Devonport	Jul 05	0.43
83	Beach Road	Nov 02	0.16
		Feb 06	0.09
		Feb 08	0.58*
87	East Coast Rd	Oct 02	0.35***
		Feb 06	0.60‘
		Feb 08	0.82***
	Weighted average		**0.35**

Note for symbols of statistical significance: *** → 0.1%, ** → 1%, * → 5%, ‘ →10%

Table C.20 Corridor and date-specific service elasticities for evening service timetable improvements

Corridor		Date	Evening service elasticity
13	Ranui - Swanson	Aug 03	0.08
17	Titarangi	Nov 08	1.61***
81	Devonport	Jul 05	0.67***
83	Beach Road	Oct 02	0.51*
		Jul 05	1.26**
		Dec 09	0.82
87	East Coast Rd	Oct 02	0.26
		Jul 05	0.03
		Feb 08	0.27
	Weighted average		**0.61**

Note for symbols of statistical significance: *** → 0.1%, ** → 1%, * → 5%, ‘ →10%

Table C.21 Corridor and date-specific service elasticities for weekend service timetable improvements

Corridor		Date	Weekend service elasticity
007	Pt Chev – St Heliers	Apr 09	0.39
11	Glendene	Aug 03	-0.64
13	Ranui - Swanson	Aug 03	0.22
15	Glen Eden	Aug 03	-0.04
17	Titirangi	Aug 03	-3.94***
30	Manukau Rd	Nov 03	1.29
47	Papakura	Oct 06	-0.45
83	Beach Road	Jul 02	0.98
		Jul 05	0.28
87	East Coast Rd	Jul 02	0.48
		Jul 05	0.86
		Feb 08	-0.73
	Weighted average		**0.27**

Note for symbols of statistical significance: *** → 0.1%, ** → 1%, * → 5%, ‘ →10%

C8 Reference list

Booz Allen Hamilton (2005) *Appraisal of Stagecoach Auckland bus patronage trends*. Report to Stagecoach NZ/Auckland Regional Transport Authority (ARTA)

Appendix D: Econometric analysis of patronage growth on the Wellington rail system

D1 Introduction

In section 6.4 of the main report we presented our conclusions regarding the contribution of explanatory variables to Wellington rail patronage growth over the four-year period 2005–Q3 through to 2009–Q4. Then in section 6.5 we presented our findings in regard to elasticities and other estimates for those explanatory variables.

Those conclusions and findings are based on a thorough econometric methodology[44] which helps us understand as much as we can about what is driving patronage growth at a line level. We then bundled data from all the lines together and used an econometric tool (called a panel data model) to estimate what is driving patronage across the Wellington train system, while controlling for any explanatory variables that are unique to particular lines such as maintenance disruptions or line-specific service improvements.

The following sections show how the econometric methodology was applied to analysis of Wellington rail patronage, and describe the analyses underlying our conclusions and findings.

- *D2 Data collection and data manipulation* – the analytical process begins with data collection. The data then has to be checked and manipulated into a form so it is suitable for econometric analysis.
- *D3 Graphical analysis* – we believe it is important to look at the data and make sense of it intuitively before proceeding onto econometric analysis. In section D3 we look at patronage growth along each of the main train lines and seek to explain and understand any trends or anomalies in the data. The observations here feed into the models tested in sections D4 to D7.
- *D4 Data analysis* – there are a number of statistical problems that can potentially undermine the validity of the econometric analysis. (These problems are technically referred to as multicollinearity, spurious regression and endogeneity.) In section D4 we show that we have examined the data for presence of these problems and have responded accordingly where there is evidence of a problem.
- *D5 Model building process* – the process of building models for patronage growth involves looking at the data and fitting a general model that explains the patterns in the data as well as possible. We then investigate the contribution of the explanatory variables in the general model, removing those that look suspect or indeterminate, and whittling the model down to its core components. Section D5 describes the process by which each of the initial models was whittled down into preferred models.
- *D6 Diagnostic analysis* – the preferred model will still not be statistically valid unless the residuals of the model meet certain criteria. In section D6 we show our examination of the residuals of each individual line, in which we look for evidence of autocorrelation, non-normality or omitted variables
- *D7 Estimates and findings* – in section D7 we show the estimates produced using the final models.

[44] See chapter 2 of the main report for presentation and explanation of the econometric methodology.

D2 Data collection and data manipulation

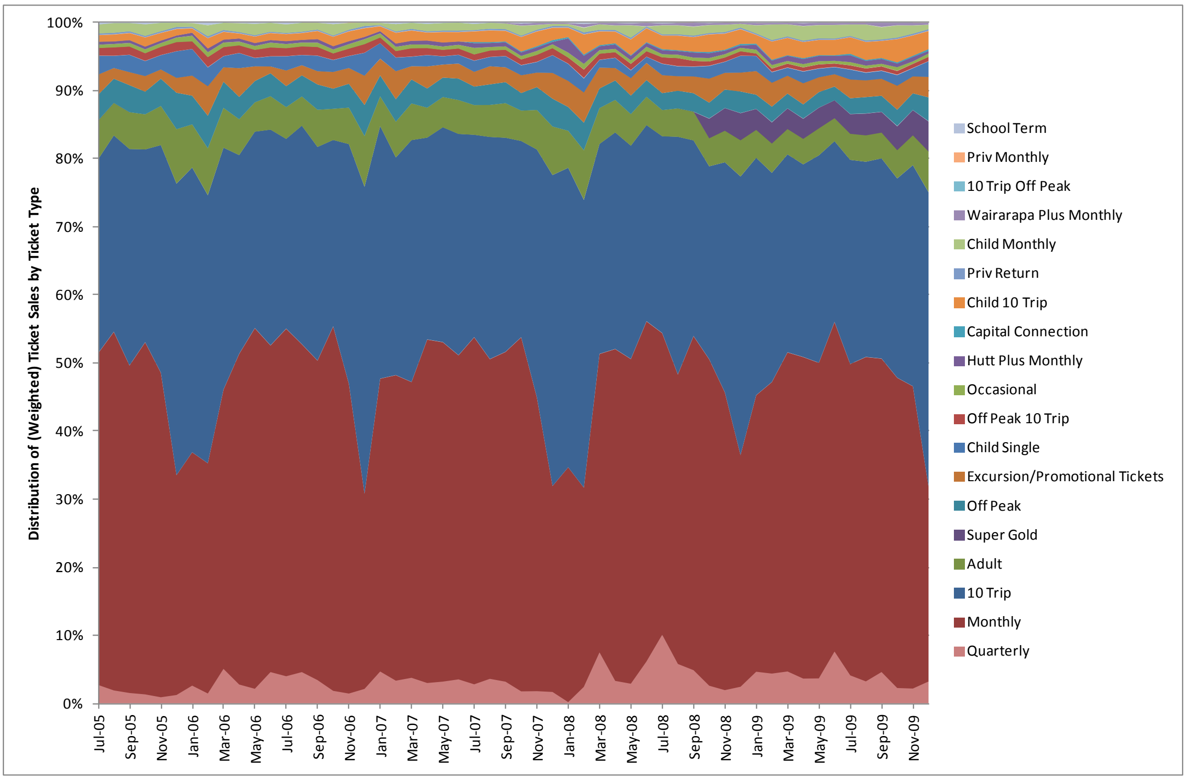
D2.1 Patronage data

KiwiRail provided ticket sales data from 2005-Q3 through to 2009-Q4. Due to limitations of this ticket sales data, the best approach was to use certain ticket types as a proxy for overall patronage:

- adult (single) tickets
- 10-trip tickets
- monthly tickets
- quarterly tickets.

These ticket types make up 80% to 90% of total patronage, as shown in figure D.1 below. Unfortunately, SuperGold 'ticket' sales were not available by line or zone so they could not be incorporated into the econometric analysis.

Figure D.1 Distribution of ticket sales by ticket type



We looked at growth in sales of the selected ticket types (10-trip, monthly and quarterly) on three lines[45]:

- the Johnsonville line
- the Upper Hutt/Melling line
- the Paraparaumu line (currently Kapiti).

[45] The Wairarapa line was excluded because it is a distinctly different market and it seems inappropriate to group it together with the other lines.

The ticket sales data was disaggregated by origin and destination. For the sake of consistency through time we chose to focus on segments of ticket sales in which the origin or destination was Wellington city. These segments are shown in table D.1.

Table D.1 Line segments

Segment	Description of origin/destination
H4	Wellington – Waterloo/Melling
H5	Wellington – Pomare/Taita
H6	Wellington – Trentham
H7	Wellington – Upper Hutt
J3	Wellington – Johnsonville
P4	Wellington – Linden
P5	Wellington – Porirua
P6	Wellington – Plimmerton
P7	Wellington – Muri
P8	Wellington – Paekakariki
P9	Wellington – Paraparaumu

We note that there are a number of issues associated with the ticket sales data provided:

- We do have some doubts about the accuracy of the data; there are a number of dips in the data that seem difficult to explain.
- The data is ticket-based and is derived from sales not use. The timing of purchases does not necessarily reflect actual use. Furthermore, the data cannot be broken down by time period (weekday peak, weekday interpeak, weekday evening, weekend) and this means that we cannot control for time period specific factors as effectively.

D2.2 Service change data

To our knowledge, there has been limited documentation of historic service changes on the Wellington rail system. We were informed by KiwiRail that the main change between 2005 and late 2009 was in November 2008: four extra commuting services per working day were added on both the Hutt and Paraparaumu lines.

D2.3 Other data

We collected and incorporated data on a number of explanatory variables: fares, petrol prices, retail sales and employment. Where applicable, these variables were then adjusted for inflation and hence the rest of the report refers to them as real fares, real petrol prices and real retail sales.

Retail sales and employment data was available for a number of territorial authorities in the wider Wellington region (Wellington city, Porirua city, Lower Hutt city, Upper Hutt city and Kapiti Coast district). For the sake of simplicity, we chose to focus on retail sales and employment in the ‘Wellington city’ territorial authority because we consider that employment, shopping and other activities in the Wellington CBD is strongly associated with most rail travel in Wellington. Our research shows, for example, that over 60% of employment arises in Wellington city. Furthermore, we expect that employment is strongly correlated across all these areas.

We also collected data on cars licensed by territorial authority but, after examination we found evidence of substantial corruption in the data so it was discarded.

Reliability data was obtained from KiwiRail but unfortunately it was not available further back than 2007–Q3. We therefore decided that it was not practical to incorporate reliability data into the econometric modelling since the period covered by the ticket sales dataset went from 2005–Q2 through to 2009–Q4.

In section 2.2.2 of the main report, we explain why we decided against incorporating population statistics into the econometric analyses. In general, we have doubts about the statistical robustness of findings produced using population statistics because they are low frequency (ie data is only annual) low accuracy (ie data is only an estimate), exhibit low variance (ie populations exhibit steady growth rates over time) and could only be obtained for broad geographical regions (ie territorial authorities).

Table D.2 shows various miscellaneous events that we judged may have had a discernible impact on Wellington rail patronage growth.

Table D.2 Miscellaneous events

Event	Months affected	Quarters affected	Notes relating to event
Fare increases	Sep 06, Sep 09	2006–Q3, 2009–Q3	Fares were increased in September 2006 and again in September 2009. Both fare increases were about 14% on average, but this varied by line and zone.
Crossing of the $2.00 nominal petrol price threshold	May 08 through Aug 08	2008–Q2, 2008–Q3	During the period 22 May 2008 to 13 Aug 2008 the nominal price of regular petrol crossed the $2.00 threshold. There is reason to believe that the crossing of this threshold may have been a key trigger for behavioural change. (However, is important to note that the impact of thresholds like the $2.00 mark is not concrete – it may reflect a number of other issues around the same time (eg media attention on 'peak oil') and may very well have changed as people have become accustomed to higher petrol prices.)
Introduction of SuperGold Card	Oct 08	2008–Q3	The SuperGold Card was introduced in October 2008, providing free off-peak and weekend travel for persons over 65.
Line maintenance	Dec 08, Jan 10	2008–Q4, 2010–Q1	There is evidence of significant line maintenance on both lines during these dates, causing a number of buses to be employed as a replacement for the trains. These disruptions could have had an impact on patronage.
Closure of Johnsonville line	Jan 09, Feb 09	2009–Q1	The Johnsonville line was closed from 28 December 2008 to 7 February 2009. This was done to enable a lowering of the track and a widening of the tunnels, hence enabling newer and bigger trains to run on this line.
Easter holidays	Mar or Apr depending on calendar	Q1 or Q2 depending on calendar	The Easter holidays occur sometimes in March and sometimes in April, depending on the calendar at the time. This can affect patronage because the timetables are more limited and because patrons are on holiday and hence less likely to use public transport.

D3 Graphical analysis

D3.1 Key themes from graphical analysis of all lines

This section presents the key themes drawn out from a graphical analysis of all lines. See sections D3.2 to D3.4 for discussion of specific lines (and zone segments within each of those lines).

The key themes from graphical analysis are:

- Sales of 10-trip tickets and adult tickets were generally stable throughout the period studied. The main exception was that sales of both ticket types fell in response to the introduction of the SuperGold in October 2008. Also, sales of adult tickets appear to have been negatively affected by a fare increase in September 06.
- Sales of monthly and quarterly tickets exhibit low patronage in 2006-Q1 and 2008-Q1, apparently due to line maintenance. There is also some evidence that sales of monthly and quarterly tickets were affected by rising petrol prices from late-2007 through to late-2008.

D3.2 Graphical analysis of the Hutt line

This section shows graphical analysis of ticket sales for a selection of origin-destinations along the Hutt line. The overall patterns from analysis of the Hutt line are:

- The sales of both adult tickets and 10-trip tickets were generally stable throughout the period studied, but appeared to fall in 2008-Q4, apparently in response to the introduction of the SuperGold Card in October 2008. We also note that adult tickets seemed to exhibit a pronounced fall in sales in 2006-Q4 (apparently in response to the fare increase in September 2006).
- The sales of monthly and quarterly tickets also exhibited evidence of unusually low patronage in 2006-Q1 and 2008-Q1. It is possible that this may have been due to line-maintenance. But there is no evidence of a change to any other ticket types, which suggests that a data problem is a more likely explanation.
- There is some evidence that sales of monthly and quarterly tickets also responded to petrol price changes; the period of rising petrol price from 2007-Q4 through to 2008-Q3 is generally associated with increased sales of monthly and quarterly tickets.

D3.2.1 Graphs for Hutt Line – Wellington to/from Waterloo/Melling (zone 4)

Figure D.2 Wellington to/from Waterloo/Melling (zone 4) – analysis of (single) adult ticket sales

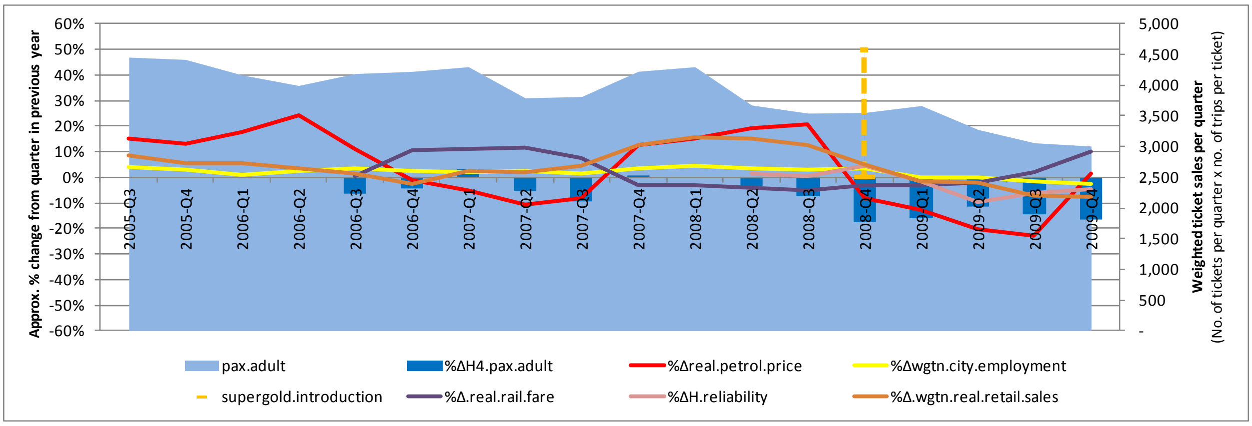


Figure D.3 Wellington to/from Waterloo/Melling (zone 4) – analysis of 10-trip ticket sales

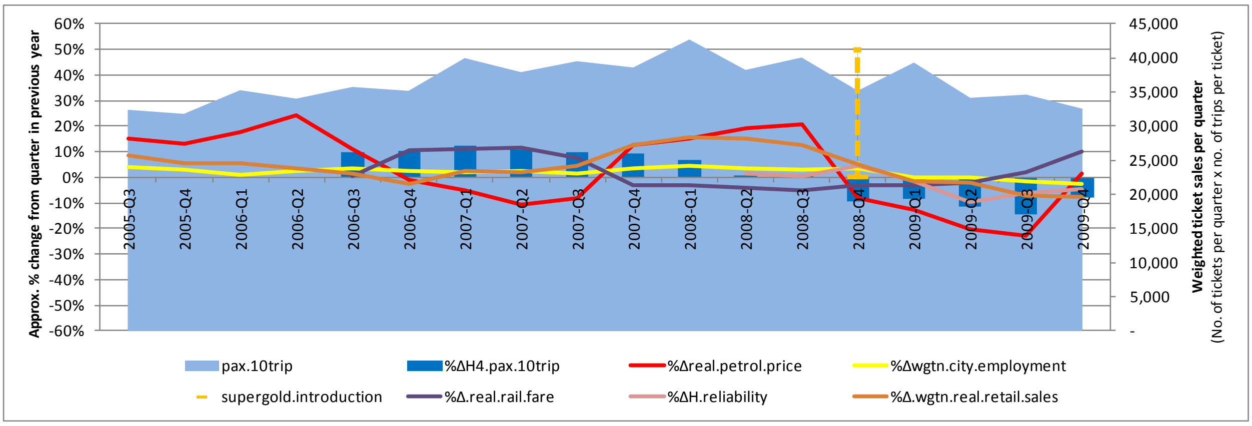
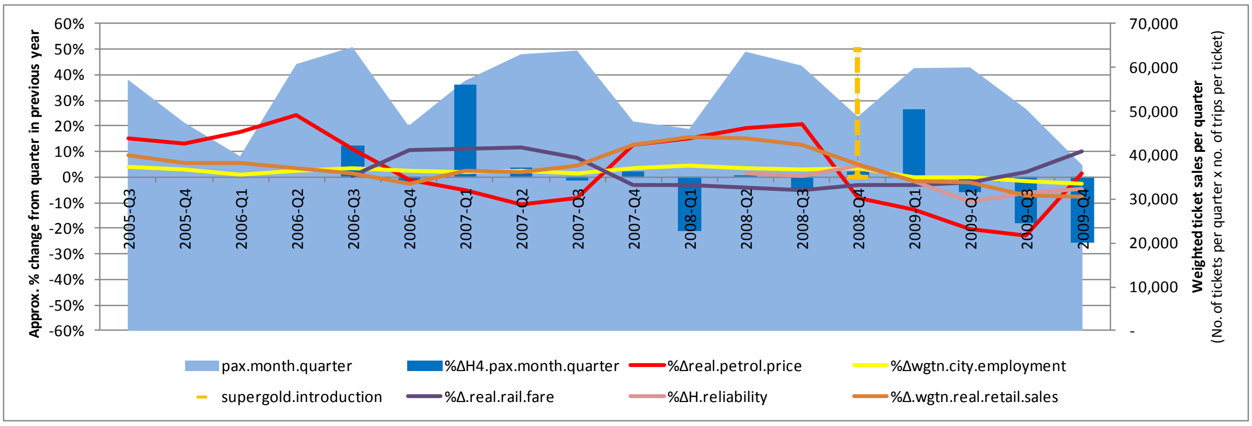


Figure D.4 Wellington to/from Waterloo/Melling (zone 4) – analysis of monthly and quarterly ticket sales



D3.2.2 Graphs for Hutt line – Wellington to/from Pomare/Taita (zone 5)

Figure D.5 Wellington – Pomare/Taita (zone 5) – analysis of adult (single) ticket sales

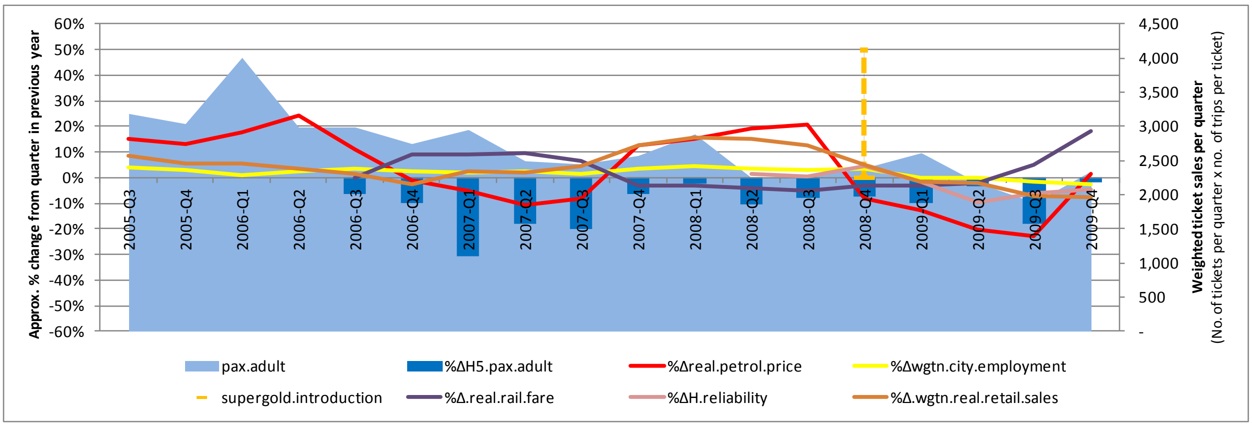


Figure D.6 Wellington – Pomare/Taita (zone 5) – analysis of 10-trip ticket sales

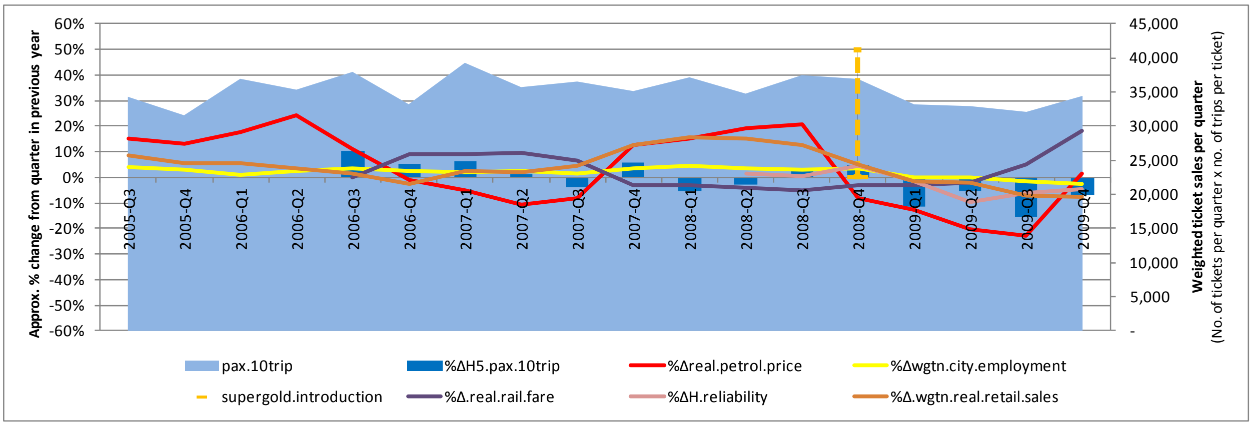
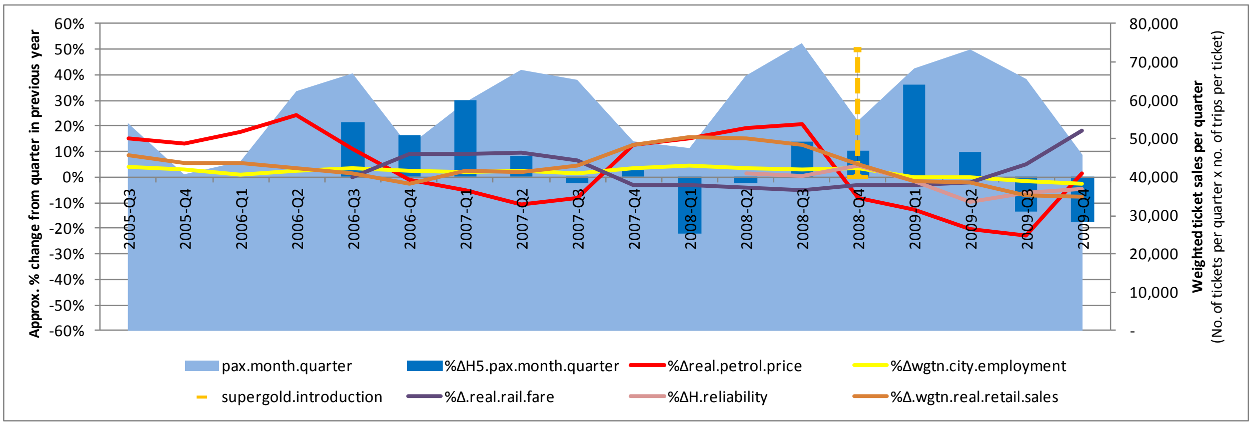


Figure D.7 Wellington – Pomare/Taita (zone 5) – analysis of monthly and quarterly ticket sales



D3.2.3 Graphs for Hutt line – Wellington to/from Trentham (zone 6)

Figure D.8 Wellington – Trentham (zone 6) – analysis of adult (single) ticket sales

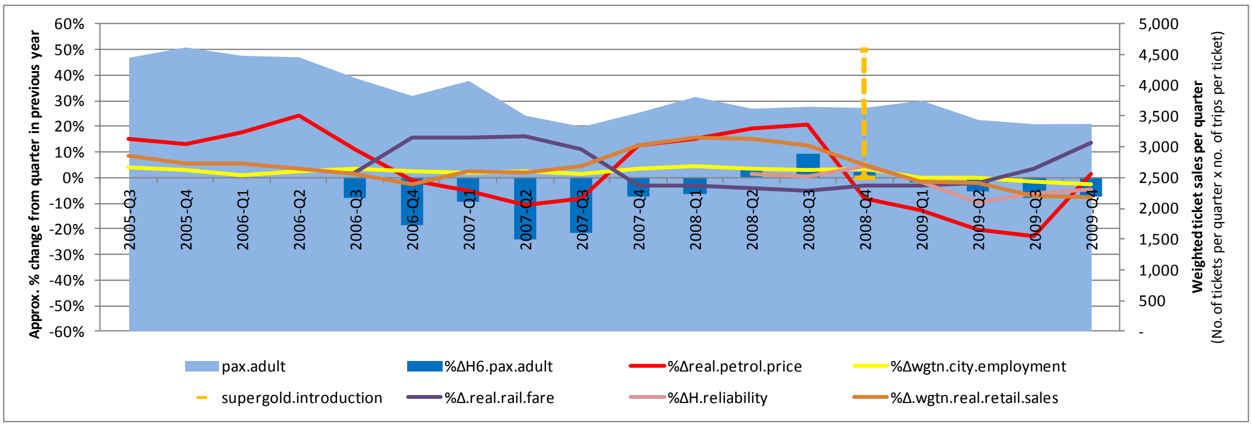


Figure D.9 Wellington – Trentham (zone 6) – analysis of 10-trip ticket sales

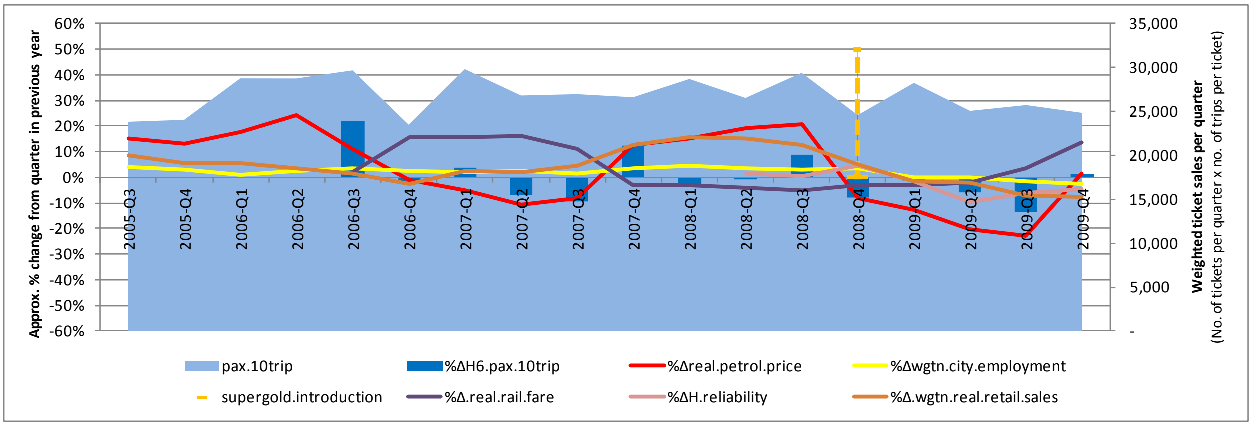
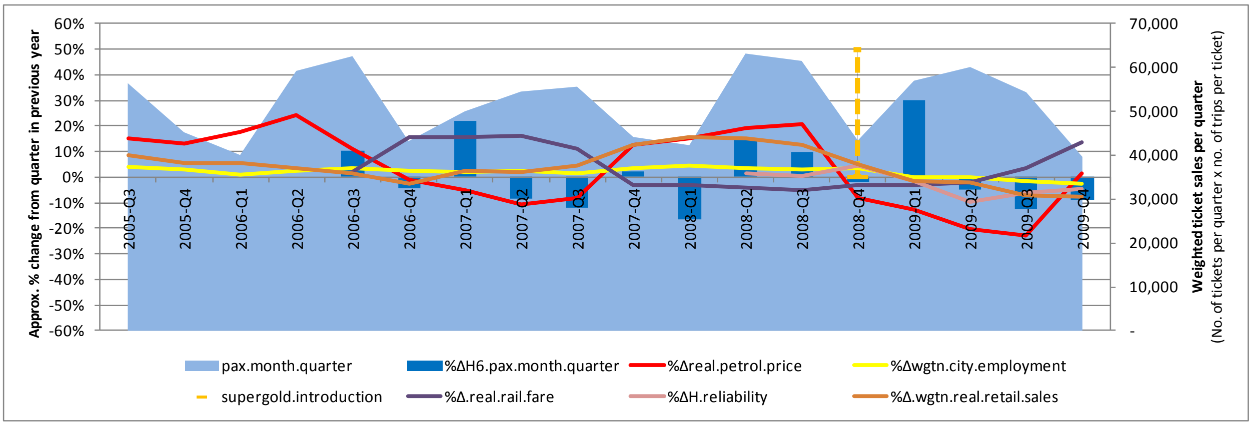


Figure D.10 Wellington – Trentham (zone 6) – analysis of monthly and quarterly ticket sales



D3.2.4 Graphs for Hutt line – Upper Hutt (zone 7)

Figure D.11 Wellington – Upper Hutt (zone 7) – analysis of adult (single) ticket sales

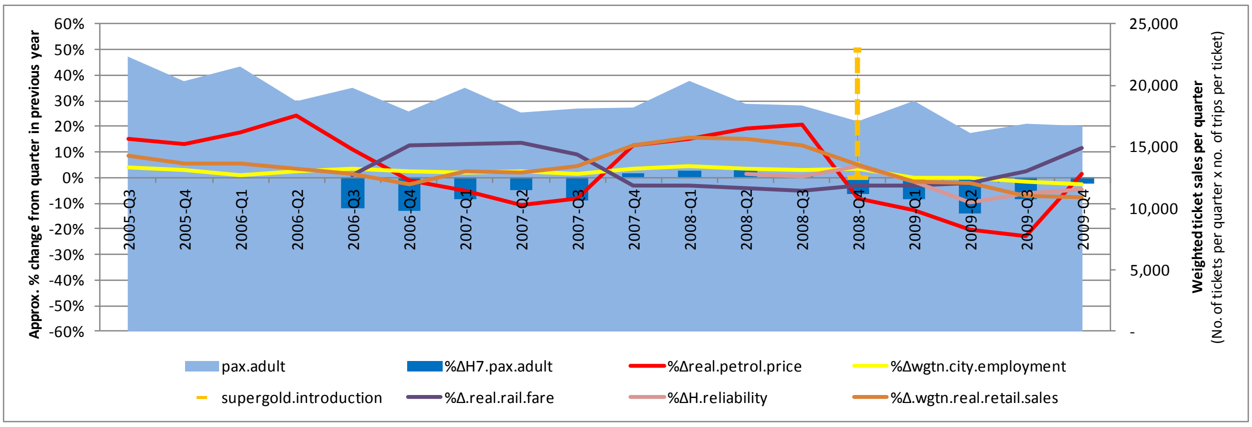


Figure D.12 Wellington – Upper Hutt (zone 7) – analysis of 10-trip ticket sales

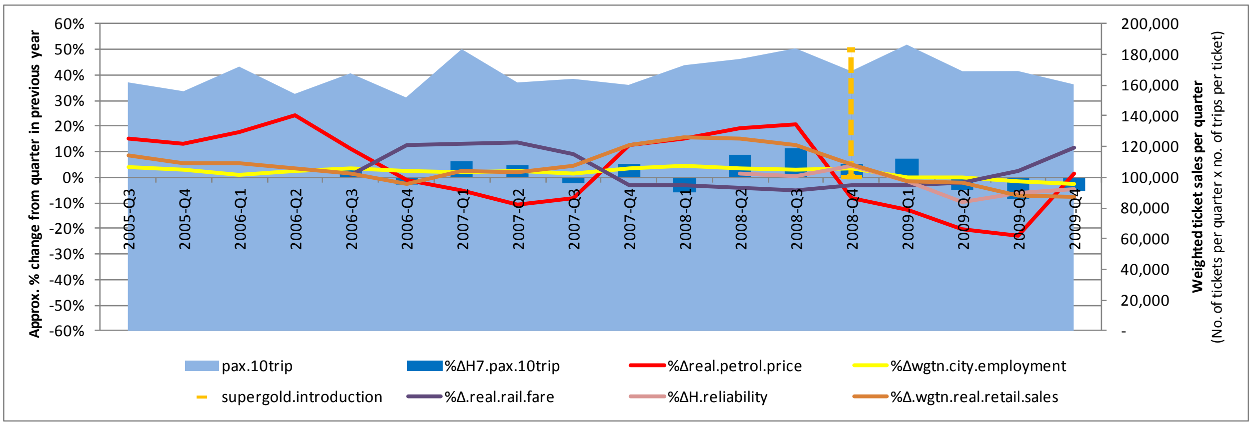
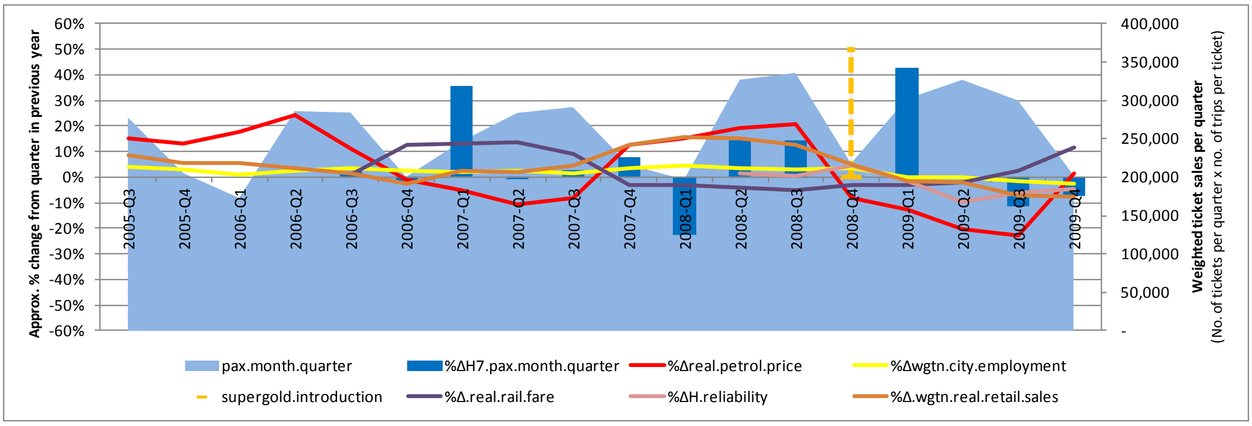


Figure D.13 Wellington – Upper Hutt (zone 7) – analysis of monthly and quarterly ticket sales



D3.3 Graphical analysis of the Johnsonville line

This section shows graphical analysis of ticket sales for the Johnsonville line. The Johnsonville line differs from the other lines in that there is only one zone. The overall patterns from graphical analysis of the Johnsonville line are:

- The sales of adult and 10-trip tickets have been generally stable. There was a fall in both adult and 10-trip tickets in 2008–Q4 which could be attributable to the introduction of the SuperGold Card.
- There was also a temporary fall in sales of both adult and 10-trip tickets in 2009–Q1. This was most likely due to the closure of the Johnsonvile line in January 2009 and early February 2009, as discussed in table D.2, section D2.3
- The sales of monthly and quarterly tickets exhibited evidence of unusually low patronage in 2008–Q1. Again, this could be due to either line-maintenance or a data problem.

D3.3.1 Graphs for Wellington to/from Johnsonvile

Figure D.14 Wellington – Johnsonville (zone 3) – analysis of adult (single) ticket sales

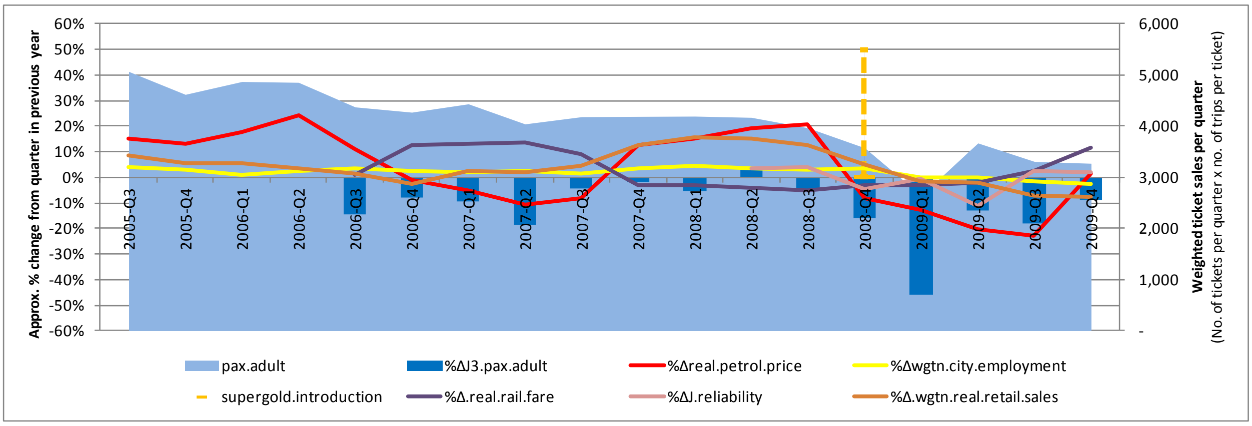


Figure D.15 Wellington – Johnsonville (zone 3) – analysis of 10-trip ticket sales

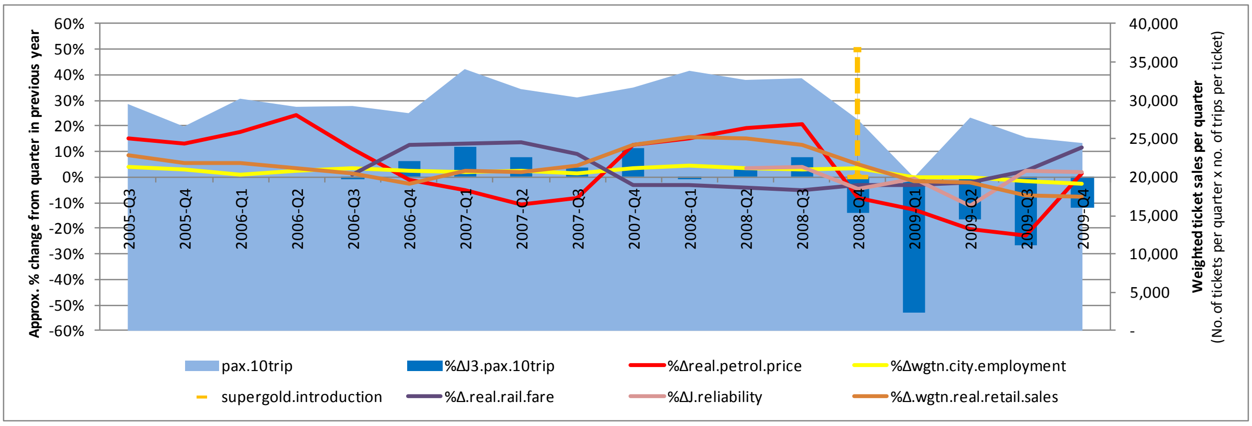
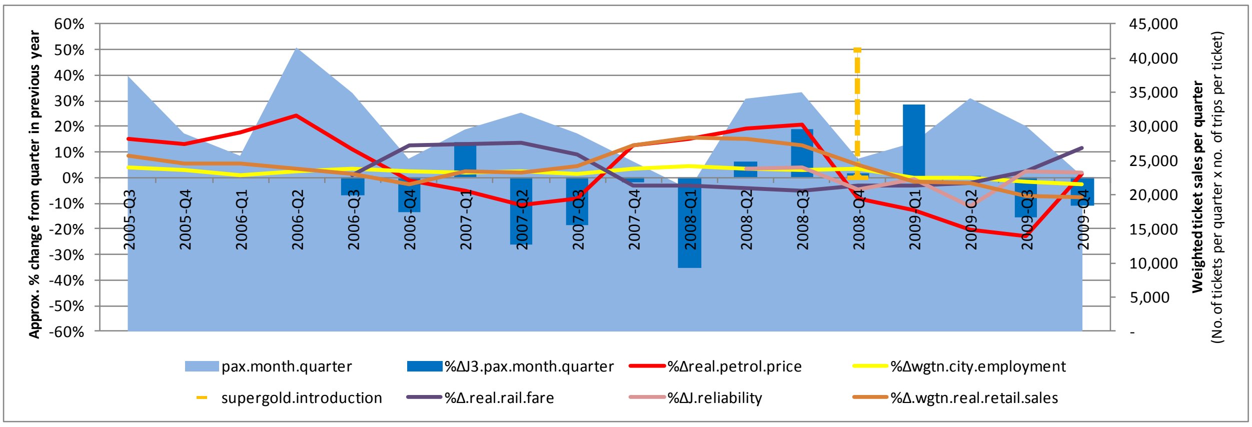


Figure D.16 Wellington – Johnsonville (zone 3) – analysis of monthly and quarterly ticket sales



D3.4 Graphical analysis of the Paraparaumu line

This section shows graphical analysis of ticket sales for a selection of origin-destinations along the Paraparaumu line. The overall patterns from analysis of the Paraparaumu line are:

- The sales of adult (single) tickets on the Wellington – Muri (zone 7) section of the Paraparaumu line show an unexplained drop in 2008-Q3, which was subsequently reversed. We attribute this to a data error of some type and therefore removed this section from econometric analysis.
- Other than that, both adult and 10-trip ticket sales showed a generally stable trend interrupted by a fall around the fare increase in 2006-Q4 and another fall around 2008-Q4 with the introduction of the SuperGold Card.
- The sales of monthly and quarterly tickets also exhibit evidence of unusually low patronage in 2006-Q1 and 2008-Q1, as was observed elsewhere.

D3.4.1 Graphs for Wellington to/from Linden (zone 4, Paraparaumu)

Figure D.17 Wellington – Linden (zone 4) – analysis of adult (single) ticket sales

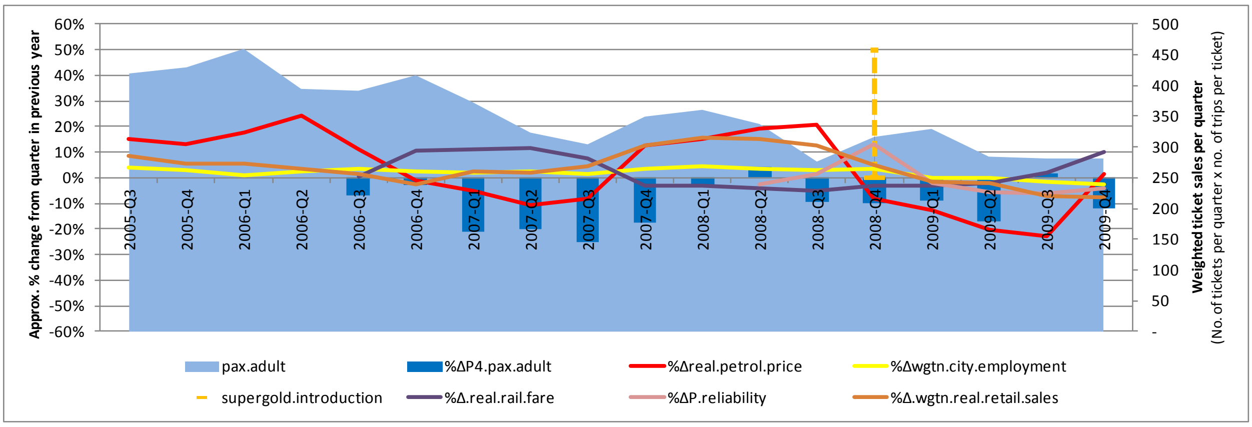


Figure D.18 Wellington – Linden (zone 4) – analysis of 10-trip ticket sales

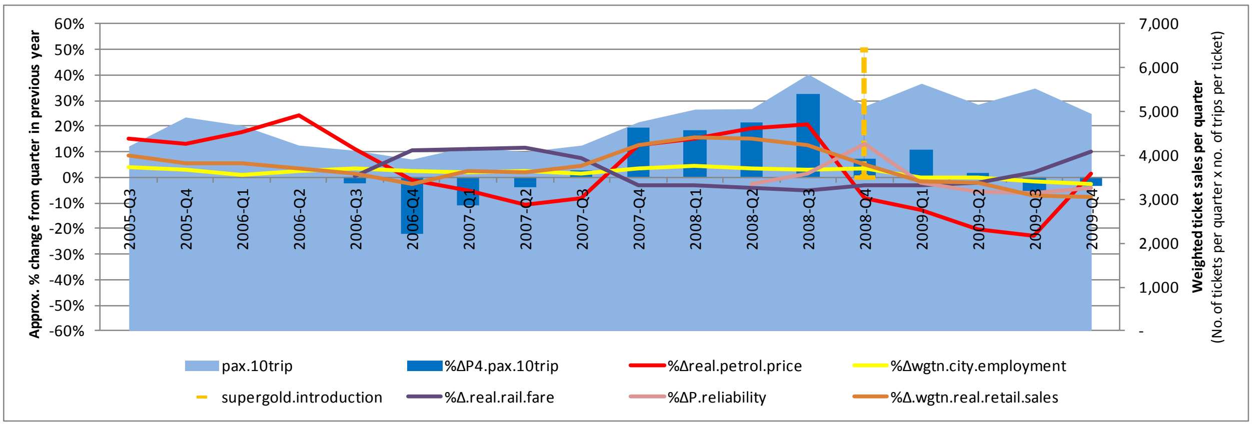
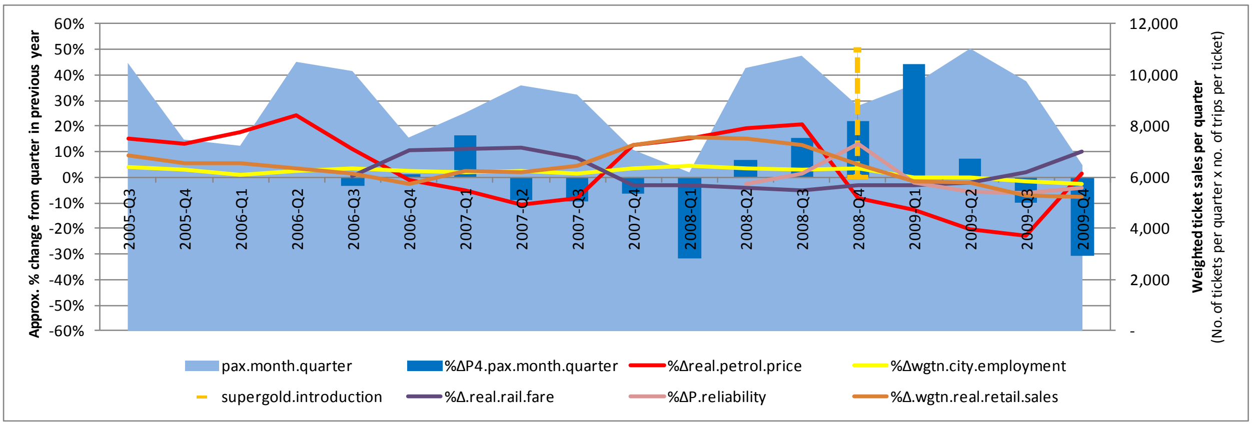


Figure D.19 Wellington – Linden (zone 4) – analysis of monthly and quarterly ticket sales



D3.4.2 Graphs for Wellington to/from Porirua (zone 5, Paraparaumu)

Figure D.20 Wellington – Porirua (zone 5) – analysis of adult (single) ticket sales

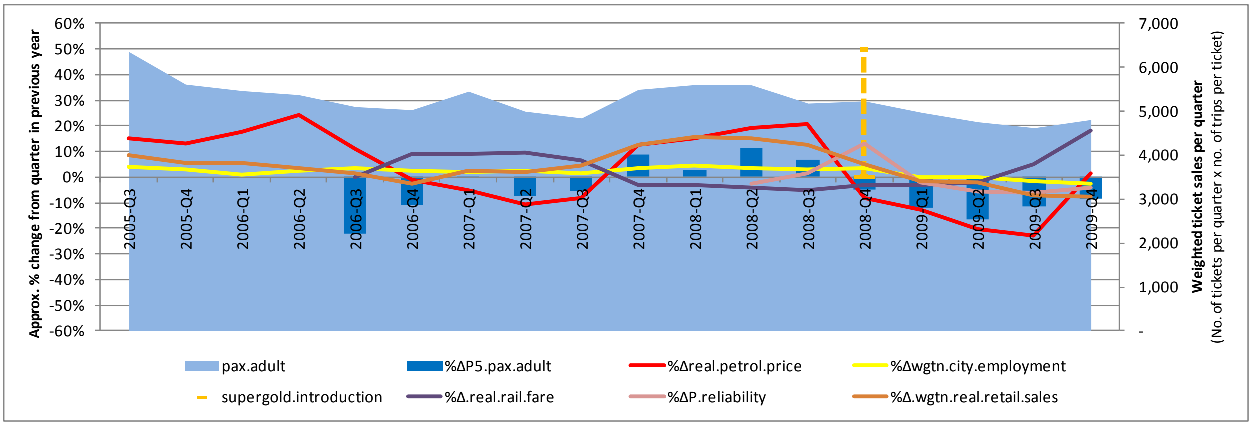


Figure D.21 Wellington – Porirua (zone 5) – analysis of 10-trip ticket sales

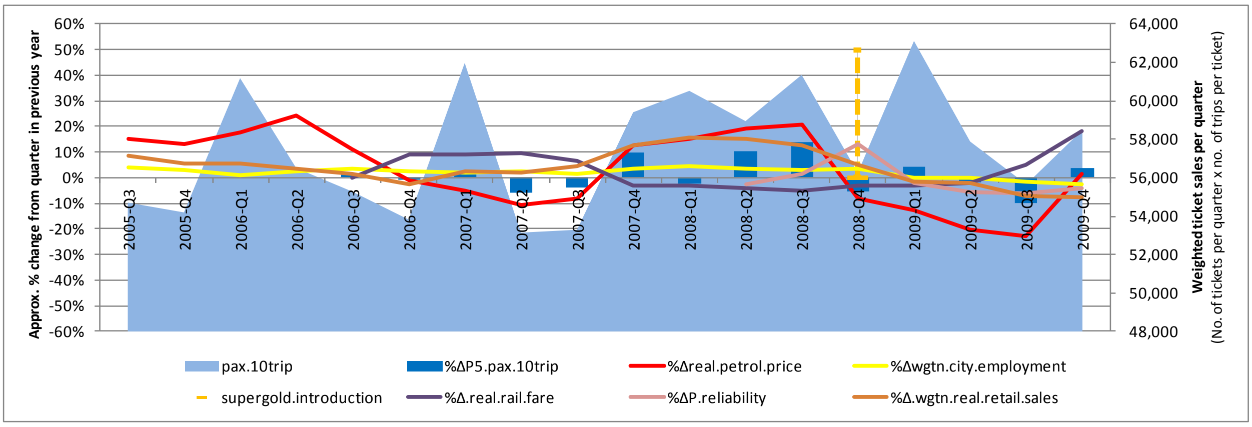
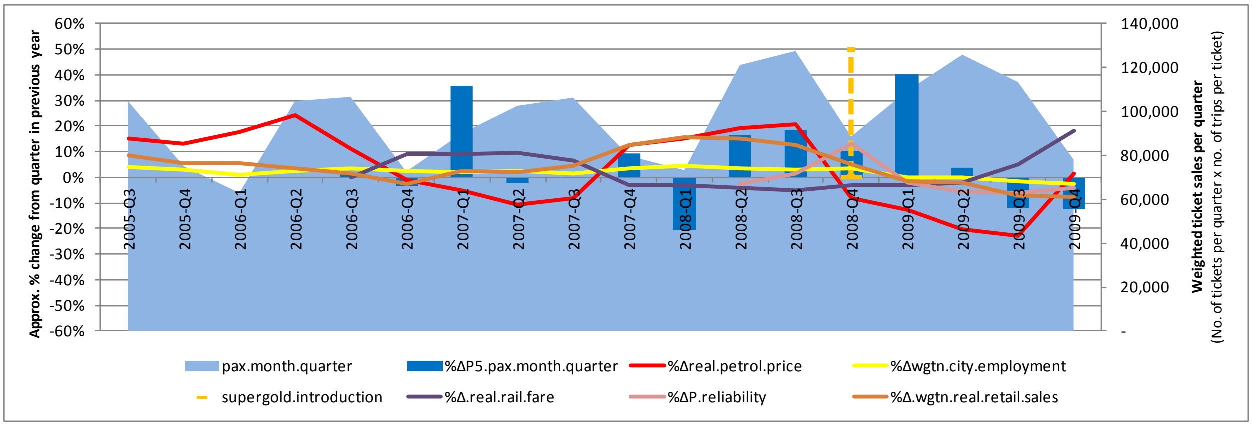


Figure D.22 Wellington – Porirua (zone 5) – analysis of monthly and quarterly ticket sales



D3.4.3 Graphs for Wellington to/from Plimmerton (zone 6, Paraparaumu)

Figure D.23 Wellington – Plimmerton (zone 6) – analysis of adult (single) ticket sales

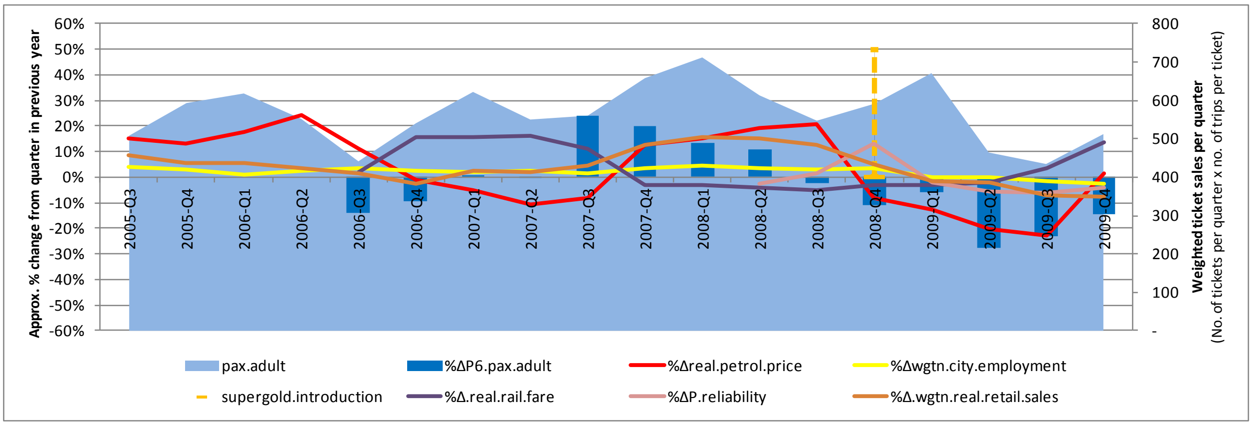


Figure D.24 Wellington – Plimmerton (zone 6) – analysis of 10-trip ticket sales

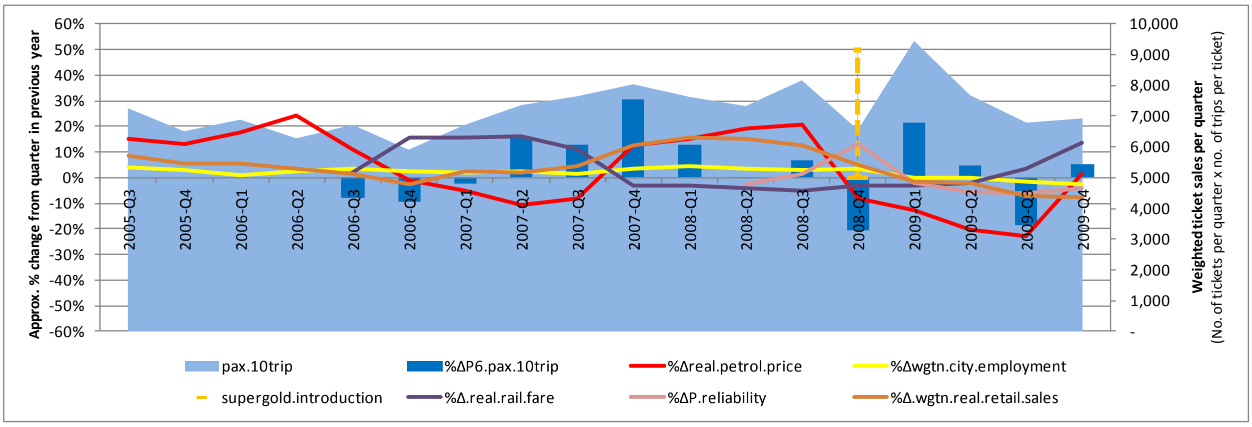
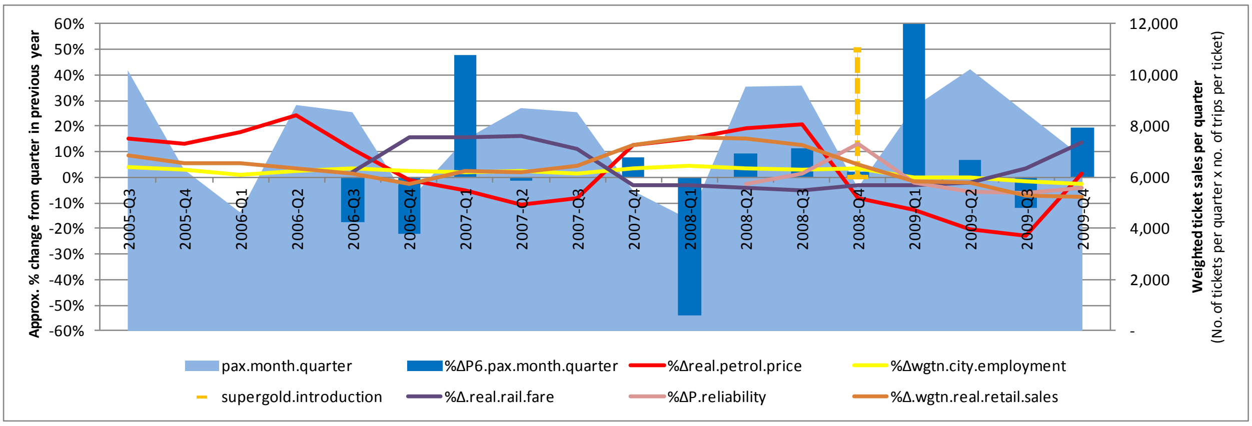


Figure D.25 Wellington – Plimmerton (zone 6) – analysis of monthly and quarterly ticket sales



D3.4.4 Graphs for Wellington to/from Muri (zone 7, Paraparaumu)

Figure D.26 Wellington – Muri (zone 7) – analysis of adult (single) ticket sales

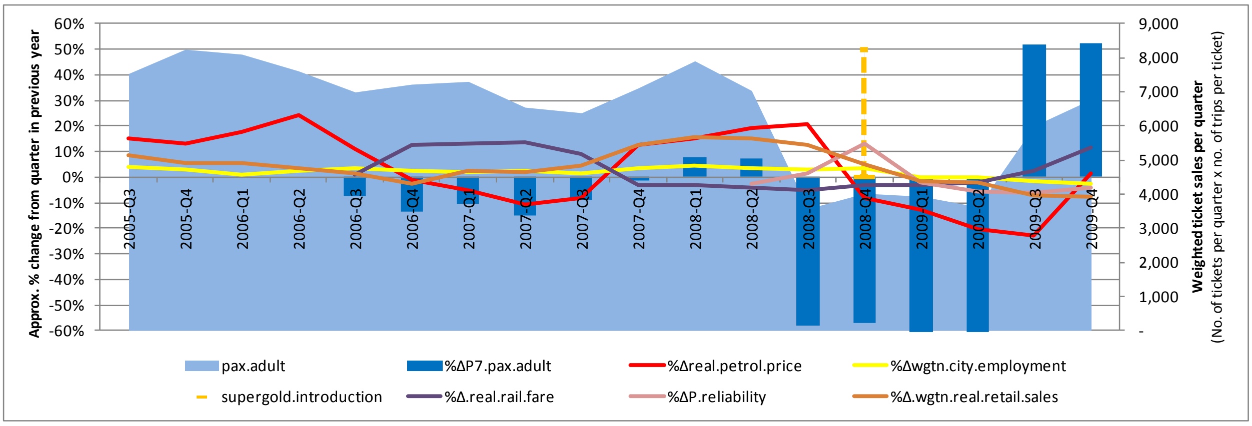


Figure D.27 Wellington – Muri (zone 7) – analysis of 10-trip ticket sales

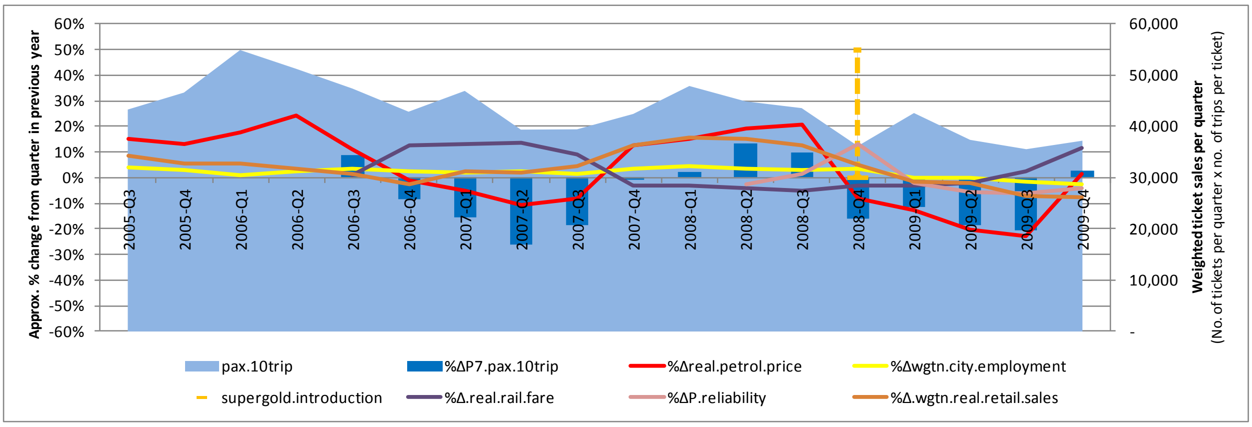
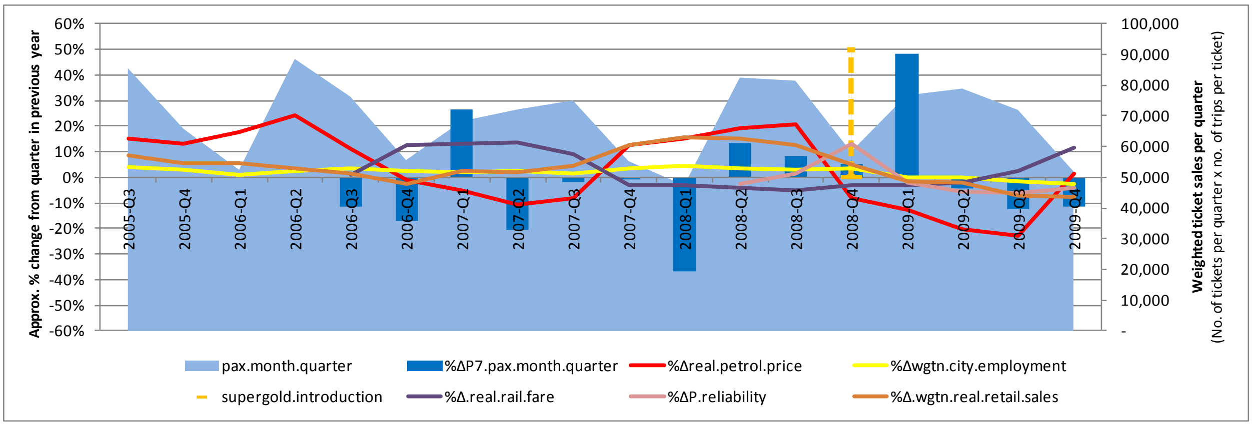


Figure D.28 Wellington – Muri (zone 7) – analysis of monthly and quarterly ticket sales



D3.4.5 Graphs for Wellington to/from Paekakariki (zone 8, Paraparaumu)

Figure D.29 Wellington – Paekakariki (zone 8) – analysis of adult (single) ticket sales

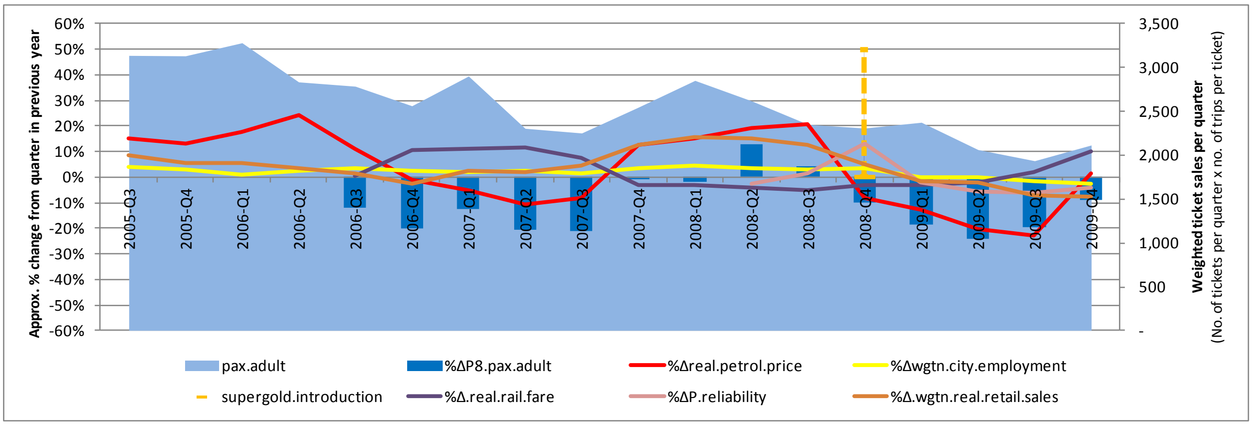


Figure D.30 Wellington – Paekakariki (zone 8) – analysis of 10-trip ticket sales

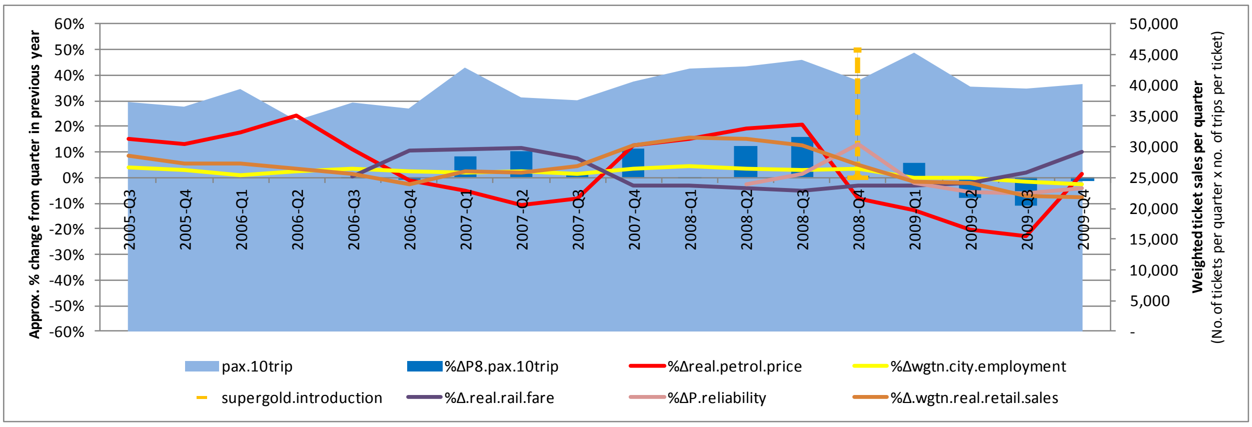
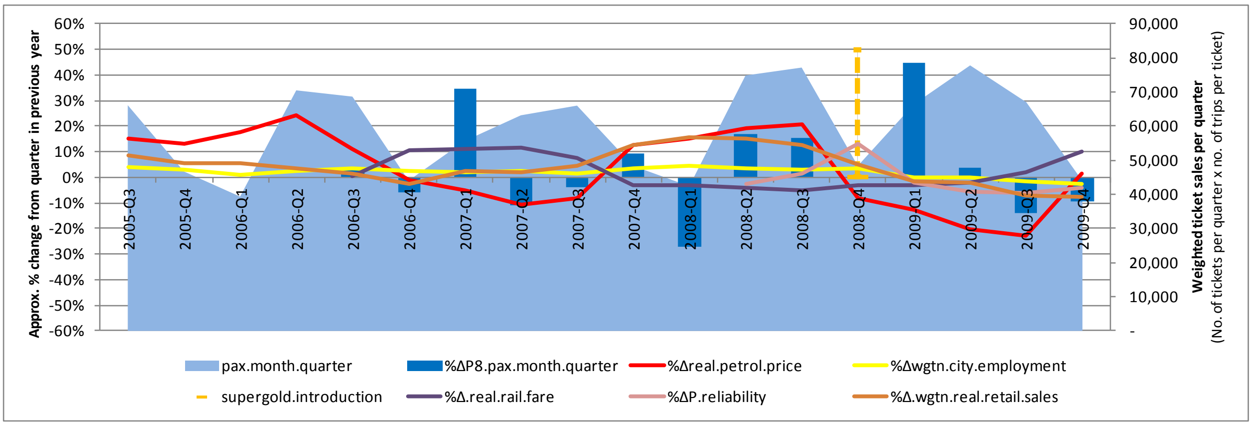


Figure D.31 Wellington – Paekakariki (zone 8) – analysis of monthly and quarterly ticket sales



D3.4.6 Graphs for Wellington to/from Pararapumu (zone 9, Paraparaumu)

Figure D.32 Wellington – Paraparaumu (zone 9) – analysis of adult (single) ticket sales

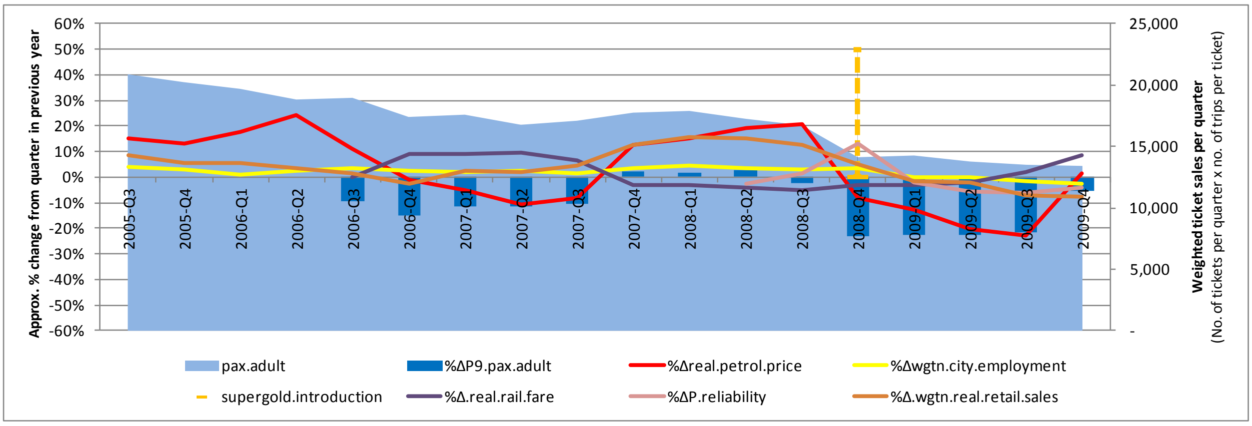


Figure D.33 Wellington – Paraparaumu (zone 9) – analysis of 10-trip ticket sales

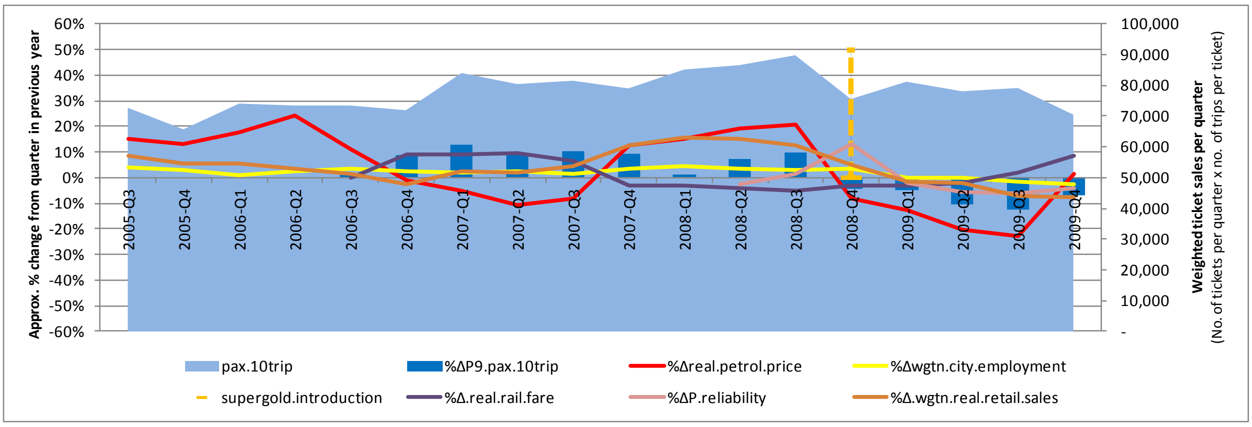
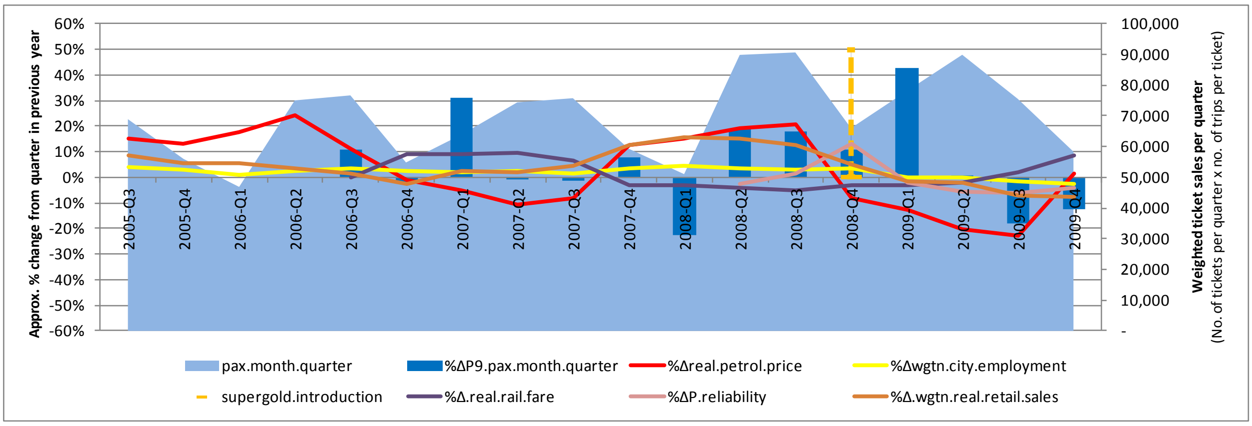


Figure D.34 Wellington – Paraparaumu (zone 9) – analysis of monthly and quarterly ticket sales



D4 Data analysis

D4.1 Multicollinearity analysis

As noted in section 2.4.1 of the main report, high correlations between explanatory variables can make econometric estimation difficult. This section uses correlation tables to examine the extent to which such correlations might be problematic.

Table D.3 shows the correlations between the explanatory variables for the period from 2006-Q3 to 2009-Q4. A number of these correlations are quite high. In part, this is due to the short period covered; with only three years of data (after seasonal differencing) there is always a high likelihood that some variables are correlated – this problem would be mitigated if data for a longer period was available.

Table D.3 Correlations between explanatory variables for period from 2006-Q3 to 2009-Q4

	dip.month.tix.Jan.Feb.06	dip.month.tix.Jan.Feb.08	dip.10trip.tix.Jville.Jan.Feb.09	real.rail.fare	real.petrol.price	petrol.price.threshold.dummy.2dollar	supergoldcard.dummy.Oct08	Easter.dummy	wgtn.city.employment	wgtn.city.real.retail.sales	extra.commuter.services.dummy.Nov08
dip.month.tix.Jan.Feb.06	1.0										
dip.month.tix.Jan.Feb.08	0.0	1.0									
dip.10trip.tix.Jville.Jan.Feb.09	0.0	-0.2	1.0								
real.rail.fare	-0.4	0.0	-0.1	1.0							
real.petrol.price	0.1	0.4	-0.1	-0.3	1.0						
petrol.price.threshold.dummy.2dollar	0.0	0.0	0.0	-0.2	0.8	1.0					
supergoldcard.dummy.Oct08	0.2	-0.4	0.1	-0.4	-0.7	-0.6	1.0				
Easter.dummy	0.0	0.7	-0.2	0.0	-0.1	-0.5	0.0	1.0			
wgtn.city.employment	0.0	0.4	-0.1	-0.3	0.6	0.5	-0.4	0.1	1.0		
wgtn.city.real.retail.sales	0.0	0.4	-0.1	-0.6	0.8	0.7	-0.4	0.0	0.8	1.0	
extra.commuter.services.dummy.Nov08	0.2	-0.4	-0.1	-0.2	-0.7	-0.6	0.9	0.0	-0.6	-0.5	1.0

There was a +0.8 correlation between (general) real petrol price fluctuations and the crossing of the nominal $2.00 petrol price threshold; this could make distinguishing between the two components of petrol price impacts difficult. Therefore, we experimented with different combinations of these two components during the model building process (see section D5).

There were strong correlations with real retail sales: a +0.8 correlation with the real petrol price; and a +0.8 correlation with employment. We therefore had concerns about the impact of this variable and tested the impact of its removal during the model building process (see section D5); the general finding was that the removal of real retail sales improved the plausibility of coefficients for the remaining variables, and also made the time-trends more plausible.

Finally, the introduction of extra commuter services on the Hutt and Paraparaumu lines in November 2003 had a very strong +0.9 correlation with the introduction of the SuperGold Card (October 2008). This problem was difficult to address. Both these variables were retained but the uncertainties surrounding the subsequent estimates were noted in our analysis.

D4.2 Stationarity analysis

In section 2.4.2 of the main report we noted that the conventional approach in transport economics is to carry out econometric regressions with all the variables defined in levels. However, with this approach, there is a risk that the regressions can lead to spurious results if the variables are classed as nonstationary (ie they exhibit strong trends over time).

Our approach to mitigate this risk is to take seasonal differences and to look at growth rates in patronage and explanatory variables between one quarter and the preceding quarters. There is still some risk of nonstationarity and/or insufficient variation in the explanatory variables so we have proceeded with formal testing to further mitigate against the risk of spurious results.

Table D.5 shows testing for stationarity or nonstationarity of key explanatory variables. These tests were inconclusive. But this is unsurprising due to the short period covered (ie four years of data). However, a glance at the graphs of the data shown in section D3 gives weight to our assumption of stationarity.

Table D.5 Stationarity of continuous explanatory variables

		Augmented Dickey Fuller Test for stationarity[(a)]			KPSS test for nonstationarity[(a)]			
		Null hypothesis: variable is nonstationary			Null hypothesis: variable is stationary			
Variable[(b)]	**Period**	**Critical value**	**p-value**	**Decision**	**Critical value**	**p-value**	**Decision**	**Conclusion**
%Δ in real petrol prices	2005-Q4 to 2009-Q4	-1.50	0.76	Do not reject null → series is nonstationary	0.092	>0.10	Do not reject null → series is stationary	Inconclusive
%Δ in real retail sales	2005-Q4 to 2009-Q4	-1.35	0.82	Do not reject null → series is nonstationary	0.103	>0.10	Do not reject null → series is stationary	Inconclusive
%Δ in employment	2005-Q4 to 2009-Q4	-0.37	0.98	Do not reject null → series is nonstationary	0.111	>0.10	Do not reject null → series is stationary	Inconclusive

[(a)] The ADF test incorporated 4 lags and the KPSS test employed a long version of the truncation lag parameter, which had 4-5 lags.

[(b)] Service variables and real fare were excluded from the analysis because they represent ‘one-off’ structural changes that cannot plausibly be regarded as stationary, regardless of the results of empirical testing.

Tables D.6 to D.9 show testing for stationarity or nonstationarity of dependent variables. Again, these tests are inconclusive due to the short period.

Table D.6 Stationarity of dependent variable (aggregate ticket sales)

			Augmented Dickey Fuller Test for stationarity[(a)]			KPSS test for nonstationarity[(a)]			
			Null hypothesis: variable is nonstationary			Null hypothesis: variable is stationary			
Variable	**Line and zone**	**Period**	**t-statistic**	**p-value**	**Decision**	**t-statistic**	**p-value**	**Decision**	**Conclusion**
%Δ in aggregate ticket sales	H4	2005-Q4 to 2009-Q4	-1.25	0.86	Do not reject null → series is nonstationary	0.23	>0.10	Do not reject null → series is stationary	Inconclusive
%Δ in aggregate ticket sales	H5	2005-Q4 to 2009-Q4	-1.26	0.86	Do not reject null → series is nonstationary	0.15	>0.10	Do not reject null → series is stationary	Inconclusive
%Δ in aggregate ticket sales	H6	2005-Q4 to 2009-Q4	-1.01	0.92	Do not reject null → series is nonstationary	0.14	>0.10	Do not reject null → series is stationary	Inconclusive
%Δ in aggregate ticket sales	H7	2005-Q4 to 2009-Q4	-1.07	0.91	Do not reject null → series is nonstationary	0.13	>0.10	Do not reject null → series is stationary	Inconclusive
%Δ in aggregate ticket sales	J3	2005-Q4 to 2009-Q4	-2.10	0.54	Do not reject null → series is nonstationary	0.12	>0.10	Do not reject null → series is stationary	Inconclusive
%Δ in aggregate ticket sales	P4	2005-Q4 to 2009-Q4	0.39	0.99	Do not reject null → series is nonstationary	0.13	>0.10	Do not reject null → series is stationary	Inconclusive
%Δ in aggregate ticket sales	P5	2005-Q4 to 2009-Q4	-0.57	0.97	Do not reject null → series is nonstationary	0.13	>0.10	Do not reject null → series is stationary	Inconclusive
%Δ in aggregate ticket sales	P6	2005-Q4 to 2009-Q4	-1.79	0.65	Do not reject null → series is nonstationary	0.14	>0.10	Do not reject null → series is stationary	Inconclusive
%Δ in aggregate ticket sales	P7	2005-Q4 to 2009-Q4	-0.63	0.96	Do not reject null → series is nonstationary	0.12	>0.10	Do not reject null → series is stationary	Inconclusive
%Δ in aggregate ticket sales	P8	2005-Q4 to 2009-Q4	-0.68	0.96	Do not reject null → series is nonstationary	0.14	>0.10	Do not reject null → series is stationary	Inconclusive
%Δ in aggregate ticket sales	P9	2005-Q4 to 2009-Q4	-0.72	0.96	Do not reject null → series is nonstationary	0.18	>0.10	Do not reject null → series is stationary	Inconclusive

(a) The ADF test incorporated 4 lags and the KPSS test employed a long version of the truncation lag parameter, which had 3 lags.

Table D.7 Stationarity of dependent variable (monthly and quarterly ticket sales)

			Augmented Dickey Fuller Test for stationarity[a]			KPSS test for nonstationarity[a]			
			Null hypothesis: variable is nonstationary			Null hypothesis: variable is stationary			
Variable	Line and zone	Period	t-statistic	p-value	Decision	t-statistic	p-value	Decision	Conclusion
%Δ in monthly/quarterly ticket sales	H4	2005–Q4 to 2009–Q4	-0.84	0.94	Do not reject null → series is nonstationary	0.17	>0.10	Do not reject null → series is stationary	Inconclusive
%Δ in monthly/quarterly ticket sales	H5	2005–Q4 to 2009–Q4	-1.22	0.87	Do not reject null → series is nonstationary	0.15	>0.10	Do not reject null → series is stationary	Inconclusive
%Δ in monthly/quarterly ticket sales	H6	2005–Q4 to 2009–Q4	-0.69	0.96	Do not reject null → series is nonstationary	0.13	>0.10	Do not reject null → series is stationary	Inconclusive
%Δ in monthly/quarterly ticket sales	H7	2005–Q4 to 2009–Q4	-0.79	0.95	Do not reject null → series is nonstationary	0.13	>0.10	Do not reject null → series is stationary	Inconclusive
%Δ in monthly/quarterly ticket sales	J3	2005–Q4 to 2009–Q4	-0.88	0.94	Do not reject null → series is nonstationary	0.11	>0.10	Do not reject null → series is stationary	Inconclusive
%Δ in monthly/quarterly ticket sales	P4	2005–Q4 to 2009–Q4	-0.58	0.97	Do not reject null → series is nonstationary	0.12	>0.10	Do not reject null → series is stationary	Inconclusive
%Δ in monthly/quarterly ticket sales	P5	2005–Q4 to 2009–Q4	-0.46	0.98	Do not reject null → series is non--stationary	0.12	>0.10	Do not reject null → series is stationary	Inconclusive
%Δ in monthly/quarterly ticket sales	P6	2005–Q4 to 2009–Q4	-1.10	0.91	Do not reject null → series is nonstationary	0.13	>0.10	Do not reject null → series is stationary	Inconclusive
%Δ in monthly/quarterly ticket sales	P7	2005–Q4 to 2009–Q4	-0.30	0.98	Do not reject null → series is nonstationary	0.12	>0.10	Do not reject null → series is stationary	Inconclusive
%Δ in monthly/quarterly ticket sales	P8	2005–Q4 to 2009–Q4	-0.51	0.97	Do not reject null → series is nonstationary	0.12	>0.10	Do not reject null → series is stationary	Inconclusive
%Δ in monthly/quarterly ticket sales	P9	2005–Q4 to 2009–Q4	-0.49	0.98	Do not reject null → series is nonstationary	0.13	>0.10	Do not reject null → series is stationary	Inconclusive

[a] The ADF test incorporated 4 lags and the KPSS test employed a long version of the truncation lag parameter, which had 3 lags.

Table D.8 Stationarity of dependent variable (10-trip ticket sales)

			Augmented Dickey Fuller Test for stationarity[(a)]			KPSS test for nonstationarity[(a)]			
			Null hypothesis: variable is nonstationary			Null hypothesis: variable is stationary			
Variable	**Line and Zone**	**Period**	**t-statistic**	**p-value**	**Decision**	**t-statistic**	**p-value**	**Decision**	**Conclusion**
%Δ in 10-trip ticket sales	H4	2005–Q4 to 2009–Q4	-1.74	0.67	Do not reject null → series is nonstationary	0.33	>0.10	Do not reject null → series is stationary	Inconclusive
%Δ in 10-trip ticket sales	H5	2005–Q4 to 2009–Q4	-2.05	0.55	Do not reject null → series is nonstationary	0.09	>0.10	Do not reject null → series is stationary	Inconclusive
%Δ in 10-trip ticket sales	H6	2005–Q4 to 2009–Q4	-2.22	0.49	Do not reject null → series is nonstationary	0.17	>0.10	Do not reject null → series is stationary	Inconclusive
%Δ in 10-trip ticket sales	H7	2005–Q4 to 2009–Q4	-0.80	0.95	Do not reject null → series is nonstationary	0.11	>0.10	Do not reject null → series is stationary	Inconclusive
%Δ in 10-trip ticket sales	J3	2005–Q4 to 2009–Q4	-1.75	0.67	Do not reject null → series is nonstationary	0.14	>0.10	Do not reject null → series is stationary	Inconclusive
%Δ in 10-trip ticket sales	P4	2005–Q4 to 2009–Q4	-1.64	0.71	Do not reject null → series is nonstationary	0.11	>0.10	Do not reject null → series is stationary	Inconclusive
%Δ in 10-trip ticket sales	P5	2005–Q4 to 2009–Q4	-0.43	0.98	Do not reject null → series is nonstationary	0.10	>0.10	Do not reject null → series is stationary	Inconclusive
%Δ in 10-trip ticket sales	P6	2005–Q4 to 2009–Q4	-1.45	0.78	Do not reject null → series is nonstationary	0.11	>0.10	Do not reject null → series is stationary	Inconclusive
%Δ in 10-trip ticket sales	P7	2005–Q4 to 2009–Q4	0.91	0.99	Do not reject null → series is nonstationary	0.11	>0.10	Do not reject null → series is stationary	Inconclusive
%Δ in 10-trip ticket sales	P8	2005–Q4 to 2009–Q4	-2.10	0.53	Do not reject null → series is nonstationary	0.10	>0.10	Do not reject null → series is stationary	Inconclusive
%Δ in 10-trip ticket sales	P9	2005–Q4 to 2009–Q4	-2.09	0.54	Do not reject null → series is nonstationary	0.24	>0.10	Do not reject null → series is stationary	Inconclusive

[(a)] The ADF test incorporated 4 lags and the KPSS test employed a long version of the truncation lag parameter, which had 3 lags.

Table D.9 Stationarity of dependent variable (adult ticket sales)

			Augmented Dickey Fuller Test for stationarity[a]			KPSS test for nonstationarity[a]			
			Null hypothesis: variable is nonstationary			Null hypothesis: variable is stationary			
Variable	Line and Zone	Period	t-statistic	p-value	Decision	t-statistic	p-value	Decision	Conclusion
%Δ in adult ticket sales	H4	2005–Q4 to 2009–Q4	-2.21	0.49	Do not reject null → series is nonstationary	0.15	>0.10	Do not reject null → series is stationary	Inconclusive
%Δ in adult ticket sales	H5	2005–Q4 to 2009–Q4	-2.07	0.54	Do not reject null → series is nonstationary	0.10	>0.10	Do not reject null → series is stationary	Inconclusive
%Δ in adult ticket sales	H6	2005–Q4 to 2009–Q4	-0.95	0.93	Do not reject null → series is nonstationary	0.11	>0.10	Do not reject null → series is stationary	Inconclusive
%Δ in adult ticket sales	H7	2005–Q4 to 2009–Q4	-1.72	0.68	Do not reject null → series is nonstationary	0.10	>0.10	Do not reject null → series is stationary	Inconclusive
%Δ in adult ticket sales	J3	2005–Q4 to 2009–Q4	-2.26	0.47	Do not reject null → series is nonstationary	0.08	>0.10	Do not reject null → series is stationary	Inconclusive
%Δ in adult ticket sales	P4	2005–Q4 to 2009–Q4	-2.14	0.52	Do not reject null → series is nonstationary	0.08	>0.10	Do not reject null → series is stationary	Inconclusive
%Δ in adult ticket sales	P5	2005–Q4 to 2009–Q4	-1.76	0.66	Do not reject null → series is nonstationary	0.18	>0.10	Do not reject null → series is stationary	Inconclusive
%Δ in adult ticket sales	P6	2005–Q4 to 2009–Q4	-1.63	0.71	Do not reject null → series is nonstationary	0.14	>0.10	Do not reject null → series is stationary	Inconclusive
%Δ in adult ticket sales	P7	2005–Q4 to 2009–Q4	-2.04	0.56	Do not reject null → series is nonstationary	0.12	>0.10	Do not reject null → series is stationary	Inconclusive
%Δ in adult ticket sales	P8	2005–Q4 to 2009–Q4	-1.51	0.76	Do not reject null → series is nonstationary	0.07	>0.10	Do not reject null → series is stationary	Inconclusive
%Δ in adult ticket sales	P9	2005–Q4 to 2009–Q4	-2.29	0.46	Do not reject null → series is nonstationary	0.08	>0.10	Do not reject null → series is stationary	Inconclusive

(a) The ADF test incorporated 4 lags and the KPSS test employed a long version of the truncation lag parameter, which had 3 lags.

D4.3 Endogeneity issues

In section 2.4.3 we note that endogeneity or 'reverse causation' is another statistical issue that needs to be given careful consideration. In particular, the econometric models adopted in this research project assume that patronage growth is 'caused' by service improvements. However, it is conceivable that transport operators improve service levels as a means of coping with patronage demand.

We only had information in regard to one service improvement: in November 2008, four extra commuting services per working day were added on both the Hutt and Paraparaumu lines. They were not added on the Johnsonville line. It is possible that endogeneity is an issue here because the extra capacity on the Hutt and Paraparaumu lines may have been a response to crowding. It is also possible that patronage growth around this time was lower on the Johnsonville line for reasons unrelated to the lack of extra services. For all these reasons, we advise that the estimates in regard to service improvements be regarded with some caution.

D5 Model building process

D5.1 Development of the model for monthly and quarterly ticket sales

The model building process began with building a general model for sales of monthly and quarterly tickets. The sales of quarterly tickets were weighted to reflect the fact that they represent three times as much patronage as monthly tickets.

This general model encompassed a broad collection of explanatory variables and key factors. It included dummy variables to account for the unexplained dips in patronage.

Table D.10 shows how the general model was whittled down to produce the preferred model.

We had concerns about the high correlation between real retail sales and other explanatory variables, as discussed in section D4.1. We also had concerns about the accuracy of estimates associated with real retail sales given the short period covered. We therefore experimented with removing real retail sales, hence creating model 2. We found that removing real retail sales generally improved the plausibility of the remaining coefficients, most notably real rail fare and employment. The time trends also became closer to zero with real retail sales omitted. For all these reasons, we regarded model 2 as preferable to the general model.

We then removed Easter from model 2 because it had an implausible sign. This produced model 3 which continued to have an implausible sign for SuperGold (noting that the ticket sales data provided excluded SuperGold Cards) so this was removed as well, producing model 4.

Model 4 remained problematic because the real petrol price elasticity was negative. In section D4.1 we noted that the strong +0.8 correlation between the real petrol price and the nominal $2.00 petrol price threshold could make it difficult to distinguish between these two related effects. Therefore, we tested omitting each of these variables in turn with model 5 and model 6.

Both model 5 and model 6 produced interesting and plausible results. We consider that model 5 probably better reflected responses to petrol price changes. Model 5 also produced more plausible time trends so it was selected as our preferred model. However, model 6 also has merit so it is worth noting that model 6 produced slightly different findings (ie the fare elasticity was lower, the employment elasticity was higher and the estimated impact of services improvements on rail patronage was higher).

Table D.10 Development of the model for monthly and quarterly ticket sales

Time trends and explanatory variables		General	Model 2	Model 3	Model 4	Model 5 (preferred)	Model 6
Time trend	Hutt zone 4 – Waterloo Melling	-12%**	-9%*	-8%*	-8%*	-5%	-9%**
	Hutt zone 5 – Taita.Pomare	-6%	-3%	-2%	-1%	1%	-2%
	Hutt zone 6 – Trentham	-11%*	-7%‘	-6%	-5%	-3%	-7%*
	Hutt zone 7 – Upper Hutt	-7%	-3%	-2%	-2%	0%	-3%
	Jvill zone 3	-14%***	-10%**	-9%**	-8%**	-7%**	-8%***
	Para zone 4 – Linden	-11%**	-8%*	-7%*	-6%*	-4%	-7%**
	Para zone 5 – Porirua	-5%	-2%	-2%	-1%	1%	-2%
	Para zone 6 – Plimmerton	-8%*	-4%	-3%	-3%	0%	-4%
	Para zone 7 – Muri	-13%**	-9%*	-8%*	-8%*	-6%	-9%**
	Para zone 8 – Paekakariki	-8%*	-5%	-4%	-3%	-1%	-5%
	Para zone 9 – Paraparaumu	-5%	-3%	-2%	-2%	0%	-3%
Dip in monthly ticket sales (Jan/Feb 06)		-36%***	-39%***	-39%***	-39%***	-40%***	-39%***
Dip in monthly ticket sales (Jan/Feb 08)		-50%***	-42%***	-38%***	-39%***	-44%***	-40%***
Extra commuter services (Nov 08)		6%	8%	7%	11%*	7%	14%**
Real rail fare		0.23	-0.39	-0.46‘	-0.57*	-0.65*	-0.45*
Real petrol price		0.17	-0.07	-0.08	-0.16	0.14	Omitted to test interaction with $2 threshold
Nominal $2.00 petrol price threshold		20%*	31%***	25%***	24%***	Omitted to test interaction with real petrol price	21%***
Real retail sales (Wellington city)		0.87*	Omitted due to interaction with employment				
Employment (Wellington city)		0.07	1.53 *	1.44 *	1.58*	1.33‘	1.65*
Introduction of SuperGold Card (Oct 08)		14%	7%	6%	Removed due to implausible sign		
Easter		8%*	5%	Removed due to implausible sign			

D5.2 Development of the model for 10-trip ticket sales

The general model for 10-trip ticket sales also encompassed a broad collection of explanatory variables and key factors. We also incorporated a dummy variable to control for the dip in rail patronage on the Johnsonville line.

Table D.11 shows how the general model for sales of 10-trip tickets was whittled down to become the preferred model. We followed a similar process to that with the monthly and quarterly ticket sales model (see section D5.1). We experimented with removing real retail sales, hence creating model 2. We found that removing real retail sales generally improved the plausibility of the remaining coefficients, including employment.

As with the monthly and quarterly ticket sales model, we had concerns about the correlation between the real petrol price and the nominal $2.00 petrol price threshold. We again tested omitting each of the petrol price variables in turn with model 3 and model 4.

Overall, we expressed a preference for model 2 (incorporating both the real petrol price and $2.00 petrol price threshold) because it produced time trends close to zero while still representing the complex nature of responses to petrol prices.

Table D.11 Development of model for 10-trip ticket sales

Time trends and explanatory variables		General model	Model 2 (preferred)	Model 3	Model 4
Time trends	Hutt zone 4 – Waterloo.Melling	0%	2%	4%	2%
	Hutt zone 5 – Taita.Pomare	-3%	-1%	1%	-1%
	Hutt zone 6 – Trentham	-2%	1%	3%	1%
	Hutt zone 7 – Upper.Hutt	0%	3%	5%	3%
	Jvill zone 3	3%	6%‘	8%*	6%‘
	Para zone 4 – Linden	5%	7%*	9%**	7%*
	Para zone 5 – Porirua	-1%	2%	4%	2%
	Para zone 6 – Plimmerton	3%	6%	8%*	6%‘
	Para zone 7 – Muri	-8%*	-6%	-4%	-6%
	Para zone 8 – Paekakariki	2%	4%	6%	4%
	Para zone 9 – Paraparaumu	0%	2%	4%	2%
Dip in adult and 10-trip ticket sales on Johnsonville Line (Jan/Feb 09)		-46%***	-46%***	-46%***	-46%***
Extra commuter services (Nov 08)		25%**	26%**	25%**	26%**
Real rail fare		-0.30	-0.73*	-0.83**	-0.73***
Real petrol price		0.01	0.01	0.13	Omitted to test interaction with $2 threshold
Nominal $2.00 petrol price threshold		6%	15%‘	Omitted to test interaction with real petrol price	15%‘
Real retail sales (Wellington city)		0.92**	Omitted due to interaction with employment		
Employment (Wellington city)		-0.82	0.77	0.57	0.77
Introduction of SuperGold Card (Oct 08)		-26%**	-28%***	-32%***	-28%***
Easter		-1%	1%	-1%	1%

D5.3 Development of the model for adult (single) ticket sales

We developed a general model for sales of adult (single) tickets. This model also incorporated a dummy variable to control for the dip in rail patronage on the Johnsonville line.

Table D.12 shows how we developed a preferred model for sales of adult tickets. Again, we followed a similar process to that with the monthly and quarterly ticket sales model (see section D5.1). We experimented with removing real retail sales, hence creating model 2. We found that removing real retail sales generally improved the plausibility of the remaining coefficients, including the time trends and employment.

We then removed SuperGold from model 2 due to an incorrect sign, hence producing model 3.

The coefficients for both the real fare and the $2.00 nominal petrol price threshold had implausible signs so both were removed, leading to model 4, the preferred model.

Table D.12 Development of the model for adult (single) ticket sales

Time trends and explanatory variables		General model	Model 2	Model 3	Model 4 (preferred)	Model 5
Time trends	Hutt zone 4 – Waterloo Melling	-14%***	-13%***	-12%***	-11%***	-11%***
	Hutt zone 5 – Taita Pomare	-17%***	-15%***	-15%***	-14%***	-14%***
	Hutt zone 6 – Trentham	-14%***	-12%**	-12%**	-10%***	-10%***
	Hutt zone 7 – Upper Hutt	-12%*	-10%‘	-9%‘	-8%‘	-8%‘
	Jvill zone 3	-15%***	-13%***	-12%***	-11%***	-11%***
	Para zone 4 – Linden	-17%***	-16%***	-15%***	-14%***	-14%***
	Para zone 5 – Porirua	-11%**	-9%*	-9%*	-7%*	-7%*
	Para zone 6 – Plimmerton	-9%*	-6%‘	-6%‘	-4%*	-4%*
	Para zone 8 – Paekakariki	-16%***	-14%***	-14%***	-13%***	-13%***
	Para zone 9 – Paraparaumu	-16%***	-14%***	-14%***	-13%***	-13%***
Dip in adult and 10-trip ticket sales on Johnsonville line (Jan/Feb 09)		-38%***	-37%***	-36%***	-37%***	-38%***
Extra commuter services (Nov 08)		1%	3%	6%	3%	2%
Real rail fare		0.67*	0.23	0.16	Removed due to implausible sign	
Real petrol price		0.46*	0.42*	0.38*	0.28	Omitted to test interaction with $2 threshold
Nominal $2.00 petrol price threshold		-13%	-1%	-2%	Removed due to implausible sign	9%
Real retail sales (Wellington city)		1.05***	Removed due to implausible sign			
Employment (Wellington city)		-0.86	1.14	1.26‘	1.01‘	1.22*
Introduction of SuperGold Card (Oct 08)		7%	4%	Removed due to implausible sign		
Easter		-5%**	-3%‘	-3%‘	-3%*	-2%

D5.4 Development of the model for aggregate ticket sales

Table D.13 shows the model development process for a model for a model to explain growth in sales of all of the most common ticket types: adult (single), 10-trip, monthly and quarterly. These ticket sales were weighted by the average number of trips per ticket, and then aggregated.

As with the disaggregated models, the removal of real retail sales improved the plausibility of the remaining coefficients, including real rail fare and the time trends, leading to model 2. During the next iteration we removed Easter due to an implausible sign, leading to model 3.

We then used model 4 and model 5 to test the impact, respectively, of omitting *real petrol price* and then the *$2.00 nominal petrol price threshold*. Model 4 was selected as the preferred model, in part because in produced time trends that were close to zero.

Table D.13 Development of the model for aggregate ticket sales

Time trends and explanatory variables		General model	Model 2	Model 3	Model 4 (preferred)	Model 5
Time trend	Hutt zone 4 – Waterloo Melling	-11%***	-5%‘	-5%‘	-3%	-6%*
	Hutt zone 5 – Taita Pomare	-8%**	-2%	-2%	0%	-3%
	Hutt zone 6 – Trentham	-11%***	-4%	-4%	-2%	-5%‘
	Hutt zone 7 – Upper Hutt	-8%*	-1%	-2%	1%	-2%
	Jvill zone 3	-10%***	-4%	-3%	-2%	-4%‘
	Para zone 4 – Linden	-8%**	-3%	-3%	-1%	-3%
	Para zone 5 – Porirua	-7%*	-1%	-1%	1%	-2%
	Para zone 6 – Plimmerton	-8%**	-1%	-1%	1%	-2%
	Para zone 7 – Muri	-15%***	-9%**	-8%**	-6%*	-9%**
	Para zone 8 – Paekakariki	-7%**	-2%	-2%	0%	-2%
	Para zone 9 – Paraparaumu	-8%**	-3%	-3%	-1%	-3%
Dip in monthly ticket sales (Jan/Feb 06)		-16%***	-20%***	-22%***	-21%***	-22%***
Dip in monthly ticket sales (Jan/Feb 08)		-38%***	-27%***	-21%***	-25%***	-21%***
Dip in adult and 10-trip ticket sales on Johnsonville line (Jan/Feb 09)		-28%**	-28%**	-25%*	-28%**	-25%*
Extra commuter services (Nov 08)		13%*	16%*	17%**	15%*	17%**
Real rail fare		0.49‘	-0.44‘	-0.57**	-0.60**	-0.51**
Real petrol price		0.30‘	0.00	-0.07	0.16	Omitted to test interaction with $2 threshold
Nominal $2.00 petrol price threshold		3%	24%***	16%**	Omitted to test interaction with real petrol price	15%**
Real retail sales (Wellington city)		1.46***	Omitted due to interaction with employment			
Employment (Wellington city)		-0.52	1.51*	1.80**	1.44*	1.79**
Introduction of SuperGold Card (Oct 08)		1%	-9%	-11%‘	-13%‘	-10%‘
Easter		8%**	6%*	Removed due to implausible sign		

D6 Diagnostic analysis

D6.1 Diagnostic analysis for the model for monthly and quarterly ticket sales

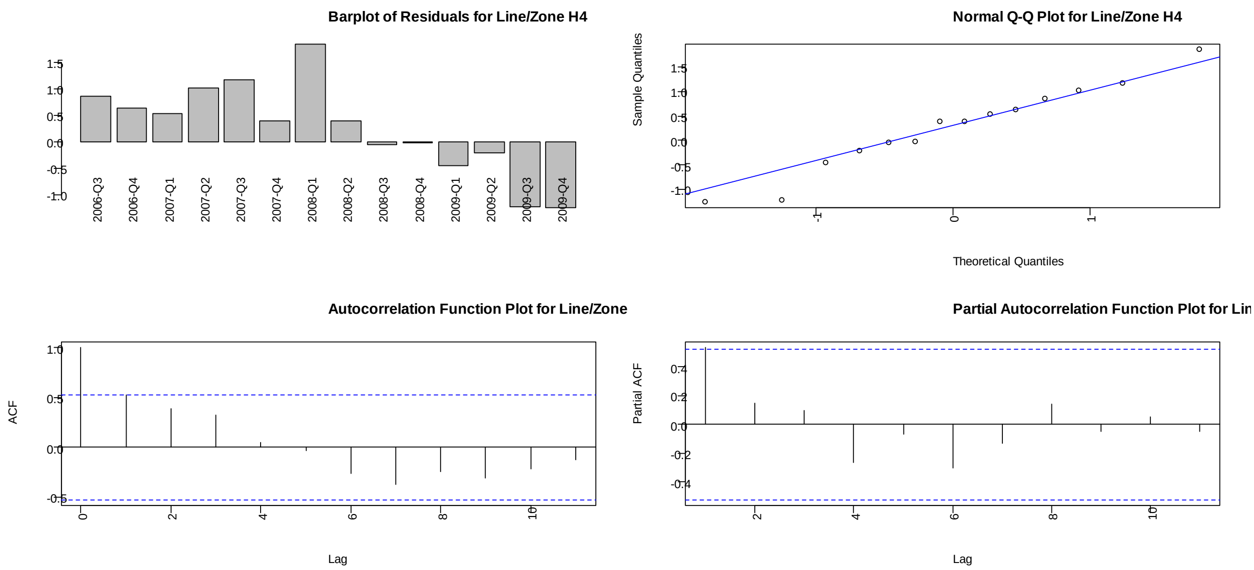
The figures below show diagnostic plots for the residuals from model 5 (the preferred model) used to explain (weighted) sales of monthly and quarterly tickets (see section D5.1).

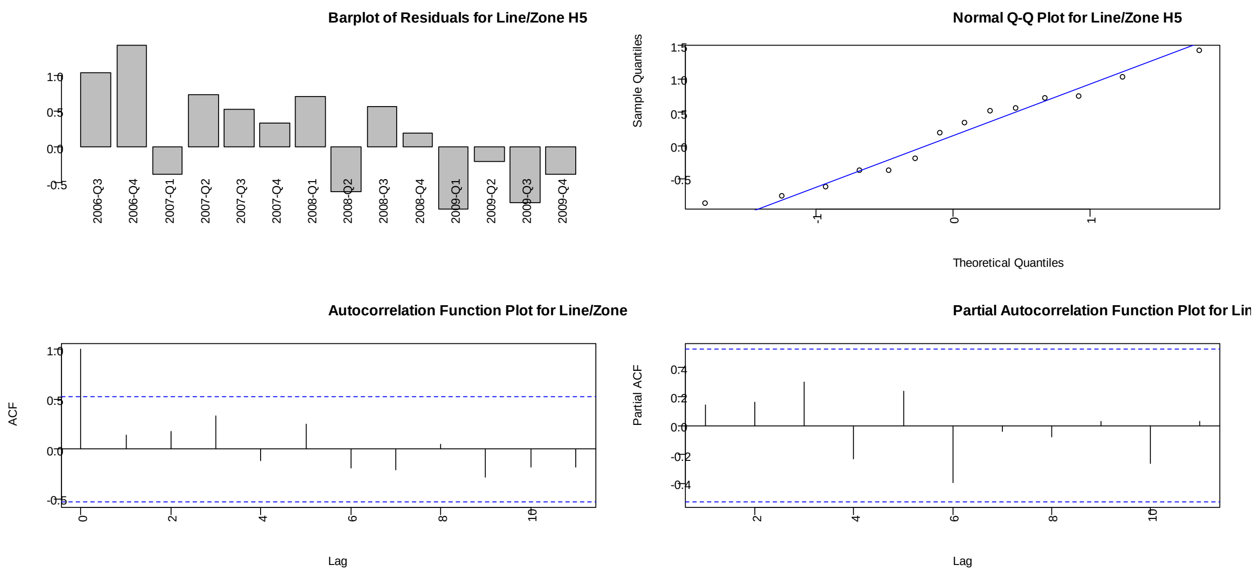
The diagnostic plots show that the residuals for both lines are generally consistent with the key assumption of normality.

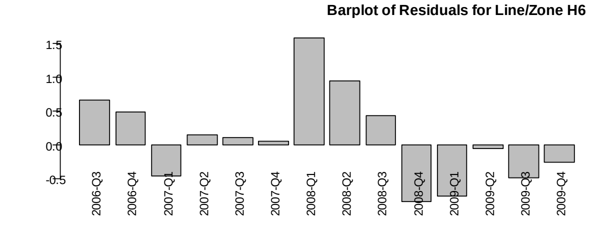
However, there is evidence of autocorrelation and 'clustering' in residuals:

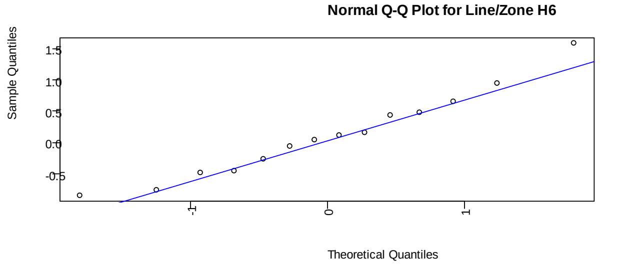
- For the Hutt line, the residuals were mostly positive up until 2008-Q4 and then mostly negative from that point onwards. This suggests that we might have omitted some variable that caused growth to drop off at that point; this is not unexpected given that we did not possess details regarding service changes and/or reliability throughout the period covered.
- The Johnsonville line exhibits almost the opposite pattern to the Hutt line: residuals were negative up until 2008-Q3 and then mostly positive from that point onwards.

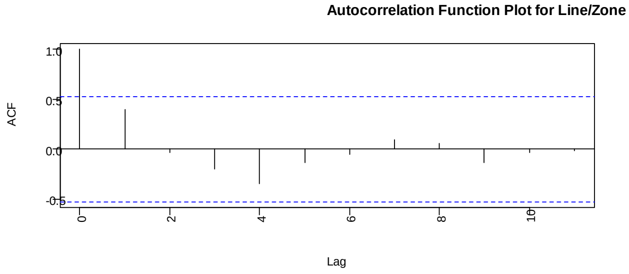
There is no strong evidence of autocorrelation on the Paraparaumu line. However, the observations above suggest that we may have omitted some important variables. Unfortunately, we do not have much historical data on events around this time so this problem is unavoidable and model findings must therefore be interpreted with some caution.

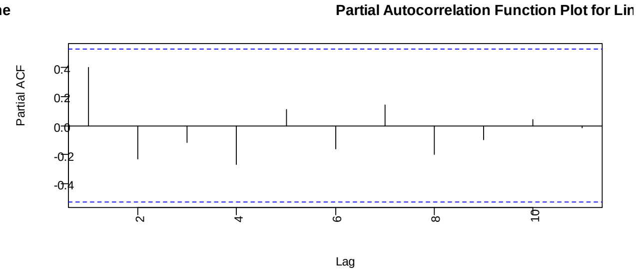


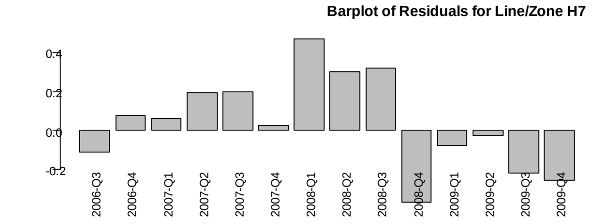


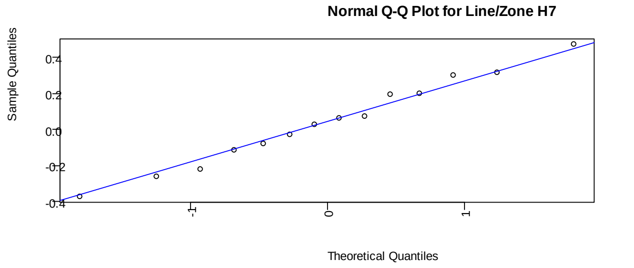

Barplot of Residuals for Line/Zone H6

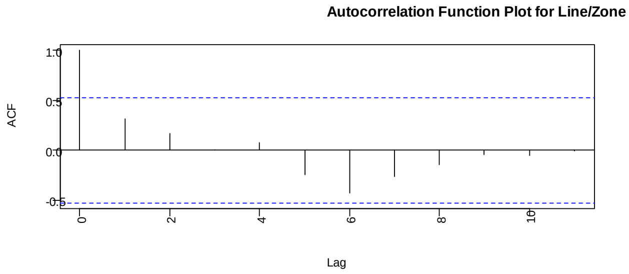

Normal Q-Q Plot for Line/Zone H6
Sample Quantiles
Theoretical Quantiles

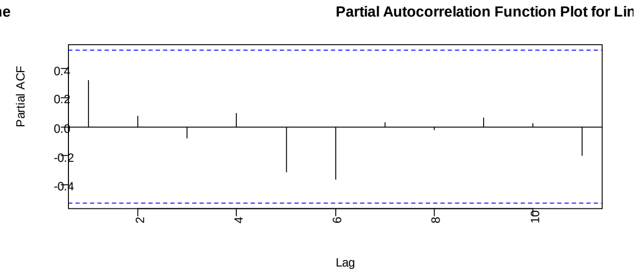

Autocorrelation Function Plot for Line/Zone
ACF
Lag

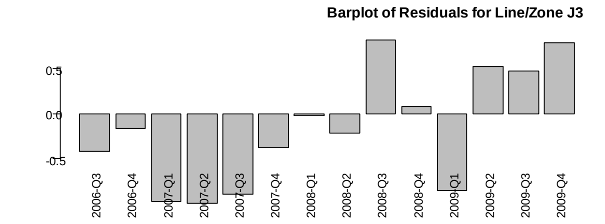

Partial Autocorrelation Function Plot for Lin
Partial ACF
Lag

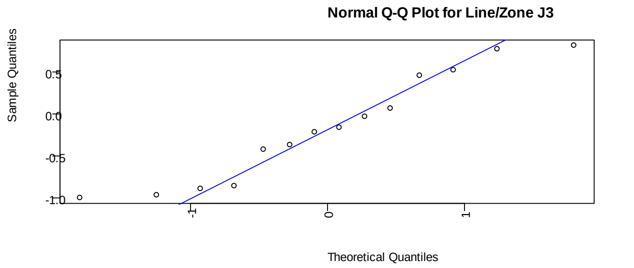

Barplot of Residuals for Line/Zone H7

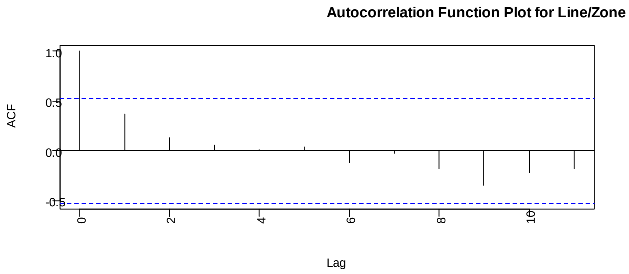

Normal Q-Q Plot for Line/Zone H7
Sample Quantiles
Theoretical Quantiles

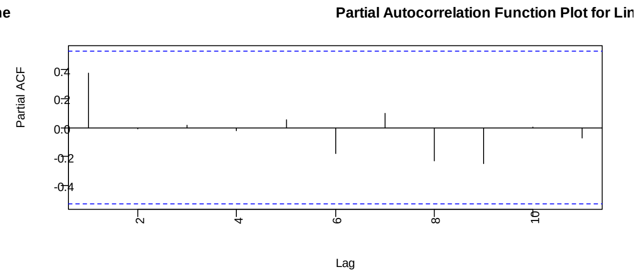

Autocorrelation Function Plot for Line/Zone
ACF
Lag

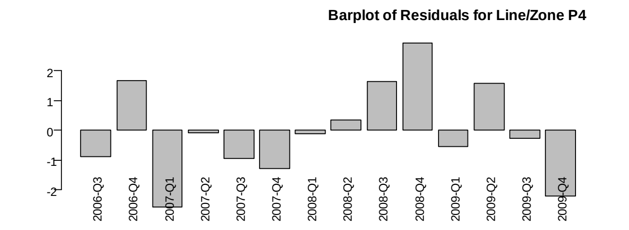

Partial Autocorrelation Function Plot for Lin
Partial ACF
Lag

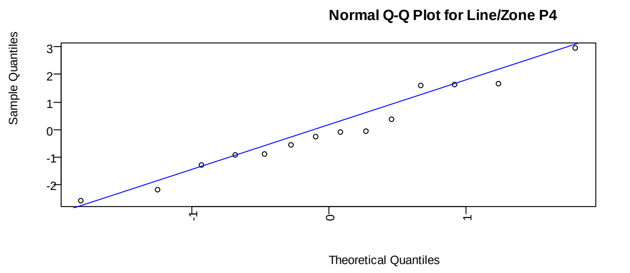

Barplot of Residuals for Line/Zone J3

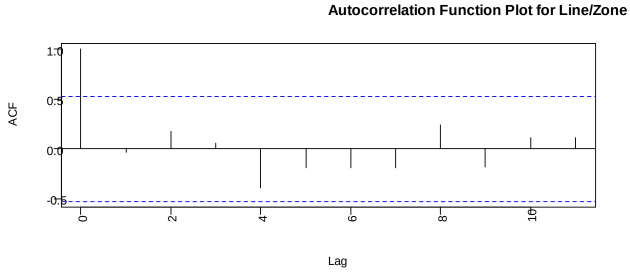

Normal Q-Q Plot for Line/Zone J3
Sample Quantiles
Theoretical Quantiles

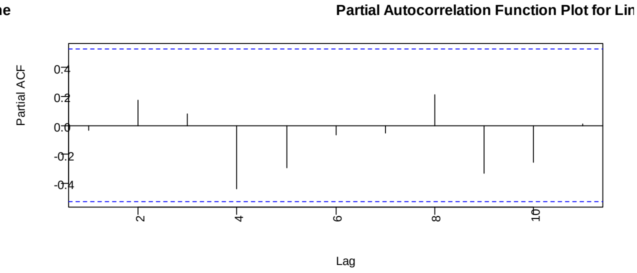

Autocorrelation Function Plot for Line/Zone
ACF
Lag

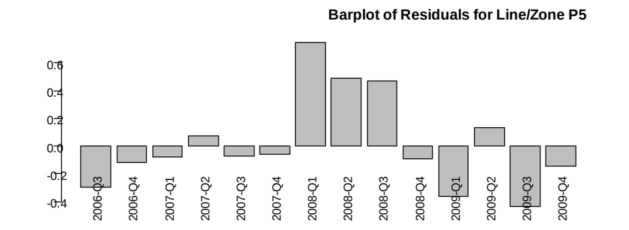

Partial Autocorrelation Function Plot for Lin
Partial ACF
Lag

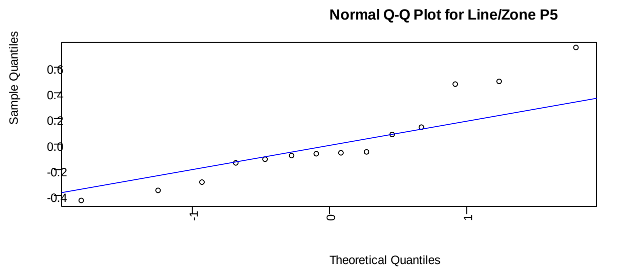

Barplot of Residuals for Line/Zone P4

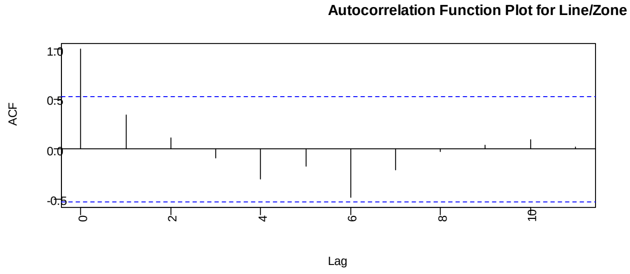

Normal Q-Q Plot for Line/Zone P4
Sample Quantiles
Theoretical Quantiles

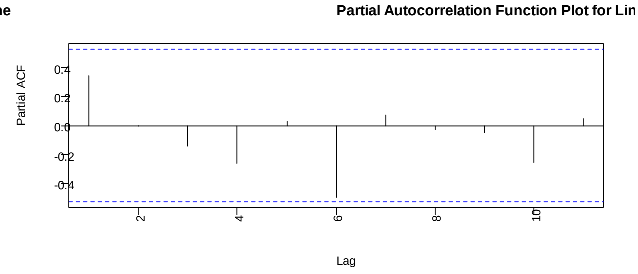

Autocorrelation Function Plot for Line/Zone
ACF
Lag

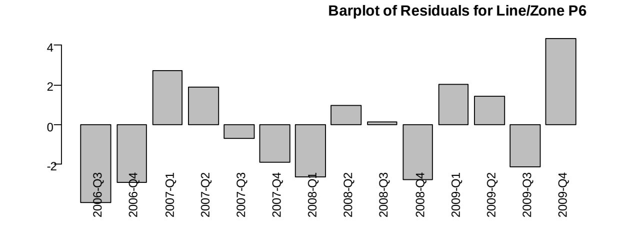

Partial Autocorrelation Function Plot for Lin
Partial ACF
Lag

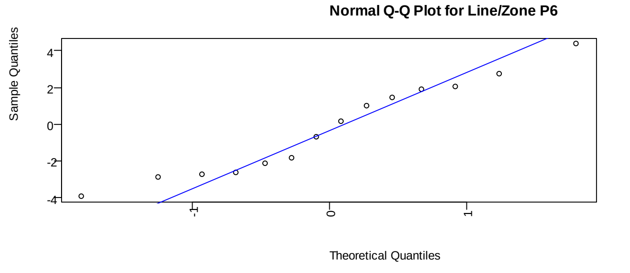

Barplot of Residuals for Line/Zone P5

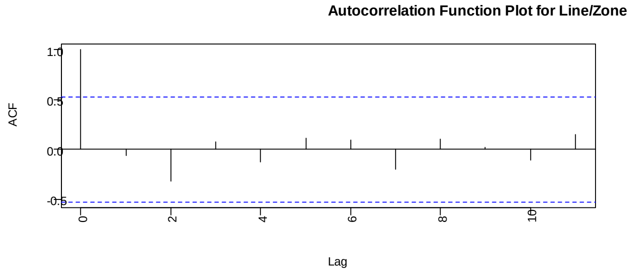

Normal Q-Q Plot for Line/Zone P5
Sample Quantiles
Theoretical Quantiles

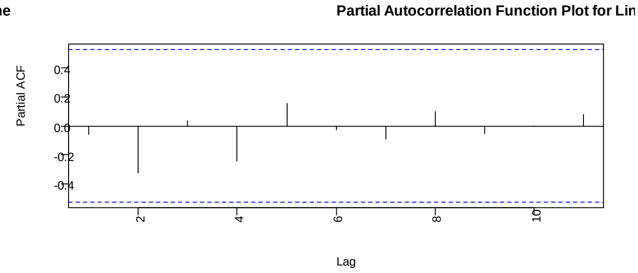

Autocorrelation Function Plot for Line/Zone
ACF
Lag

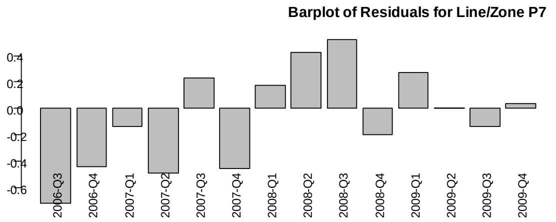

Partial Autocorrelation Function Plot for Lin
Partial ACF
Lag

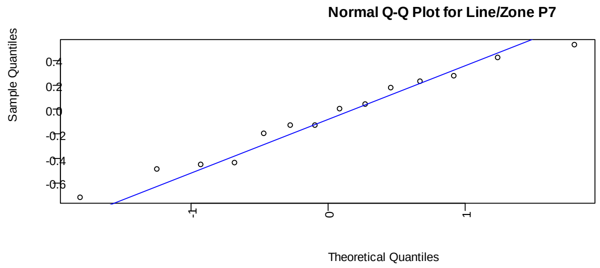

Barplot of Residuals for Line/Zone P6

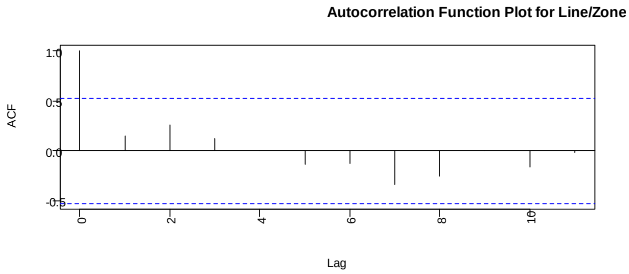

Normal Q-Q Plot for Line/Zone P6
Sample Quantiles
Theoretical Quantiles

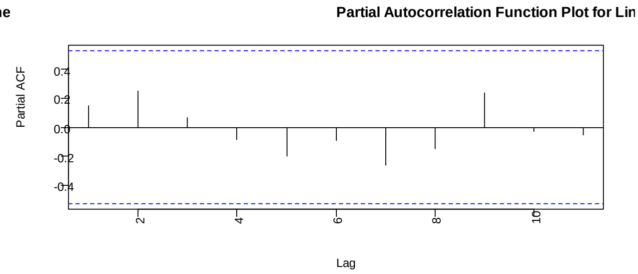

Autocorrelation Function Plot for Line/Zone
ACF
Lag

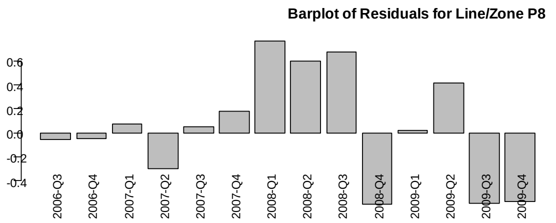

Partial Autocorrelation Function Plot for Lin
Partial ACF
Lag

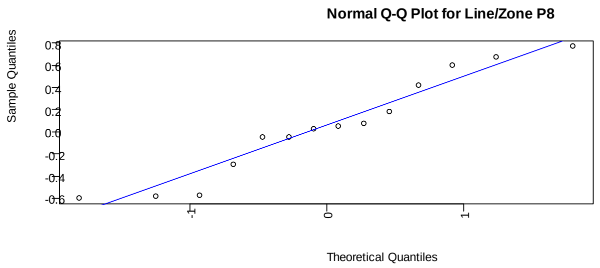

Barplot of Residuals for Line/Zone P7

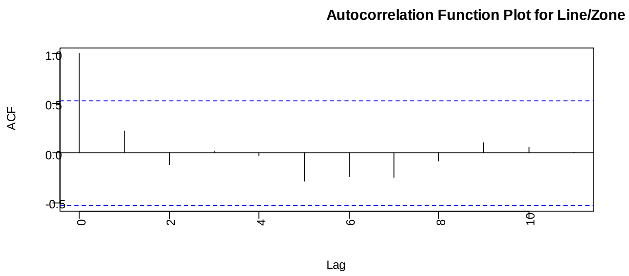

Normal Q-Q Plot for Line/Zone P7
Sample Quantiles
Theoretical Quantiles

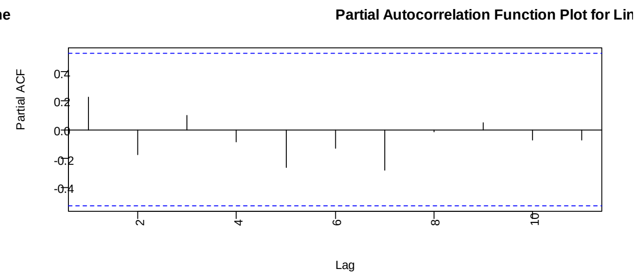

Autocorrelation Function Plot for Line/Zone
ACF
Lag

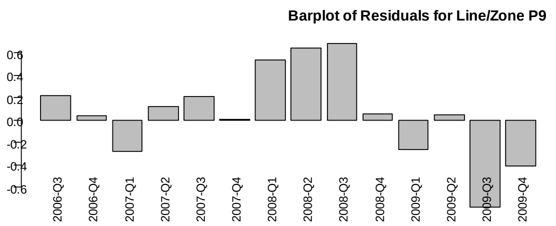

Partial Autocorrelation Function Plot for Lin
Partial ACF
Lag

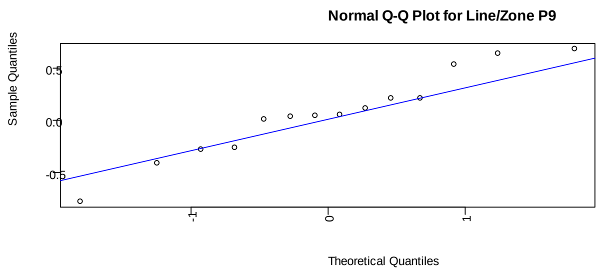

Barplot of Residuals for Line/Zone P8

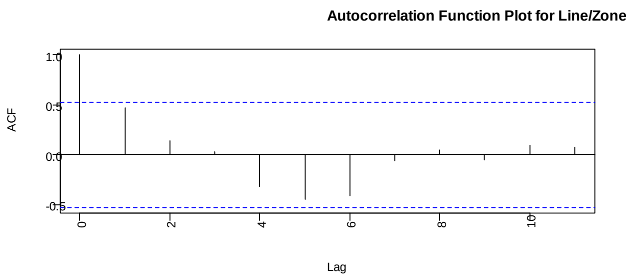

Normal Q-Q Plot for Line/Zone P8
Sample Quantiles
Theoretical Quantiles

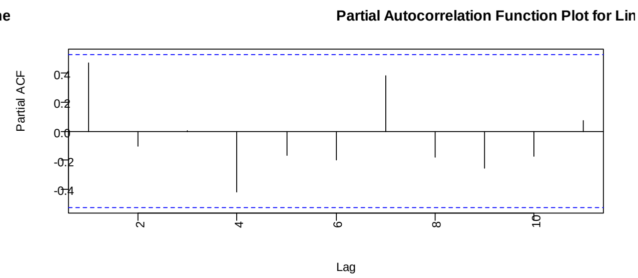

Autocorrelation Function Plot for Line/Zone
ACF
Lag


Partial Autocorrelation Function Plot for Lin
Partial ACF
Lag


Barplot of Residuals for Line/Zone P9


Normal Q-Q Plot for Line/Zone P9
Sample Quantiles
Theoretical Quantiles


Autocorrelation Function Plot for Line/Zone
ACF
Lag


Partial Autocorrelation Function Plot for Lin
Partial ACF
Lag

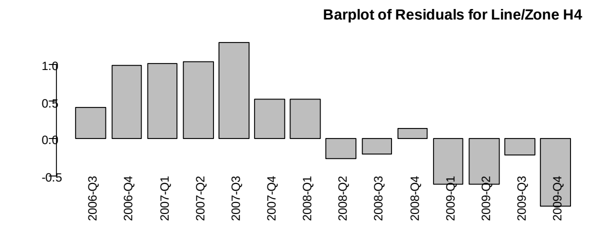
D6.2 Diagnostic analysis for the model for 10-trip ticket sales

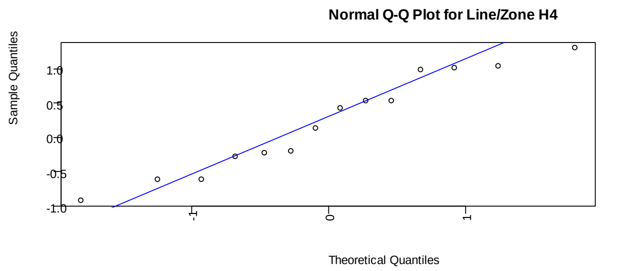
The figures below show diagnostic plots for the residuals from the preferred model (model 2) for explaining sales of 10-trip tickets (see section D5.2).

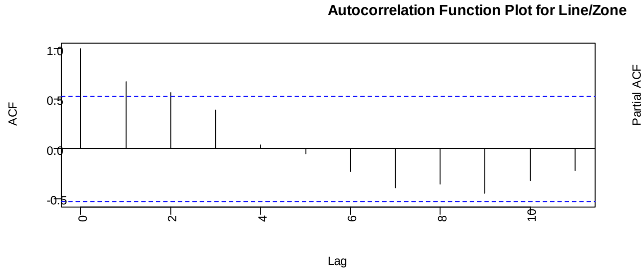
The diagnostic plots show that the residuals for both lines generally conform to key assumptions of normality.

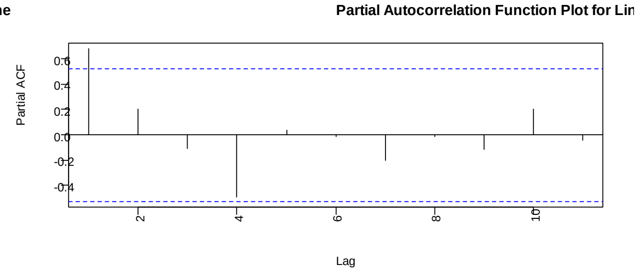
There is evidence of autocorrelation and/or 'clustering' on a few of the line-zone segments:

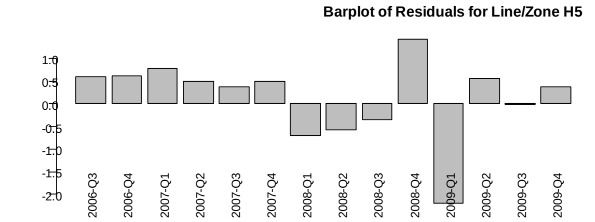
- The Hutt line – zone 4 shows evidence of positive residuals until 2008–Q2, from which point onwards the residuals are mostly negative.
- The Johnsonville line shows some evidence of autocorrelation.
- The Paraparaumu line – zone 4 and zone 9 also show evidence of autocorrelation.

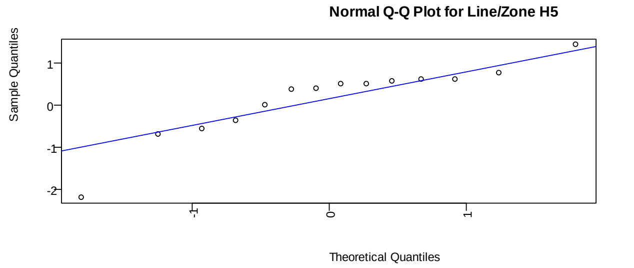


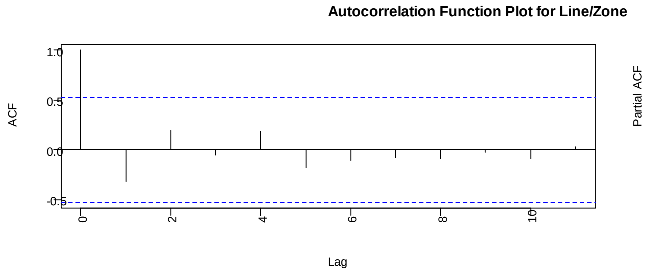


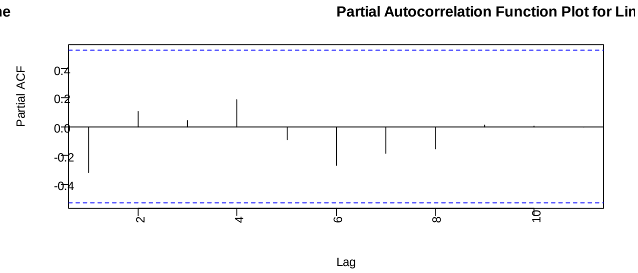


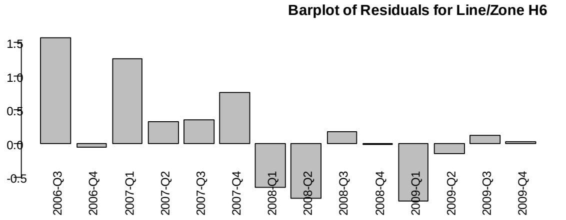


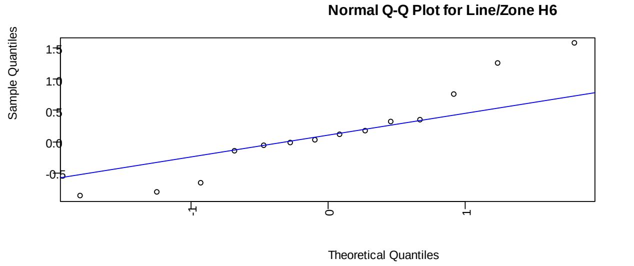


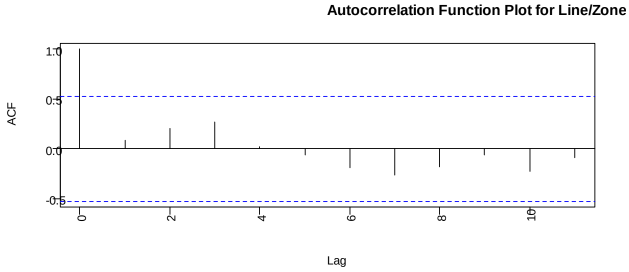


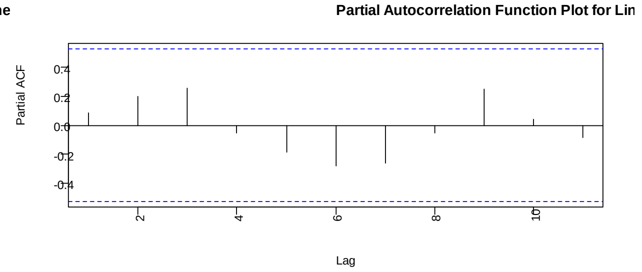


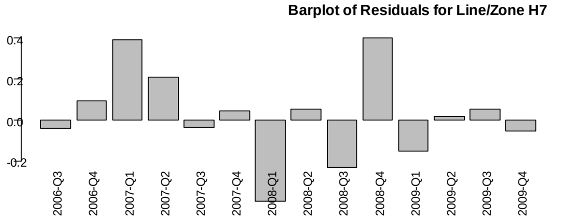


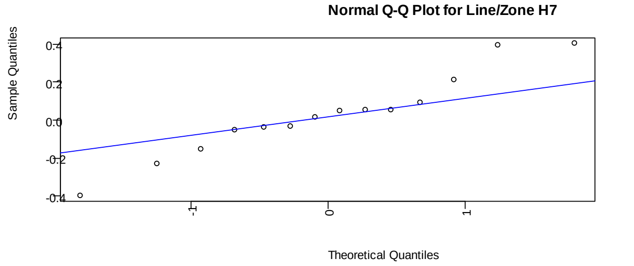

Barplot of Residuals for Line/Zone H6

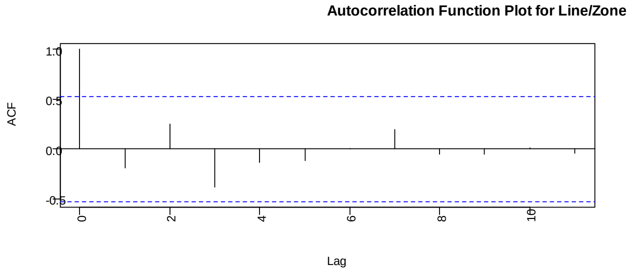

Normal Q-Q Plot for Line/Zone H6
Sample Quantiles
Theoretical Quantiles

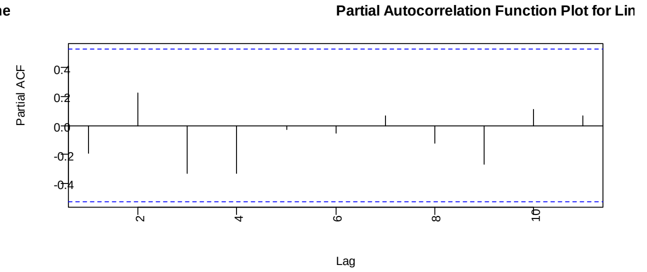

Autocorrelation Function Plot for Line/Zone
ACF
Lag

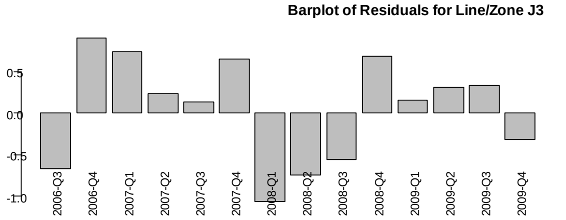

Partial Autocorrelation Function Plot for Lin
Partial ACF
Lag

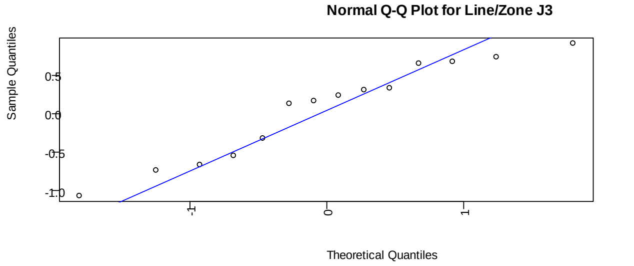

Barplot of Residuals for Line/Zone H7

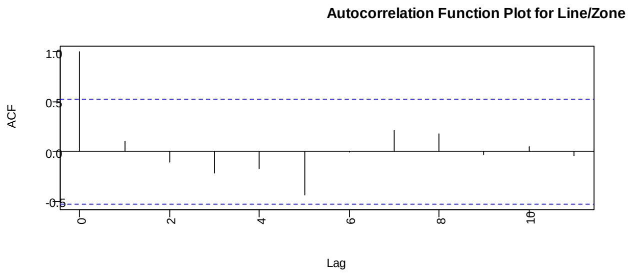

Normal Q-Q Plot for Line/Zone H7
Sample Quantiles
Theoretical Quantiles

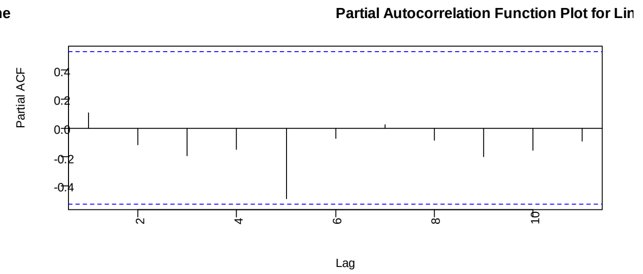

Autocorrelation Function Plot for Line/Zone
ACF
Lag

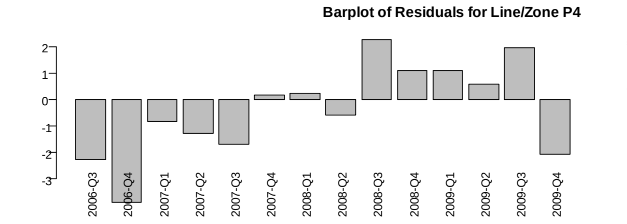

Partial Autocorrelation Function Plot for Lin
Partial ACF
Lag

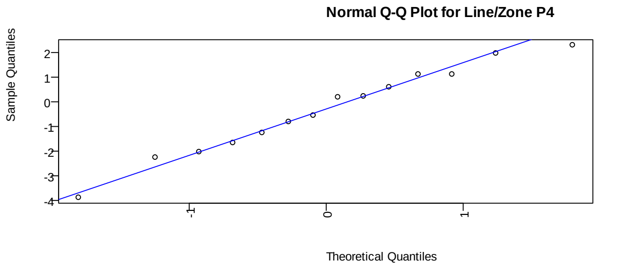

Barplot of Residuals for Line/Zone J3

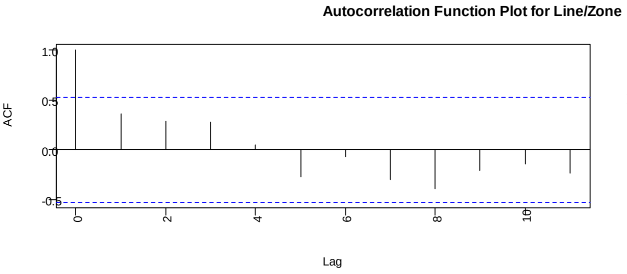

Normal Q-Q Plot for Line/Zone J3
Sample Quantiles
Theoretical Quantiles

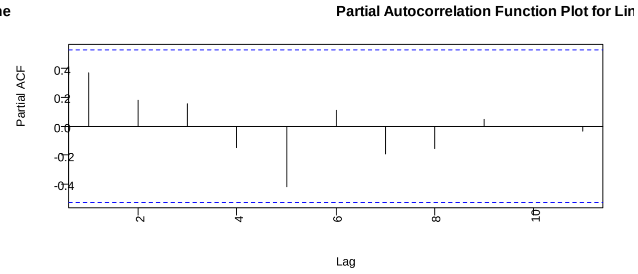

Autocorrelation Function Plot for Line/Zone
ACF
Lag

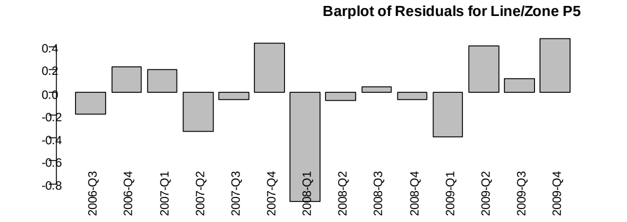

Partial Autocorrelation Function Plot for Lin
Partial ACF
Lag

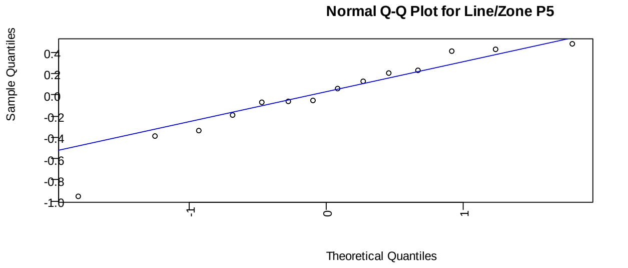

Barplot of Residuals for Line/Zone P4

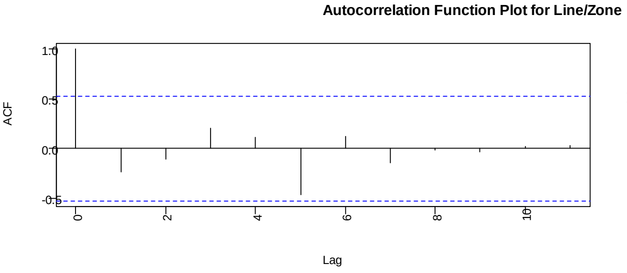

Normal Q-Q Plot for Line/Zone P4
Sample Quantiles
Theoretical Quantiles

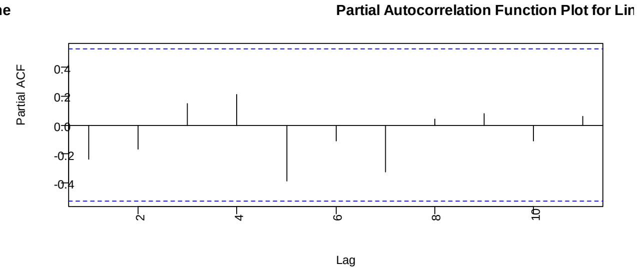

Autocorrelation Function Plot for Line/Zone
ACF
Lag

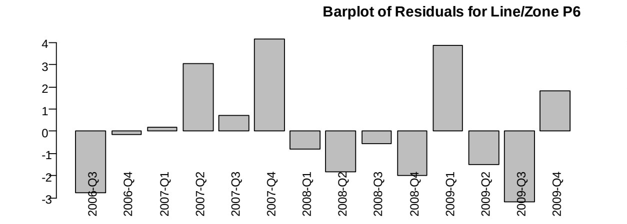

Partial Autocorrelation Function Plot for Lin
Partial ACF
Lag

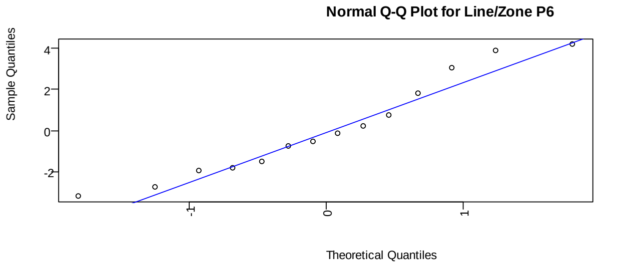

Barplot of Residuals for Line/Zone P5

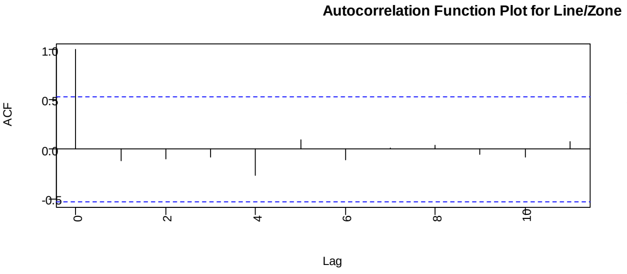

Normal Q-Q Plot for Line/Zone P5
Sample Quantiles
Theoretical Quantiles

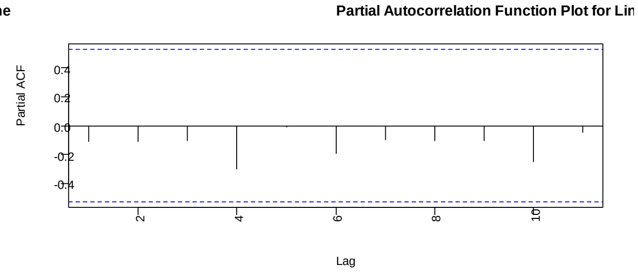

Autocorrelation Function Plot for Line/Zone
ACF
Lag

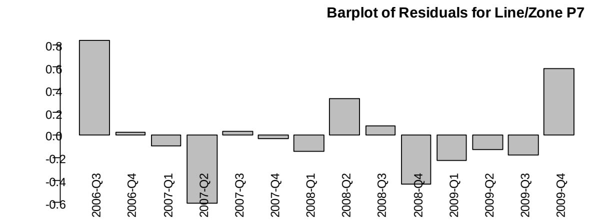

Partial Autocorrelation Function Plot for Lin
Partial ACF
Lag

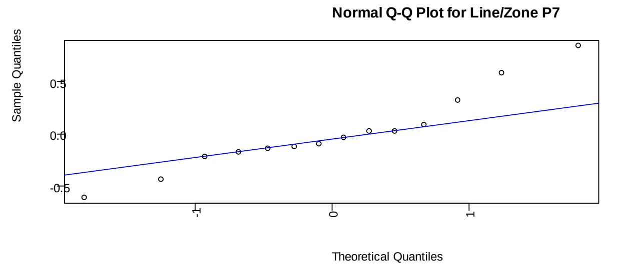

Barplot of Residuals for Line/Zone P6

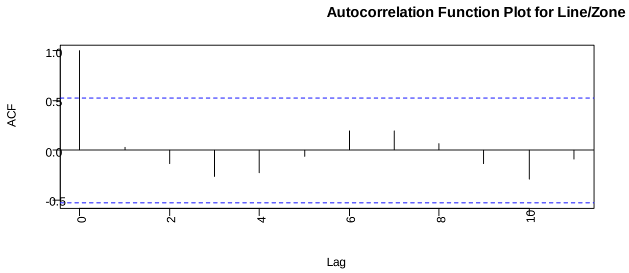

Normal Q-Q Plot for Line/Zone P6
Sample Quantiles
Theoretical Quantiles

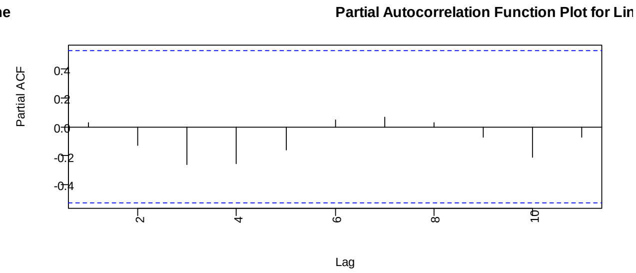

Autocorrelation Function Plot for Line/Zone
ACF
Lag

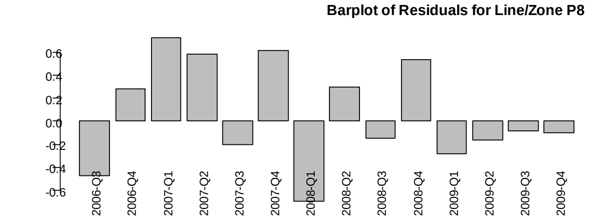

Partial Autocorrelation Function Plot for Lin
Partial ACF
Lag

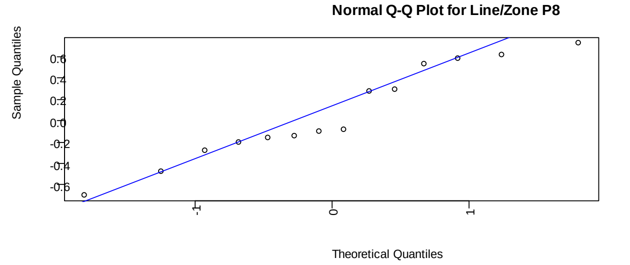

Barplot of Residuals for Line/Zone P7

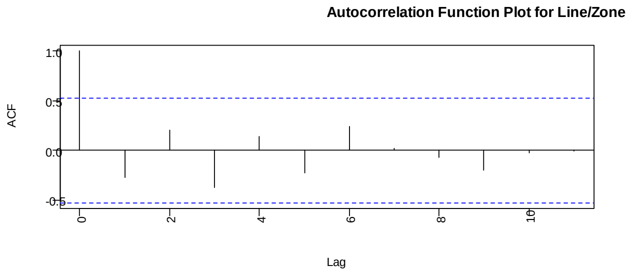

Normal Q-Q Plot for Line/Zone P7
Sample Quantiles
Theoretical Quantiles

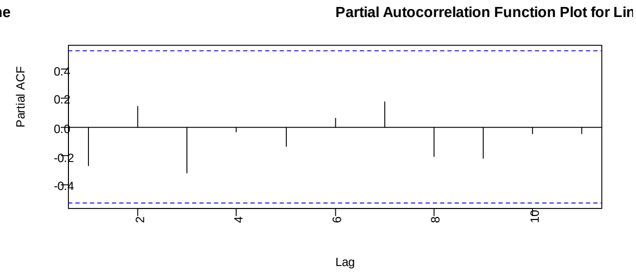

Autocorrelation Function Plot for Line/Zone
ACF
Lag

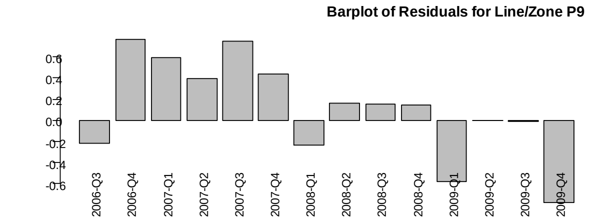

Partial Autocorrelation Function Plot for Lin
Partial ACF
Lag

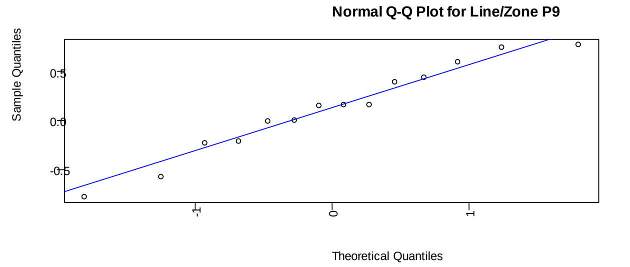

Barplot of Residuals for Line/Zone P8

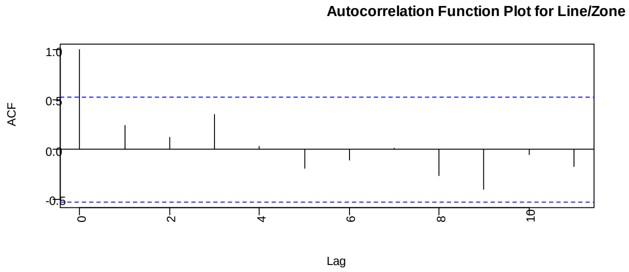

Normal Q-Q Plot for Line/Zone P8
Sample Quantiles
Theoretical Quantiles

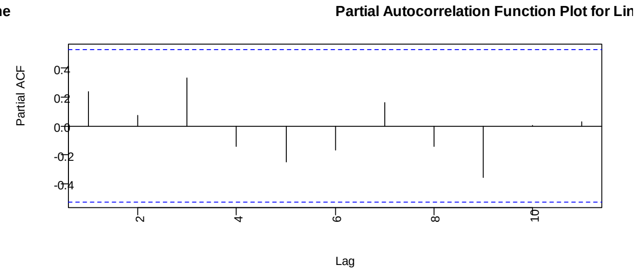

Autocorrelation Function Plot for Line/Zone
ACF
Lag


Partial Autocorrelation Function Plot for Lin
Partial ACF
Lag


Barplot of Residuals for Line/Zone P9


Normal Q-Q Plot for Line/Zone P9
Sample Quantiles
Theoretical Quantiles


Autocorrelation Function Plot for Line/Zone
ACF
Lag

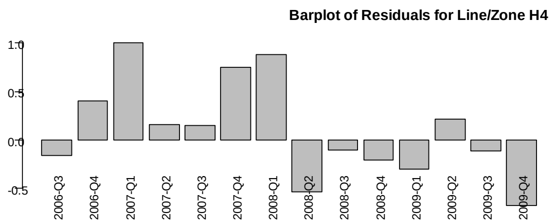

Partial Autocorrelation Function Plot for Lin
Partial ACF
Lag

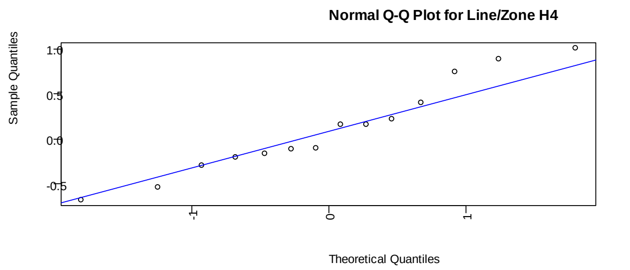
D6.3 Diagnostic analysis for the adult (single) ticket sales

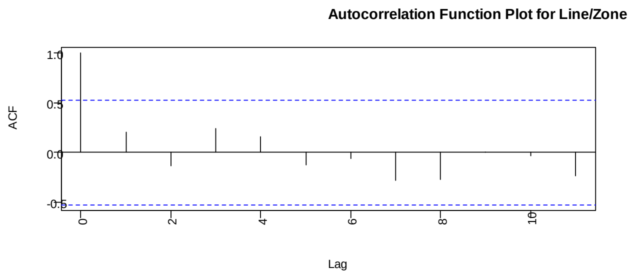
The figures below show diagnostic plots for the residuals from the preferred model (model 4) for sales of adult (single) tickets (see section D5.3).

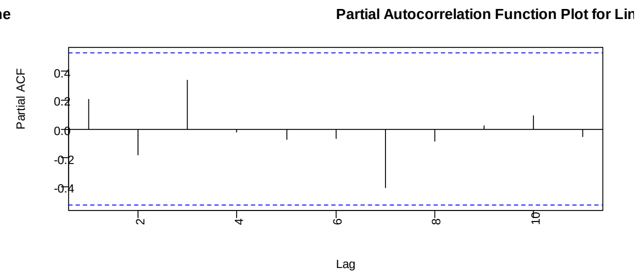
The diagnostic plots show that the residuals for all lines are consistent with the key assumption of normality.

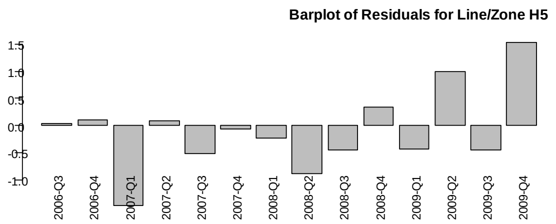
However, there is evidence of autocorrelation across a number of the lines, with drifts from positive residuals to negative residuals (or vice versa) quite common. This raises concern about the accuracy of the model.

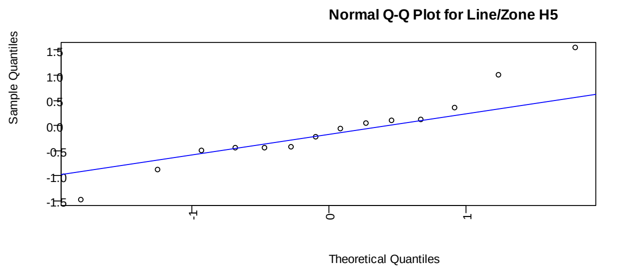


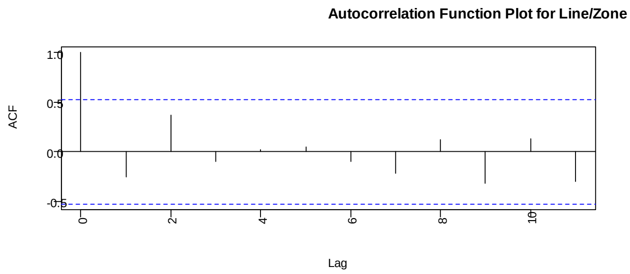


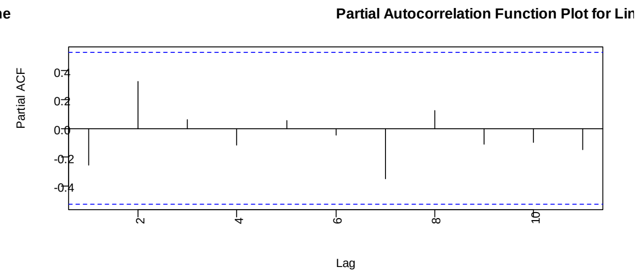


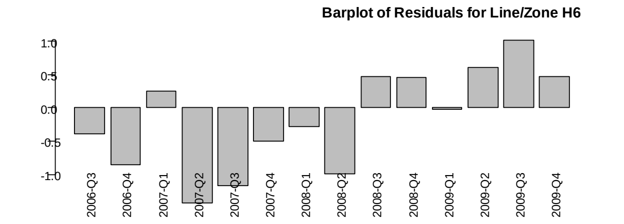


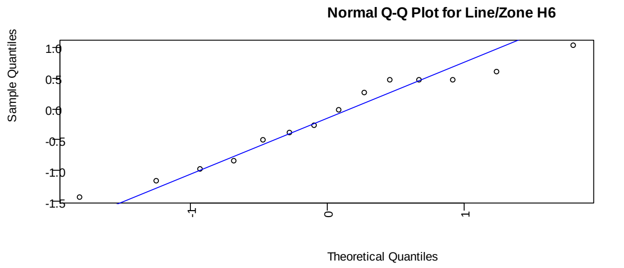


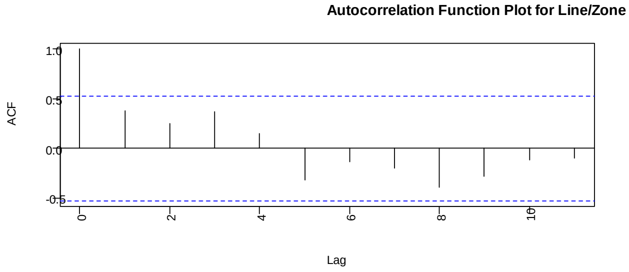


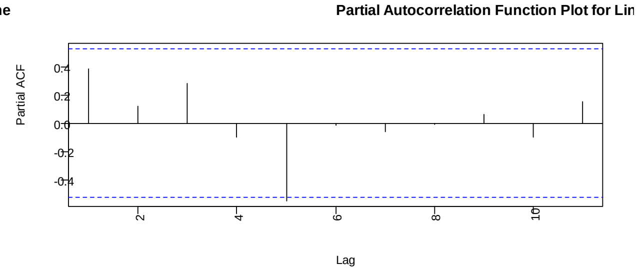


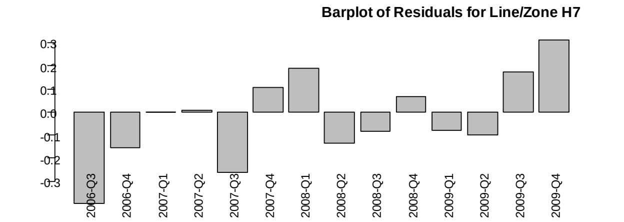


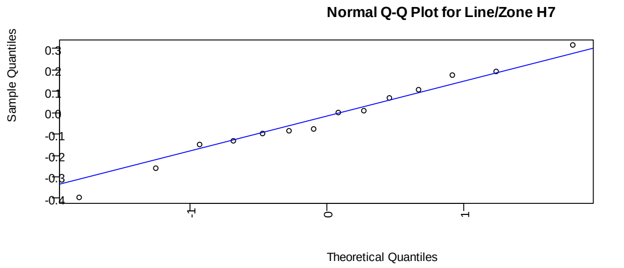

Barplot of Residuals for Line/Zone H6

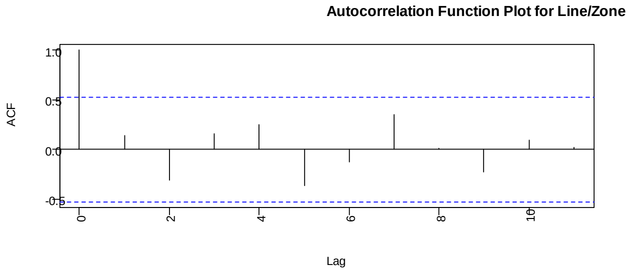

Normal Q-Q Plot for Line/Zone H6
Sample Quantiles
Theoretical Quantiles

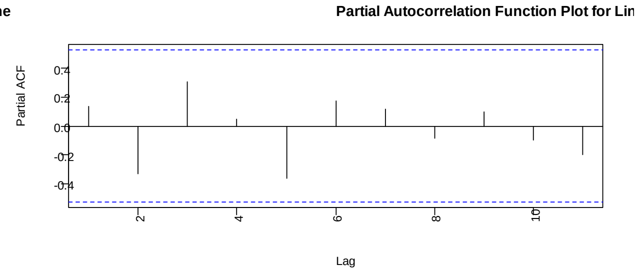

Autocorrelation Function Plot for Line/Zone
ACF
Lag

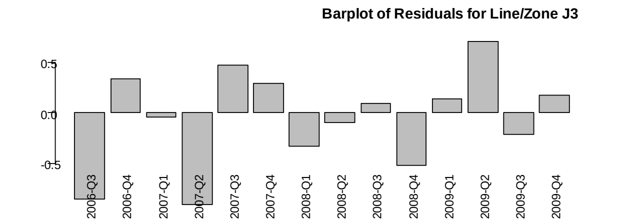

Partial Autocorrelation Function Plot for Lin
Partial ACF
Lag

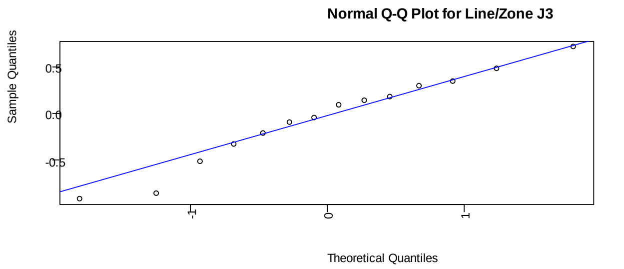

Barplot of Residuals for Line/Zone H7

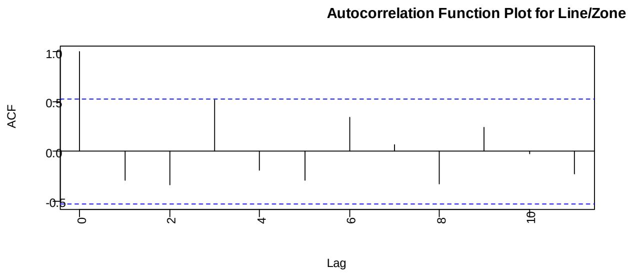

Normal Q-Q Plot for Line/Zone H7
Sample Quantiles
Theoretical Quantiles

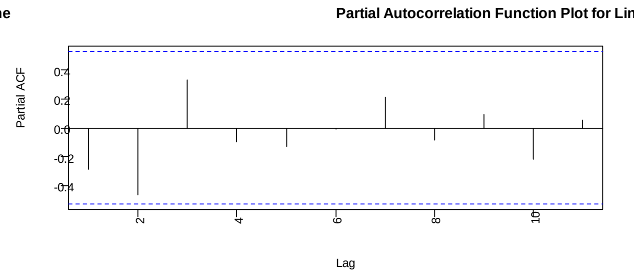

Autocorrelation Function Plot for Line/Zone
ACF
Lag

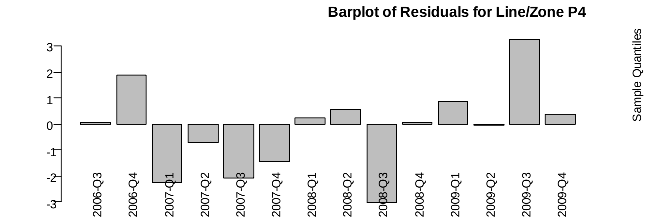

Partial Autocorrelation Function Plot for Lin
Partial ACF
Lag

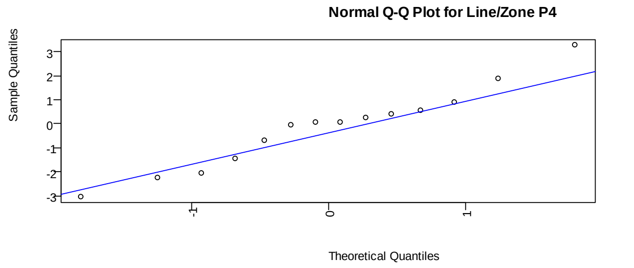

Barplot of Residuals for Line/Zone J3

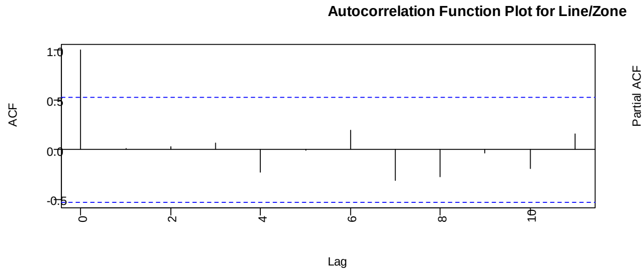

Normal Q-Q Plot for Line/Zone J3
Sample Quantiles
Theoretical Quantiles

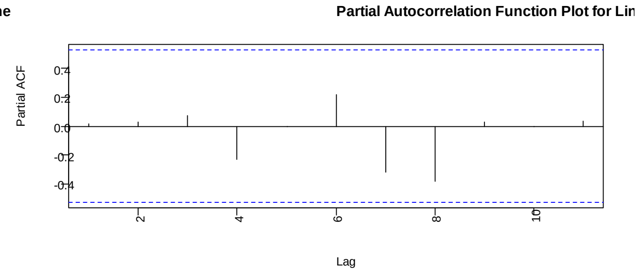

Autocorrelation Function Plot for Line/Zone
ACF
Lag

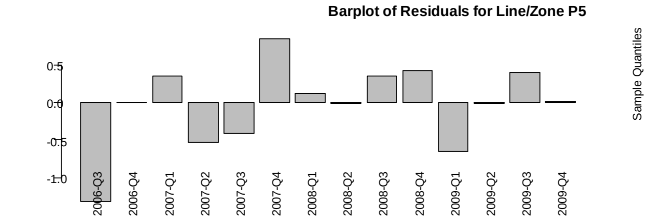

Partial Autocorrelation Function Plot for Lin
Partial ACF
Lag

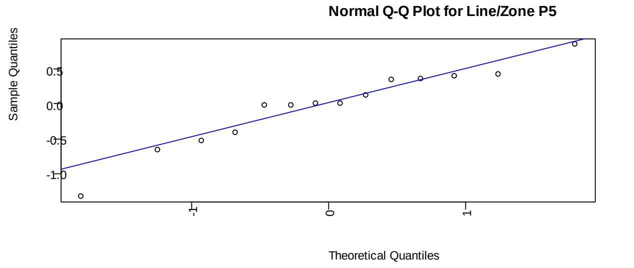

Barplot of Residuals for Line/Zone P4

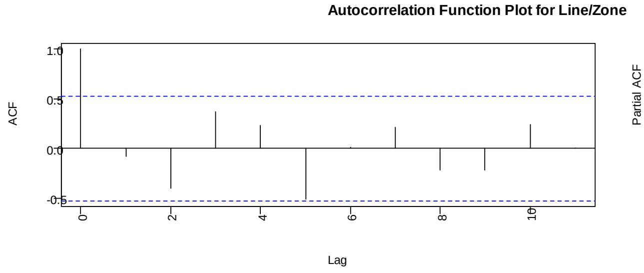

Normal Q-Q Plot for Line/Zone P4
Sample Quantiles
Theoretical Quantiles

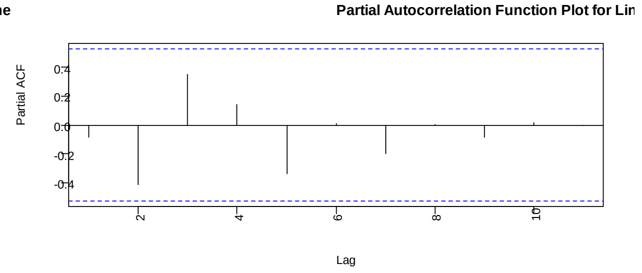

Autocorrelation Function Plot for Line/Zone
ACF
Lag

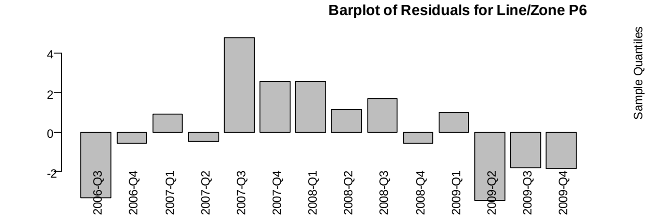

Partial Autocorrelation Function Plot for Lin
Partial ACF
Lag

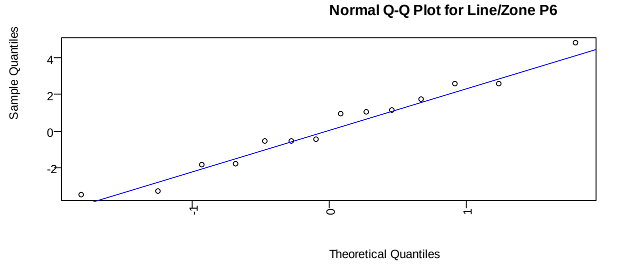

Barplot of Residuals for Line/Zone P5

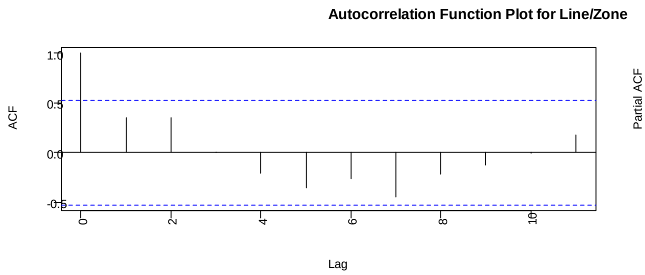

Normal Q-Q Plot for Line/Zone P5
Sample Quantiles
Theoretical Quantiles

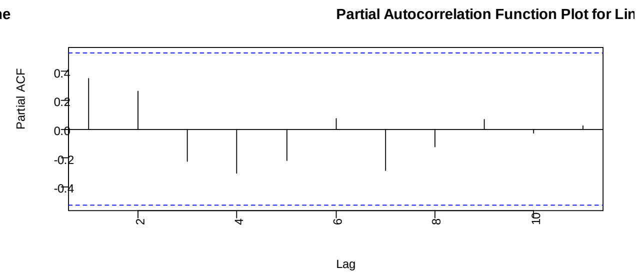

Autocorrelation Function Plot for Line/Zone
ACF
Lag

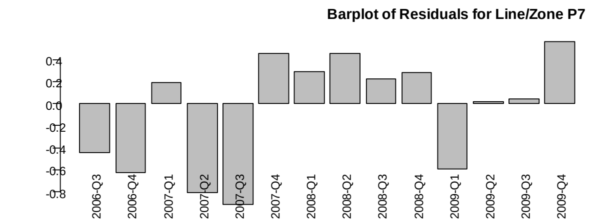

Partial Autocorrelation Function Plot for Lin
Partial ACF
Lag

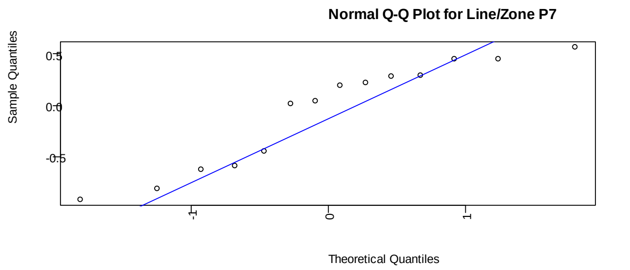

Barplot of Residuals for Line/Zone P6

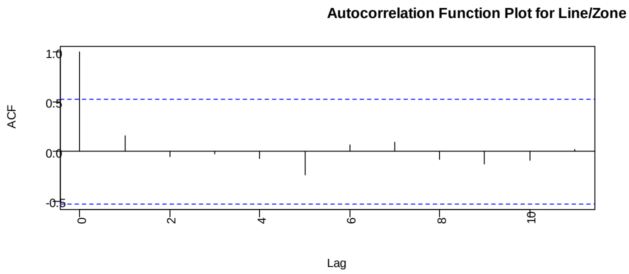

Normal Q-Q Plot for Line/Zone P6
Sample Quantiles
Theoretical Quantiles

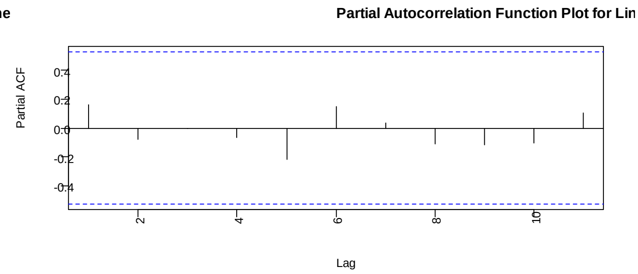

Autocorrelation Function Plot for Line/Zone
ACF
Lag

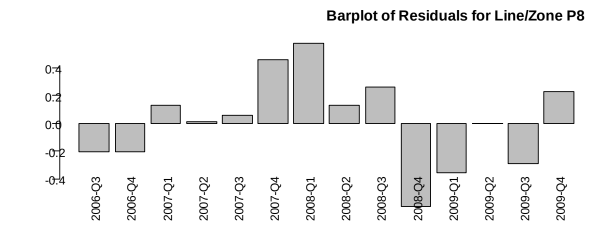

Partial Autocorrelation Function Plot for Lin
Partial ACF
Lag

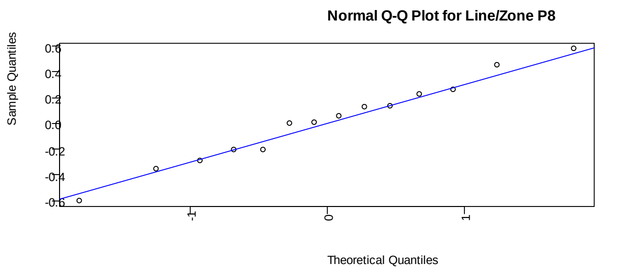


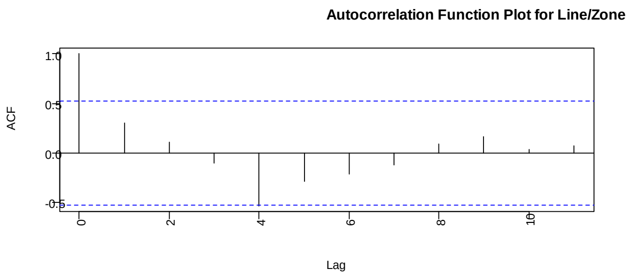


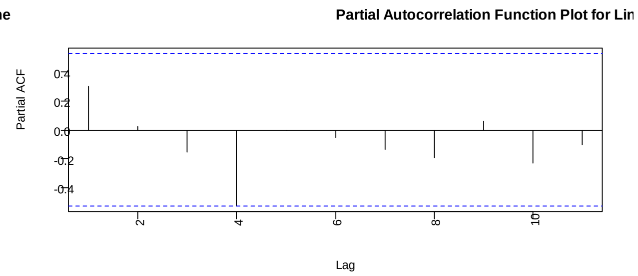












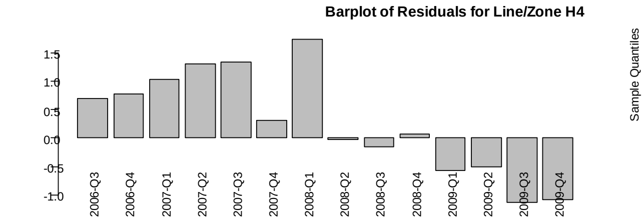
D6.4 Diagnostic analysis for aggregate ticket sales

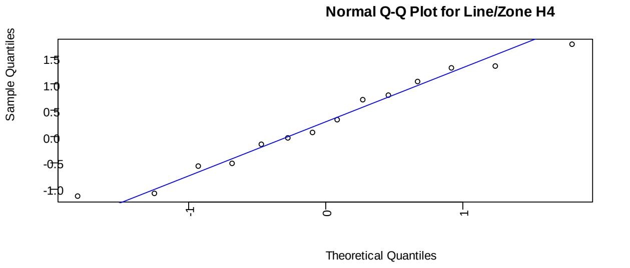
The figures below show diagnostic plots for the residuals from the preferred model (model 4) for explaining (weighted) sales of adult (single), 10-trip, monthly and quarterly tickets (see section D5.4).

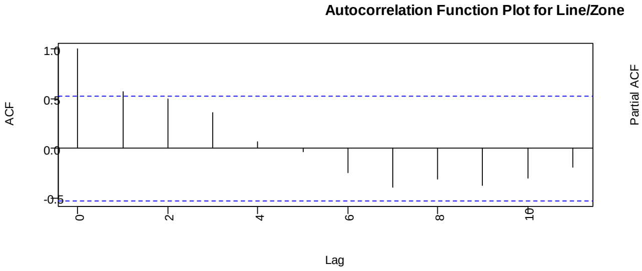
The diagnostic plots show that the residuals for both lines generally conform to key assumptions of normality.

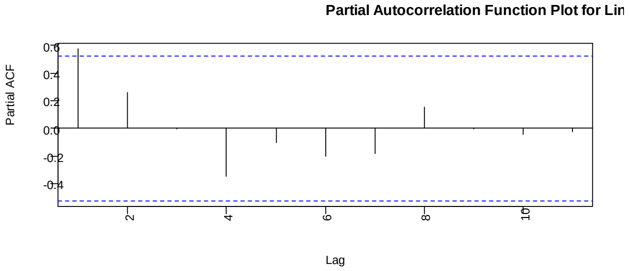
However, as observed with analysis of individual ticket types (see sections D6.1 to D6.3) there are still high levels of autocorrelation and 'clustering' in the data:

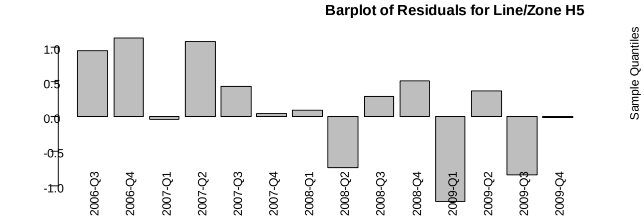
- All of the zones on the Hutt line exhibited an overall tendency to move from positive residuals toward negative residuals. This suggests that we have omitted some important factors that generated lower than expected patronage growth in recent years.
- The zones of the Paraparaumu line also exhibited some autocorrelation and clustering behaviour.

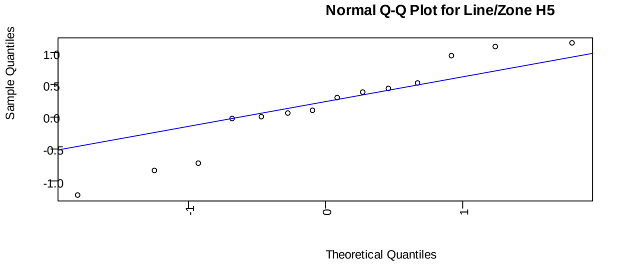

Barplot of Residuals for Line/Zone H4

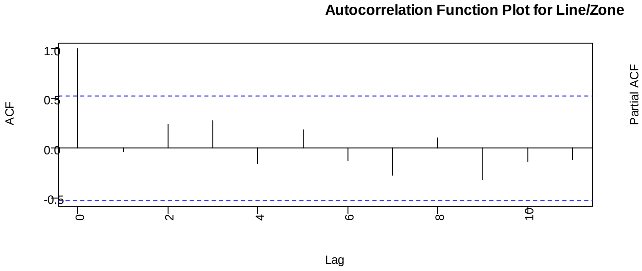

Normal Q-Q Plot for Line/Zone H4
Sample Quantiles
Theoretical Quantiles

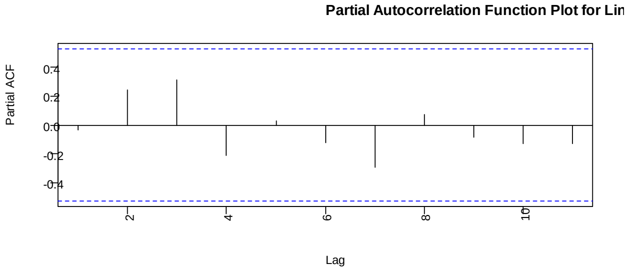

Autocorrelation Function Plot for Line/Zone
ACF
Lag

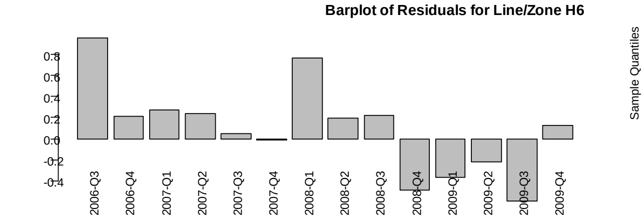

Partial Autocorrelation Function Plot for Lin
Partial ACF
Lag

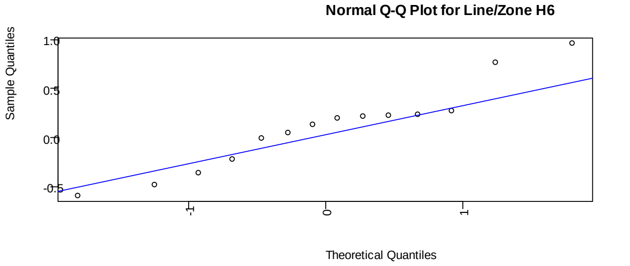

Barplot of Residuals for Line/Zone H5

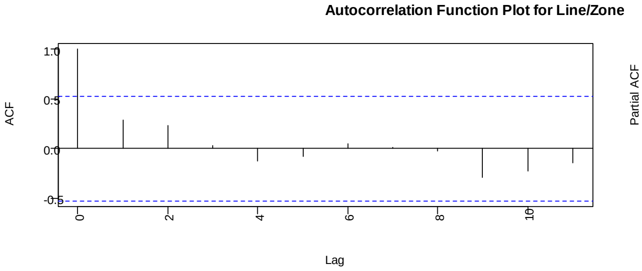

Normal Q-Q Plot for Line/Zone H5
Sample Quantiles
Theoretical Quantiles

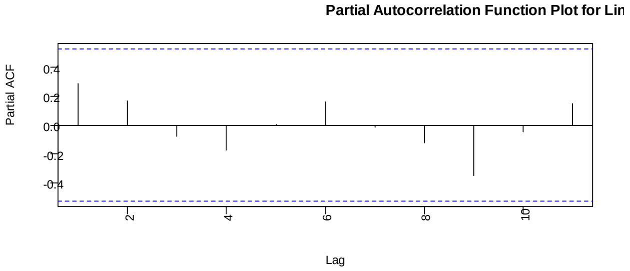

Autocorrelation Function Plot for Line/Zone
ACF
Lag

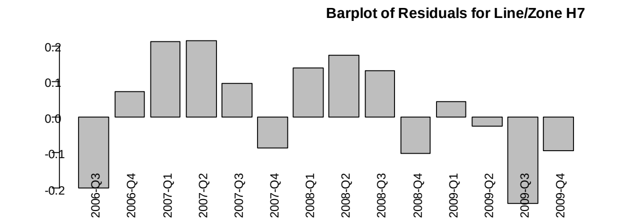

Partial Autocorrelation Function Plot for Lin
Partial ACF
Lag

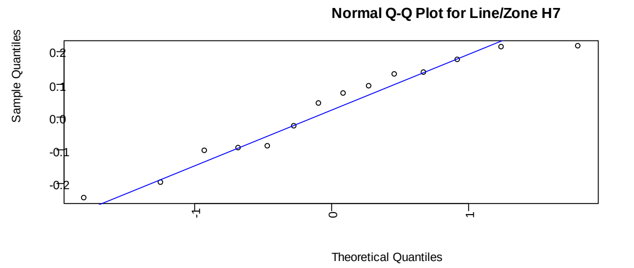

Barplot of Residuals for Line/Zone H6

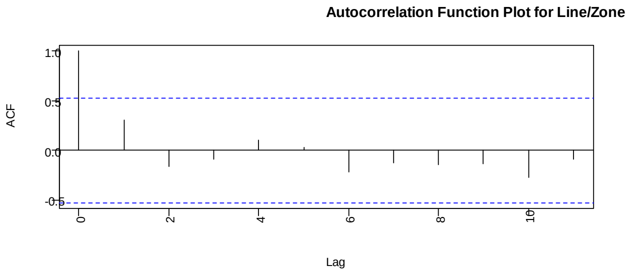

Normal Q-Q Plot for Line/Zone H6
Sample Quantiles
Theoretical Quantiles

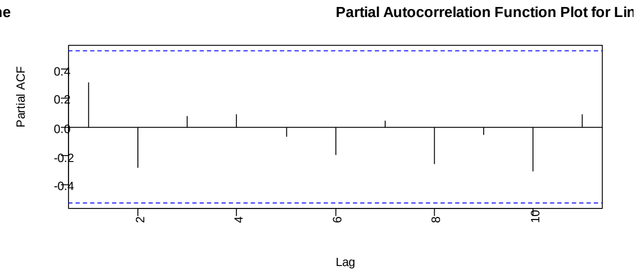

Autocorrelation Function Plot for Line/Zone
ACF
Lag

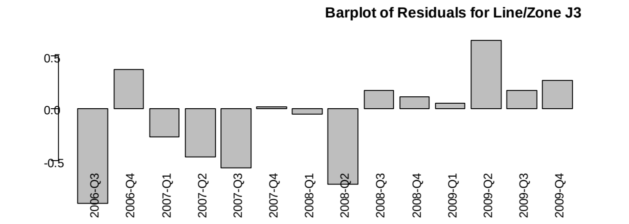

Partial Autocorrelation Function Plot for Lin
Partial ACF
Lag

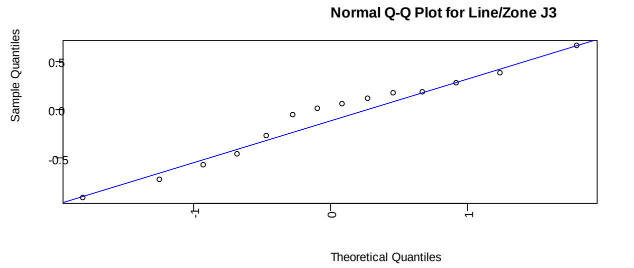

Barplot of Residuals for Line/Zone H7

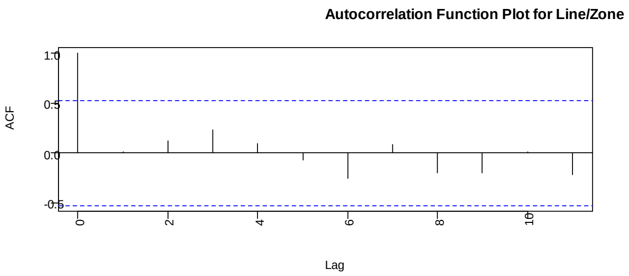

Normal Q-Q Plot for Line/Zone H7
Sample Quantiles
Theoretical Quantiles

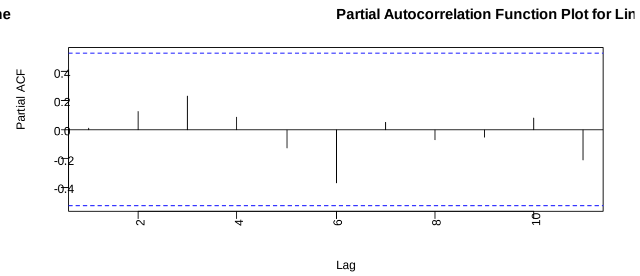

Autocorrelation Function Plot for Line/Zone
ACF
Lag

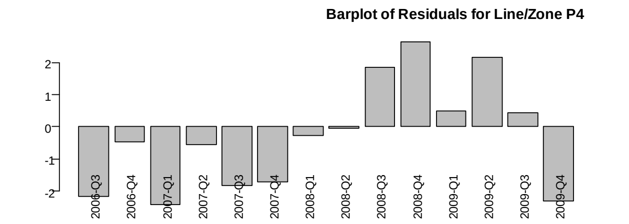

Partial Autocorrelation Function Plot for Lin
Partial ACF
Lag

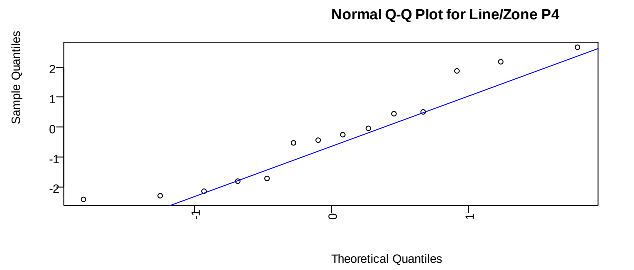

Barplot of Residuals for Line/Zone J3

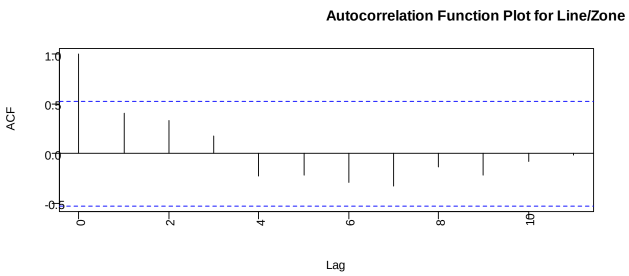

Normal Q-Q Plot for Line/Zone J3
Sample Quantiles
Theoretical Quantiles

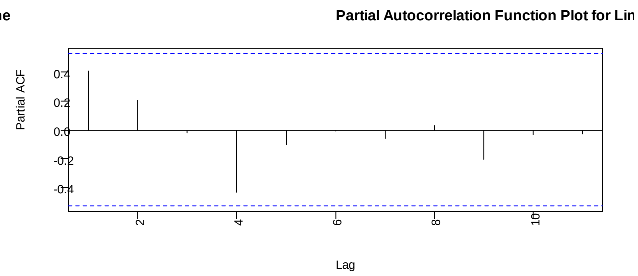

Autocorrelation Function Plot for Line/Zone
ACF
Lag

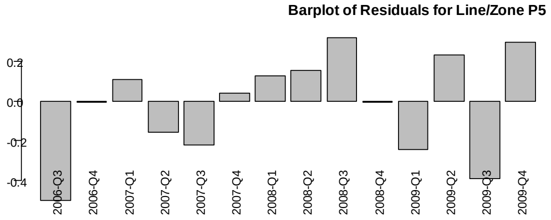

Partial Autocorrelation Function Plot for Lin
Partial ACF
Lag

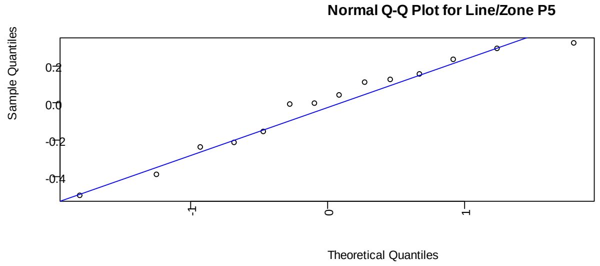

Barplot of Residuals for Line/Zone P4


Normal Q-Q Plot for Line/Zone P4
Sample Quantiles
Theoretical Quantiles


Autocorrelation Function Plot for Line/Zone
ACF
Lag


Partial Autocorrelation Function Plot for Lin
Partial ACF
Lag


Barplot of Residuals for Line/Zone P5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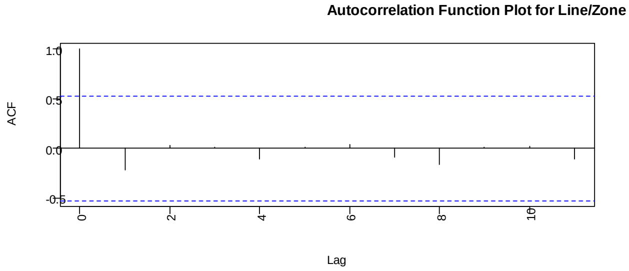
Sample Quantiles
Theoretical Quantiles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ACF
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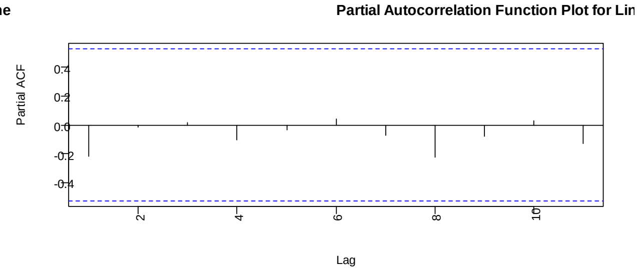
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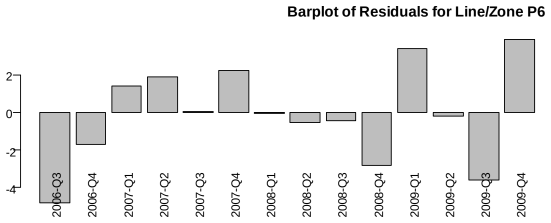
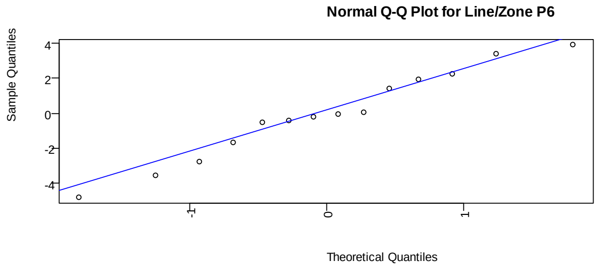

Barplot of Residuals for Line/Zone P6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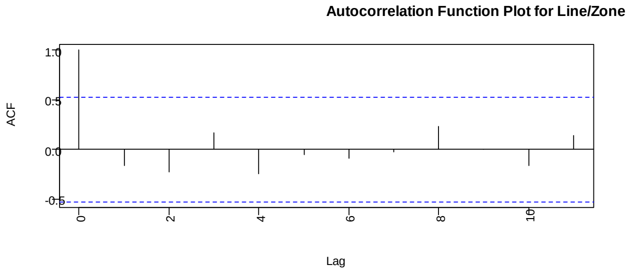
Sample Quantiles
Theoretical Quantiles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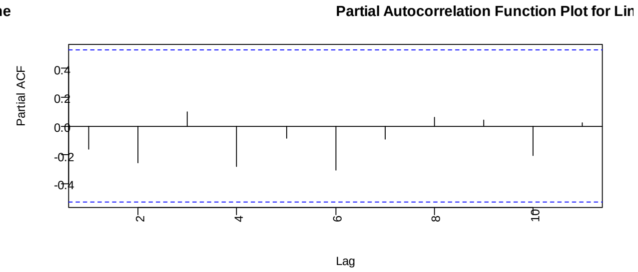
Partial Autocorrelation Function Plot for Lin
Partial ACF
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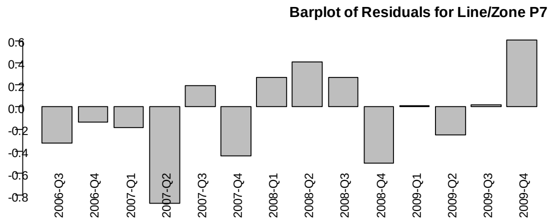
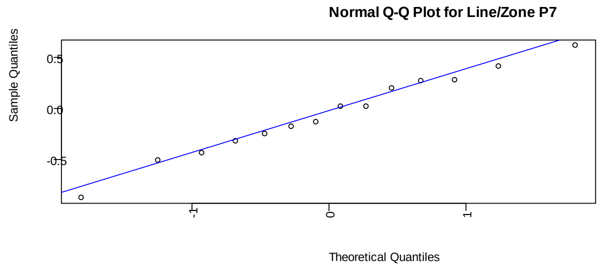

Barplot of Residuals for Line/Zone P7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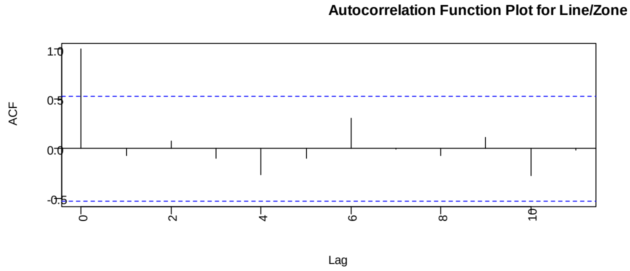
Sample Quantiles
Theoretical Quantiles


Autocorrelation Function Plot for Line/Zone
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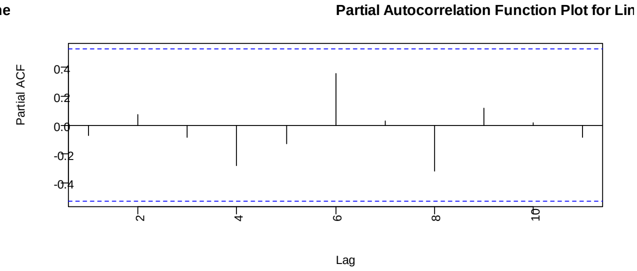
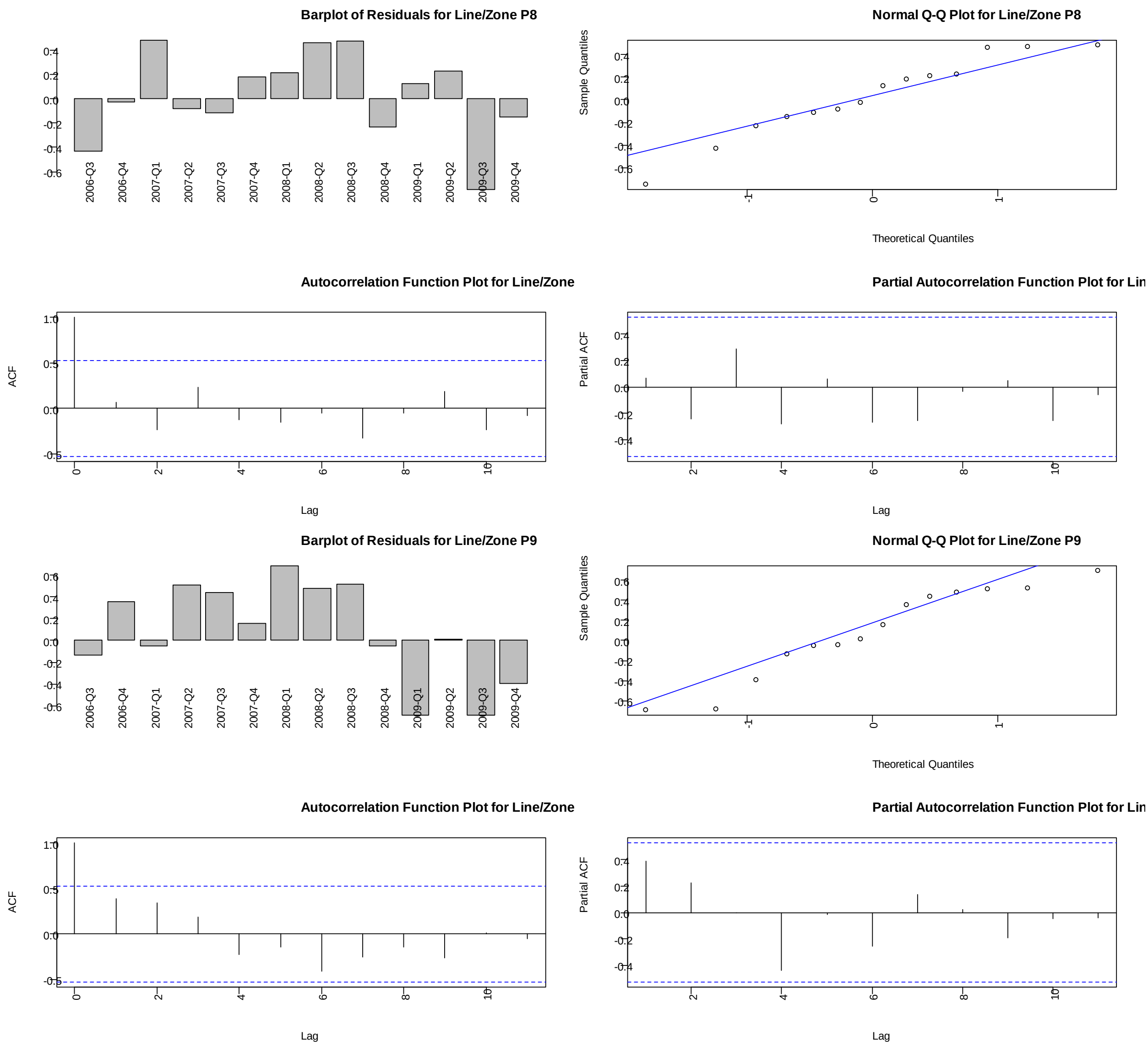
Lag


Partial Autocorrelation Function Plot for Lin
Partial ACF
Lag



D7 Estimates and findings

This section presents the coefficients estimated using our econometric panel data model.

Table D.14 below shows our estimates for the impact of economic variables, broken down by ticket type.

Table D.14 Estimates of coefficients for economic variables

Economic and service variables	Monthly + quarterly	10-trip	Adult single	Aggregate
Real rail fare	-0.65* (-1.13, -0.16)	-0.73* (-1.29, -0.17)	Removed due to implausible sign	-0.60** (-1.05, -0.16)
Real petrol price	0.14 (-0.16, 0.44)	0.01 (-0.42, 0.43)	0.28* (0.07, 0.50)	0.16 (-0.15, 0.46)
Nominal $2.00 petrol price threshold	Omitted due to interaction with real petrol price	15%‘ (-3%, 33%)	Removed due to implausible sign	Omitted due to interaction with real petrol price

Economic and service variables	Monthly + quarterly	10-trip	Adult single	Aggregate
Real retail sales (Wellington city)	Omitted due to interaction with employment	Omitted due to interaction with employment	Omitted due to interaction with employment	Omitted due to interaction with employment
Employment (Wellington city)	1.33‘ (-0.09, 2.74)	0.77 (-0.73, 2.26)	1.01‘ (-0.10, 2.13)	1.44* (0.19, 2.69)
Introduction of SuperGold Card (Oct 08)	Removed due to implausible sign	-28%*** (-45%, -12%)	Removed due to implausible sign	-13%‘ (-26%, 0%)
Extra commuter services (Nov 08)	7% (-5%, 18%)	26%** (9%, 42%)	3% (-3%, 10%)	15%* (2%, 29%)

Key findings from Table D.14 are:

- The fare elasticities for aggregate ticket sales are estimated to be around -0.6 to -0.7. Of these sales of 10-trip tickets were the most responsive to fare increases, and adult tickets were the least responsive
- Petrol prices had a discernible impact on ticket sales growth. Most of the petrol price thresholds were dropped during the model building stages but some of these were quite high (see section D5).

Table D.15 examines the impact of miscellaneous events on Wellington rail patronage.

Table D.15 Estimates of miscellaneous events on patronage growth

Miscellaneous events:	Monthly + quarterly	10-trip	Adult single	Aggregate
Dip in monthly ticket sales (Jan/Feb 06)	-40%*** (-46%, -34%)			-21%*** (-25%, -16%)
Dip in monthly ticket sales (Jan/Feb 08)	-44%*** (-51%, -38%)			-25%*** (-29%, -21%)
Closure of Johnsonville line (Jan/Feb 09)		-46%*** (-65%, -26%)	-37%*** (-57%, -17%)	-28%** (-47%, -8%)
Easter	Removed due to implausible sign	1% (-3%, 5%)	-3%* (-6%, -1%)	Removed due to implausible sign

Appendix E: Econometric analysis of patronage growth on the Wellington city bus system

E1 Introduction

In section 7.4 of the main report we presented our conclusions regarding the contribution of explanatory variables to Wellington city bus patronage growth over the five-year period from 2005–Q2 to 2010–Q1. Then in section 7.5 we presented our findings in regard to elasticities and other estimates for those explanatory variables.

Those conclusions and findings are based on a thorough econometric methodology[46] that helps us understand as much as we can about what is driving patronage growth at a corridor level. We then bundle data from the bus corridors together and use an econometric tool (called a panel data model) to estimate what is driving bus patronage across the Wellington city bus system.

The following sections show how the econometric methodology was applied to analysis of Wellington city bus patronage, and describe the analyses underlying our conclusions and findings.

- *E2 Data collection and data manipulation* – the analytical process begins with data collection. The data then has to be checked and manipulated into a form suitable for econometric analysis.
- *E3 Graphical analysis* – we believe it is important to look at the data and make sense of it intuitively before proceeding onto econometric analysis. In section E3 we look at patronage growth along each of the main bus corridors and seek to explain and understand any trends or anomalies in the data. The observations here feed into the models tested in sections E4 to E7.
- *E4 Data analysis* – there are a number of statistical problems that can potentially undermine the validity of the econometric analysis. (These problems are technically referred to as multicollinearity, spurious regression and endogeneity.) In section E4 we show that we have examined the data for presence of these problems and have responded accordingly where there is evidence of a problem
- *E5 Model building process* – the process of building models for patronage growth involves looking at the data and fitting a general model that explains the patterns in the data as well as possible. We then investigate the contribution of the explanatory variables in the general model, removing those that look suspect or indeterminate, and whittling the model down to its core components. Section E5 describes the process by which each of the initial models was whittled down into preferred models.
- *E6 Diagnostic analysis* – the preferred model will still not be statistically valid unless the residuals of the model meet certain criteria. In section E6 we show our examination of the residuals of each individual line, in which we look for evidence of autocorrelation, non-normality or omitted variables.
- *E7 Estimates and findings* – in section E7 we show the estimates produced using the final models.

[46] See chapter 2 of the main report for presentation and explanation of the econometric methodology.

E2 Data collection and data manipulation

E2.1 Patronage data

Most of the bus routes in Wellington are served by a single transport operator (NZ Bus Ltd) and most of the patronage data from these bus routes can be segregated as follows:

- The 'Go Wellington' database consists primarily of bus routes that operate within 'Wellington city'.
- The 'Valley Flyer' database consists of bus routes that travel to and from Wellington city, including the Airport Flyer and services to/from Eastbourne, Upper Hutt, Stokes Valley, Western Hills, Naenae and Wainuiomata.

The remit of this research project was to produce estimates for Wellington city, and for this we focused on the 'Go Wellington' database. However, we envisage that this research project could be extended in the future to include routes covered by the 'Valley Flyer' services, the Runciman services, the Mana Coach Services and the Newlands Coach Services.

NZ Bus provided detailed patronage data, disaggregated by route, corridor, time of day and ticket type, from 2005–Q1 to 2010–Q1. The detail of the data is very exciting and the analyses presented in this report, although reasonably sophisticated, are still only a taste of what can, and we anticipate, will be produced in the future.

The time periods employed by NZ Bus in their patronage data are based on the following definitions:

- weekday peak (7am to 9am, 4pm to 6pm)
- weekday off-peak (9am to 4pm, 6pm to 12am)
- Saturday
- Sunday.

Our initial examination of both the patronage data and the service trip data revealed evidence of data corruption, most likely due to omission of data on certain days. By examining patterns in the data we were able to make 'educated guesses' about the extent of these data corruption problems and adjusted the data accordingly.

Section 2.2.1 of the main report describes the general approach used to manipulate patronage data into a form adequate for econometric modelling. For this dataset we followed this general approach and were able to produce average-weekday-patronage-per-quarter (by peak and offpeak) and average-weekend-patronage-per-'weekend equivalent' to use as dependent variables in the econometric modelling.

E2.2 Service and route data

NZ Bus Ltd also provided service trip data, disaggregated by route, corridor and time of day, from 2005-Q2 to 2010-Q1. Contacts from NZ Bus Ltd expressed a view that there were no service improvements of any note during this time period. Our analysis of the service data generally backed this up.

We still needed to examine and clean the data. We decided to focus on analysing the data at a corridor level. A 'corridor' is a collection of routes that travel along roughly the same path. Table E.1 shows the routes contained within each corridor.

Analysing the data by corridor reduces the amount of time involved in econometric analysis. There were 39 routes (including route variations and re-labelling of existing routes) and these 39 routes can be categorised into 15 corridors.

Table E.1 also shows that a number of corridors were discarded from further analysis for various reasons.

Table E.1 Routes within each corridor

Corridor	Corridor name	Routes	Decision
BKN	Brooklyn	7,8,9	Discarded due to unexplained volatility in weekend patronage data
CC	City Circular	15	Discarded because the route was discontinued in Feb 07
CPC	Campus Connection	18,47	Selected for econometric analysis
IBY	Island Bay	1,4,29,32	Selected for econometric analysis
KAR	Karori	3,6,12,17	Selected for econometric analysis
KHN	Khandallah	25,28,43,44,45,46	Selected for econometric analysis
MAI	Mairangi	13,22,23	Selected for econometric analysis
MMR	Miramar	2,5,24,27,31,42	Selected for econometric analysis
MTV	Mt Victoria	20	Selected for econometric analysis
NTP	Newtown Park	10	Selected for econometric analysis
STN	Seatoun	11,26,30	Selected for econometric analysis
STS	Stadium Shuttles	16	Discarded due to the intermittent nature of services provided
UNK	Trial route	48,49	Discarded because these were only trial routes that were discontinued
WLN	Wilton	14	Selected for econometric analysis
WRH	Wrights Hill	21	Selected for econometric analysis

E2.3 Other data

We collected and incorporated data on a number of explanatory variables: fares, petrol prices, retail sales and employment. Where applicable, these variables were then adjusted for inflation and hence the rest of the report refers to them as real fares, real petrol prices and real retail sales.

The retail sales and employment data reflect economic activity within the 'Wellington city' territorial authority, which seems appropriate since we are only focusing on Wellington city bus routes.

We also collected data on cars licensed by territorial authority but, after examination we found evidence of substantial corruption in the data so it was discarded.

We requested corridor-level or route-level data on reliability from NZ Bus Ltd. Prior to 2009, NZ Bus Ltd had carried out trip monitoring but that data was unfortunately lost when computer systems were changed. We were therefore unable to incorporate reliability measures into our econometric modelling, which was problematic given that punctuality/congestion problems clearly had an impact back in February 2007.

In section 2.2.2 of the main report, we explain why we decided against incorporating population statistics into the econometric analyses. In general, we have doubts about the statistical robustness of findings produced using population statistics because they are low frequency (ie data is only annual) low accuracy (ie data is only an estimate), exhibit low variance (ie populations exhibit steady growth rates over time) and could only be obtained for broad geographical regions (ie territorial authorities).

Ideally, econometric modelling should control for the impact of key historical events. Table E.2 shows key events that we have identified. We tested for the impact of most of these events in our econometric analysis, with the exception of the pensioner bus permits and the introduction of an electronic payment card, Snapper; we judged that impact of these events would be too difficult to identify and that any subsequent finding would be tenuous.

Table E.2 Miscellaneous events and factors

Event	Months affected	Quarters affected	Notes relating to event	Corridors affected
Fare increase in 2006	Sep 06	2006–Q3	On 4 September 2006, there was a nominal fare increase of about 20%, on average. This fare increase was accompanied by changes to the fare structure, with fares based on new zones rather than the old section-based system.	All corridors
Punctuality/ congestion problems	Feb 07	2007–Q1, 2007–Q2	From February 2007, there was an unfortunate combination of events that created the ‘perfect storm’ for punctuality/congestion problems: • The city bypass was introduced and resulted in major disruptions to traffic patterns and hence unprecedented traffic congestion until motorists found their ways around the new patterns • NZ Bus Ltd introduced a number of timetable changes to improve reliability and punctuality but these backfired as they coincided with both the city bypass and driver shortages. There is some evidence that a combination of all these factors had a (temporary) negative impact on patronage over a 6-month period, but the patronage recovered soon after that.	All corridors
Fare increase in 2008	Sep 08	2006–Q3	On 1 September 2008, there was a nominal fare increase of about 8%, on average.	All corridors
Introduction of SuperGold Card	Oct 08	2008–Q4	The SuperGold Card was introduced in October 2008, providing free off-peak and weekend travel for persons over 65.	All corridors
Pensioner bus permits no longer valid	Apr 08	2008–Q2	On 1 April 2009 pensioner bus permits were removed	All corridors
Snapper introduced	Jun 09	2009–Q3	On 14 June 2009, the Snapper electronic payment card was introduced. We understand that Snapper has been generally well received and therefore may have had a positive long-term impact on patronage.	All corridors
Easter holidays	March or April depending on calendar	Q1 or Q2 depending on calendar	The Easter holidays occur sometimes in March and sometimes in April, depending on the calendar at the time. This can affect patronage because the timetables are more limited and because patrons are on holiday and hence less likely to use the buses for transportation.	All corridors

E3 Graphical analysis

E3.1 Key themes from graphical analysis

This section presents the key themes drawn from a graphical analysis of all bus corridors selected for econometric analysis.

- There were two fare increases (September 2006, September 2008) but they did not have the same impact on patronage:
  - The September 2006 fare increase appears to have had a negative impact on offpeak weekday and weekend patronage yet no discernible impact on weekday peak patronage.
  - The September 2008 fare increase appears to have had a negative impact on peak weekday patronage but no impact on offpeak weekday or weekend; that said, the indiscernible impact on offpeak and weekend could be due to the countervailing impact of the introduction of the SuperGold Card in October 2008.
- There is modest evidence that petrol prices had an impact on patronage demand.
- There is consistent evidence of data errors in the weekend data:
  - Patronage on Saturdays exhibited a temporary spike in 2006–Q1, hence contributing to negative patronage growth in 2007–Q1. Closer examination of this spike revealed that Saturday patronage was unusually high in March 2006 for unexplained reasons.
  - Patronage on Sundays exhibited a temporary spike in 2005–Q4, hence contributing to negative patronage growth in 2006–Q4. Closer examination of the spike revealed that Sunday patronage was unusually high in December 2005 for unexplained reasons.
- A number of bus corridors appeared to exhibit a permanent jump in Sunday patronage around 2007-Q4. This jump was not observed on Saturdays and was most pronounced on corridors Karori (KAR), Mairangi (MAI, Mirimar (MMR), Seatoun (STN) and Wilton (WLN). We were not able to identify an explanation for this.

One of the peer reviewers noted that the patterns and trends observed via graphical analysis differed substantially from one bus corridor to the next. In particular, some bus corridors exhibited a more pronounced fall in peak patronage from 2008–Q4 onwards (coinciding with both SuperGold and a fare increase) while other bus corridors exhibited a more muted response.

This fall in patronage could be due to a number of factors including the level of senior patronage, school enrolments, tertiary enrolments, and the distance between the bus corridor catchment area and the CBD. We therefore recommend that future research employ a market segment approach that segregates the analysis by ticket-type and number of zones covered (see section 7.7.3 of the main report). This market segment approach may offer more insight into the causes of some of these apparent inconsistencies.

E3.2 Graphical analysis of Campus Connection bus corridor

This section gives a graphical analysis of the Campus Connection (CPC) corridor. It should be noted that patronage on this corridor is low relative to other corridors and is very sensitive to fluctuations in student numbers. With that caveat, key findings from graphical analysis of this corridor follow.

The graphical analysis of the CPC corridor exhibited a number of trends and patterns that were commonly observed across most bus corridors:

- There was a modest relationship between petrol prices and patronage growth:
  - Between 2007–Q4 and 2008–Q3 petrol prices were rising and this period was generally associated with positive patronage growth.
  - Between 2008–Q4 and 2009–Q3 petrol prices were falling and this period was generally associated with low or negative patronage growth.
- The 2006 fare increase appears to have had a (slight) negative impact on offpeak weekday patronage but does not appear to have had a negative impact on peak-time patronage.

In addition, the CPC corridor also exhibited quite dramatic falls in patronage around 2008–Q4 (offpeak only) and 2009–Q1 (both peak and offpeak). These falls appear to have been of a temporary nature because they were reversed one year later (see 2009–Q4 and 2010–Q1 for evidence of this).

(graphs omitted for confidentiality reasons)

E3.3 Graphical analysis of Island Bay bus corridor

The graphical analysis of the Island Bay (IBY) corridor exhibited a number of trends and patterns that were commonly observed across most bus corridors:

- There was a modest relationship between petrol prices and patronage growth:
  - between 2007–Q4 and 2008–Q3 petrol prices were rising and this period was generally associated with positive patronage growth
  - between 2008–Q4 and 2009–Q3 petrol prices were falling and this period was generally associated with low or negative patronage growth.
- The 2006 fare increase appears to have had a negative impact on offpeak weekday patronage but does not appear to have had a negative impact on peak-time patronage.
- There was a drop-off in peak patronage from 2008–Q4 onwards, coinciding with both the 2008 fare increase and the introduction of the SuperGold Card[47].
- Weekend patronage exhibited unexplained but temporary 'spikes' in patronage in 2005–Q4 (Sunday only) and 2006–Q1 (Saturday only). These were subsequently reversed, respectively, in 2006–Q4 and 2007–Q1.

In addition, the 2008 fare increase appears to have had a negative impact on peak patronage growth on the IBY corridor (but no impact on offpeak patronage).

(graphs omitted for confidentiality reasons)

E3.4 Graphical analysis of Karori Park bus corridor

The graphical analysis of the Karori Park (KAR) corridor exhibited a number of trends and patterns that were commonly observed across most bus corridors:

- The 2006 fare increase appears to have had a negative impact on offpeak weekday patronage but does not appear to have had a negative impact on peak-time patronage.

[47] We note that the SuperGold Card only applies to offpeak travel. However, it is possible that the introduction of the SuperGold Card encouraged some people who would otherwise have make journeys during the peak to make those journeys during the offpeak instead.

- Weekend patronage exhibited unexplained but temporary 'spikes' in patronage in 2005–Q4 (Sunday only) and 2006–Q1 (Saturday only).
- There was a drop-off in peak patronage from 2008–Q4 onwards, coinciding with both the 2008 fare increase and the introduction of the SuperGold Card.

Distinguishing features of the graphical analysis of the KAR corridor include:

- The relationship between petrol prices and patronage growth seemed more subdued than observed on other bus corridors; the growth rates on the KAR corridor were relatively stable by comparison.
- Saturday patronage exhibited a temporary drop in patronage in 2007–Q1 and 2007–Q2. The exact reasons for this are not clear, but we do note that it coincided with the rescheduling problems encountered in February 2007.
- Sunday patronage seemed to exhibit a permanent jump in patronage in 2007–Q4. We have been unable to identify an explanation for this, but note that the same pattern was observed on a number of bus corridors: Karori (KAR), Mairangi (MAI, Mirimar (MMR), Seatoun (STN) and Wilton (WLN).

(graphs omitted for confidentiality reasons)

E3.5 Graphical analysis of Khandallah bus corridor

The graphical analysis of the Khandallah (KHN) corridor exhibited a number of trends and patterns that were commonly observed across most bus corridors:

- The 2006 fare increase appears to have had a (slight) negative impact on offpeak weekday patronage but does not appear to have had any discernible negative impact on peak-time patronage.
- Weekend patronage exhibited unexplained but temporary 'spikes' in patronage in 2005–Q4 (Sunday only) and 2006–Q1 (Saturday only). These were subsequently reversed, respectively, in 2006–Q4 and 2007–Q1.

Distinguishing features of the graphical analysis of the KHN corridor include:

- The relationship between petrol prices and patronage growth seemed more subdued than observed on other bus corridors; the growth rates on the KHN corridor were relatively stable in comparison to most other bus corridors, especially during peak times.
- Unlike most other bus corridors there did not appear to be a drop-off in peak patronage from 2008–Q4 onwards, coinciding with both the 2008 fare increase and the introduction of the SuperGold Card.
- The service trip data (not shown here) implied a large fall in services provided (ie -50%) in August 2008 (ie 2008–Q3) but there was no evidence of a subsequent fall in patronage, hence suggesting that the service trip data was flawed.

(graphs omitted for confidentiality reasons)

E3.6 Graphical analysis of Mairangi bus corridor

The graphical analysis of the Mairangi (MAI) corridor exhibited a number of trends and patterns that were commonly observed across most bus corridors:

- There was a modest relationship between petrol prices and patronage growth:
    - Between 2007–Q4 and 2008–Q3 petrol prices were rising and this period was generally associated with positive patronage growth.

- Between 2008-Q4 and 2009-Q3 petrol prices were falling and this period was generally associated with low or negative patronage growth.

- There was a drop-off in peak patronage from 2008-Q4 onwards, coinciding with both the 2008 fare increase and the introduction of the SuperGold Card.
- Weekend patronage exhibited unexplained but temporary 'spikes' in patronage in 2005-Q4 (Sunday only) and 2006-Q1 (Saturday only). These were subsequently reversed, respectively, in 2006-Q4 and 2007-Q1.

Distinguishing features of the graphical analysis of the MAI corridor included:

- The 2006 fare increase did not have a discernible impact on patronage during either the peak or the offpeak.
- Sunday patronage seemed to exhibit a permanent jump in patronage in 2007-Q4. We have been unable to identify an explanation for this, but note that the same pattern was observed on a number of other bus corridors.

(graphs omitted for confidentiality reasons)

E3.7 Graphical analysis of Miramar bus corridor

The graphical analysis of the Miramar (MMR) corridor exhibited a number of trends and patterns that were commonly observed across most bus corridors:

- There was a modest relationship between petrol prices and patronage growth:
  - Between 2007-Q4 and 2008-Q3 petrol prices were rising and this period was generally associated with positive patronage growth.
  - Between 2008-Q4 and 2009-Q3 petrol prices were falling and this period was generally associated with low or negative patronage growth.
- The 2006 fare increase appears to have had a negative impact on offpeak weekday patronage but does not appear to have had any discernible negative impact on peak-time patronage.
- There was a drop-off in peak patronage from 2008-Q4 onwards, coinciding with both the 2008 fare increase and the introduction of the SuperGold Card.
- Weekend patronage exhibited unexplained but temporary 'spikes' in patronage in 2005-Q4 (Sunday only) and 2006-Q1 (Saturday only). These were subsequently reversed, respectively, in 2006-Q4 and 2007-Q1.

Distinguishing features of the graphical analysis of the MMR corridor include:

- There appears to have been a temporary drop in peak-time patronage in 2007-Q1 and 2007-Q2, coinciding with the rescheduling problems etc observed in 2007-Q1 (see table E.2 for more discussion).
- Sunday patronage seemed to exhibit a permanent jump in patronage in 2007-Q4. We have been unable to identify an explanation for this, but note that the same pattern was observed on a number of other bus corridors.

(graphs omitted for confidentiality reasons)

E3.8 Graphical analysis of Mt Victoria bus corridor

Graphical analysis of the Mt Victoria (MTV) corridor showed that patronage growth patterns were very volatile due to relatively low levels of patronage compared with other corridors. With that caveat in mind, we note that the graphical analysis of the MTV corridor identified patterns and trends that were different from those observed elsewhere:

- There was perhaps a positive relationship between petrol price changes and patronage growth, but the relationship is not as obvious as it was for other bus corridors.
- It is not clear whether the 2006 fare increase had a negative impact on either peak or offpeak weekday patronage; there was a drop in patronage (during both time periods) around 2007–Q1, but this could be due to either the 2006 fare increase or rescheduling problems etc observed in February 2007 (see table E.2 for more discussion).
- It is also not clear whether the 2008 fare increase had a negative impact on either peak or offpeak weekday patronage; there was a lot of volatility post 2008–Q4 but no clear downward trend.

There were no weekend services for the MTV corridor.

(graphs omitted for confidentiality reasons)

E3.9 Graphical analysis of Newtown Park bus corridor

The graphical analysis of the Newtown Park (NTP) corridor showed that patronage growth patterns were very volatile due to relatively low levels of patronage compared with other corridors. With that caveat in mind, we note that the graphical analysis of the NTP corridor exhibited a number of trends and patterns that were commonly observed across most bus corridors:

- There was perhaps a positive relationship between petrol price changes and patronage growth, although the relationship is not as obvious as it was for other bus corridors.
- The 2006 fare increase appears to have had a negative impact on offpeak weekday patronage but does not appear to have had any discernible negative impact on peak-time patronage.

Distinguishing features of the graphical analysis of the NTP corridor include:

- Unlike most of the other corridors, there is no evidence that the 2008 fare increase (or the introduction of SuperGold) caused a drop in peak time patronage.
- Interestingly, offpeak weekday patronage actually exhibited what appears to be a permanent jump in patronage in 2009–Q2.

There were no weekend services for the NTP corridor.

(graphs omitted for confidentiality reasons)

E3.10 Graphical analysis of Seatoun bus corridor

The graphical analysis of the Seatoun (STN) corridor exhibited a number of trends and patterns that were commonly observed across most bus corridors:

- There was a modest relationship between petrol prices and patronage growth:
  - Between 2007–Q4 and 2008–Q3 petrol prices were rising and this period was generally associated with positive patronage growth.

- Between 2008–Q4 and 2009–Q3 petrol prices were falling and this period was generally associated with low or negative patronage growth.

- The 2006 fare increase appears to have had a negative impact on offpeak weekday patronage but does not appear to have had any discernible negative impact on peak-time patronage.
- There was a drop-off in peak patronage from 2008–Q4 onwards, coinciding with the 2008 fare increase and the introduction of the SuperGold Card.
- Weekend patronage exhibited unexplained but temporary 'spikes' in patronage in 2005–Q4 (Sunday only) and 2006–Q1 (Saturday only). These were subsequently reversed, respectively, in 2006–Q4 and 2007--Q1.

Distinguishing features of the graphical analysis of the STN corridor include:

- There appears to have been a temporary drop in peak-time patronage in 2007–Q1 and 2007–Q2, coinciding with the rescheduling problems etc observed in 2007–Q1 (see table E.2 for more discussion).
- Sunday patronage seemed to exhibit a permanent jump in patronage in 2007–Q4. We have been unable to identify an explanation for this, but note that the same pattern was observed on a number of other bus corridors.

(graphs omitted for confidentiality reasons)

E3.11 Graphical analysis of Wilton bus corridor

The graphical analysis of the Wilton (WLN) corridor exhibited a number of trends and patterns that were commonly observed across most bus corridors:

- There was perhaps a positive relationship between petrol price changes and patronage growth, although the relationship is not as obvious as it was for other bus corridors.
- The 2006 fare increase appears to have had a negative impact on offpeak weekday patronage but does not appear to have had any discernible negative impact on peak-time patronage.
- There was a drop-off in peak patronage from 2008–Q4 onwards, coinciding with the 2008 fare increase and the introduction of the SuperGold Card.
- Weekend patronage exhibited unexplained but temporary 'spikes' in patronage in 2005–Q4 (Sunday only) and 2006-Q1 (Saturday only). These were subsequently reversed, respectively, in 2006–Q4 and 2007–Q1.

(graphs omitted for confidentiality reasons)

E3.12 Graphical analysis of Wrights Hill bus corridor

The graphical analysis of the Wrights Hill (WRH) corridor exhibited relatively low levels of patronage compared with other corridors so any trends should be observed with that in mind. Key findings from graphical analysis of the WRH corridor include:

- Unlike other corridors, there was not a strong relationship between petrol price fluctuations and patronage growth.
- The impacts of the September 2006 and September 2008 fare increases were also difficult to identify with any confidence; they seem to have had minimal impact on patronage demand.

There were no weekend services for the WRH corridor.

(graphs omitted for confidentiality reasons)

E4 Data analysis

E4.1 Multicollinearity analysis

As noted in section 2.4.1 of the main report, high correlations between explanatory variables can make econometric estimation difficult. This section uses correlation tables to examine the extent to which such correlations might be problematic.

Table E.3 shows the correlations between the explanatory variables for the period corresponding to the period from 2005–Q2 to 2010–Q1.

Table E.3 Correlations between explanatory variables for period from 2005–Q2 to 2010–Q1

	real.bus.fare	nominal.bus.fare.2006	nominal.bus.fare.2008	real.petrol.price	petrol.price.threshold.dummy.2dollar	reliability.problems.2007Q1	reliability.problems.2007Q2	snapper.2009Q3	pensioner.permits.dropped.2009Q2	supergoldcard.dummy.Oct08	Easter.dummy	wgtn.city.real.retail.sales	wgtn.city.employment
real.bus.fare	1.0												
nominal.bus.fare.2006	0.9	1.0											
nominal.bus.fare.2008	0.0	-0.4	1.0										
real.petrol.price	-0.6	-0.3	-0.6	1.0									
petrol.price.threshold.dummy.2dollar	-0.3	0.0	-0.4	0.7	1.0								
reliability.problems.2007Q1	0.5	0.4	0.0	-0.3	0.0	1.0							
reliability.problems.2007Q2	0.5	0.4	0.0	-0.4	-0.3	0.0	1.0						
snapper.2009Q3	-0.2	-0.3	0.0	-0.2	-0.3	0.0	0.0	1.0					
pensioner.permits.dropped.2009Q2	-0.2	-0.4	0.2	-0.4	-0.6	0.0	0.0	0.8	1.0				
supergoldcard.dummy.Oct08	0.1	-0.4	1.0	-0.7	-0.6	0.0	0.0	0.1	0.3	1.0			
Easter.dummy	-0.1	-0.1	-0.1	0.1	-0.4	-0.3	0.3	-0.1	0.2	-0.1	1.0		
wgtn.city.real.retail.sales	0.0	0.0	-0.1	0.1	0.1	0.0	0.0	-0.1	-0.1	-0.1	0.0	1.0	
wgtn.city.employment	0.0	0.2	-0.3	0.5	0.5	-0.2	-0.1	-0.8	-0.9	-0.4	0.1	0.1	1.0

One of the key themes from the graphical analysis (see section E3.1) was that the September 2008 fare increase had quite different impacts from the September 2008 fare increase. We therefore chose to incorporate these fare increases into the econometric model as separate events.

However, this differentiation between the September 2006 and September 2008 fare increases also creates a multicollinearity problem because the introduction of the SuperGold Card in October 2008 has a +1.0 correlation with the fare increase in September 2008. Our solution to this has been to remove SuperGold Card but to note that the subsequent fare elasticities reflect the combined effects of both fares and the SuperGold Card.

There are also strong correlations between employment and a few events: the introduction of Snapper (-0.8); and the removal of pensioner permits (-0.9). Our solution to this problem has been to remove these events; it is unlikely that their impact is of sufficient magnitude to be picked up by econometric analysis.

In addition, real petrol price movements have a +0.7 correlation with the crossing of the $2.00 threshold. To address this, we experimented with different combinations of both petrol price variables in the models developed and presented in section E5.

E4.2 Stationarity analysis

In section 2.4.2 of the main report we note that the conventional approach in transport economics is to carry out econometric regressions with all of the variables defined in levels. However, with this approach, there is a risk that the regressions can lead to spurious results if the variables are classed as nonstationary (ie they exhibit strong trends over time).

Our approach to mitigate this risk is to take seasonal differences and to look at growth rates in patronage and explanatory variables between one quarter and the preceding quarters. There is still some risk of nonstationarity and/or insufficient variation in the explanatory variables so we have proceeded with formal testing to further mitigate against the risk of spurious results.

Table E.4 shows testing for stationarity or nonstationarity of key explanatory variables. These tests for real petrol prices and real retail sales are inconclusive, which is unsurprising due to the short period covered (ie five years of data). However, a glance at the graphs of these variables in section E3 suggests that stationarity is a reasonable assumption.

The main 'red flag' is employment which the KPSS test indicates is nonstationary. It is unlikely that employment growth is actually nonstationary; the failure on this test most likely reflects the fact that employment exhibited stable and steady growth rates throughout most of the period covered, but exhibited a sharp decline in late 2008 as the recession hit.

Table E.4 Stationarity of continuous explanatory variables

		Augmented Dickey Fuller Test for stationarity[(a)]			KPSS test for nonstationarity[(a)]			
		Null hypothesis: variable is nonstationary			Null hypothesis: variable is stationary			
Variable[(b)]	**Time period**	**Critical value**	**p-value**	**Decision**	**Critical value**	**p-value**	**Decision**	**Conclusion**
%Δ in real petrol prices	2005-Q3 to 2010-Q1	-2.42	0.41	Do not reject null → series is nonstationary	0.131	>0.10	Do not reject null → series is stationary	Inconclusive
%Δ in real retail sales	2005-Q3 to 2010-Q1	-1.45	0.78	Do not reject null → series is nonstationary	0.267	>0.10	Do not reject null → series is stationary	Inconclusive
%Δ in employment	2005-Q3 to 2010-Q1	-1.03	0.92	Do not reject null → series is nonstationary	0.399	0.08	Reject null at 10% sig. → series is nonstationary	Nonstationary

(a) The ADF test incorporated 4 lags and the KPSS test employed a long version of the truncation lag parameter, which had 3 lags. Copied and pasted multiple times.

(b) Service variables and real fare were excluded from the analysis because they represent 'one-off' structural changes that cannot plausibly be regarded as stationary, regardless of the results of empirical testing. Check all the appendices.

Tables E.5 to E.7 shows testing for stationarity or nonstationarity of dependent variables. Again, these tests are generally inconclusive due to the short time period. However, we do note evidence of nonstationarity for the Khandallah (KHN) corridor during the peak and the Campus Connection (CPC) corridor during the offpeak. As section E6.1 notes, both of these corridors were excluded from the preferred model for various reasons.

Table E.5 Stationarity of dependent variable (peak patronage)

			Augmented Dickey Fuller Test for stationarity[a]			KPSS test for nonstationarity[a]			
			Null hypothesis: variable is nonstationary			Null hypothesis: variable is stationary			
Variable	Corridor	Time period	t-statistic	p-value	Decision	t-statistic	p-value	Decision	Conclusion
%Δ in peak patronage	CPC	2005-Q3 to 2010-Q1	-1.82	0.64	Do not reject null → series is nonstationary	0.30	>0.10	Do not reject null → series is stationary	Inconclusive
%Δ in peak patronage	IBY	2005-Q3 to 2010-Q1	-2.10	0.53	Do not reject null → series is nonstationary	0.26	>0.10	Do not reject null → series is stationary	Inconclusive
%Δ in peak patronage	KAR	2005-Q3 to 2010-Q1	-1.52	0.76	Do not reject null → series is nonstationary	0.35	>0.10	Do not reject null → series is stationary	Inconclusive
%Δ in peak patronage	KHN	2005-Q3 to 2010-Q1	-1.87	0.62	Do not reject null → series is nonstationary	0.44	0.06	Reject null at 10% sig. → series is nonstationary	Nonstationary
%Δ in peak patronage	MAI	2005-Q3 to 2010-Q1	-1.76	0.66	Do not reject null → series is nonstationary	0.27	>0.10	Do not reject null → series is stationary	Inconclusive
%Δ in peak patronage	MMR	2005-Q3 to 2010-Q1	-2.24	0.48	Do not reject null → series is nonstationary	0.11	>0.10	Do not reject null → series is stationary	Inconclusive
%Δ in peak patronage	MTV	2005-Q3 to 2010-Q1	-2.55	0.36	Do not reject null → series is nonstationary	0.14	>0.10	Do not reject null → series is stationary	Inconclusive
%Δ in peak patronage	NTP	2005-Q3 to 2010-Q1	-0.84	0.94	Do not reject null → series is nonstationary	0.22	>0.10	Do not reject null → series is stationary	Inconclusive
%Δ in peak patronage	STN	2005-Q3 to 2010-Q1	-2.55	0.36	Do not reject null → series is nonstationary	0.15	>0.10	Do not reject null → series is stationary	Inconclusive
%Δ in peak patronage	WLN	2005-Q3 to 2010-Q1	-1.57	0.74	Do not reject null → series is nonstationary	0.28	>0.10	Do not reject null → series is stationary	Inconclusive
%Δ in peak patronage	WRH	2005-Q3 to 2010-Q1	-1.58	0.73	Do not reject null → series is nonstationary	0.15	>0.10	Do not reject null → series is stationary	Inconclusive

[a] The ADF test incorporated 4 lags and the KPSS test employed a long version of the truncation lag parameter, which had 3 lags.

Table E.6 Stationarity of dependent variable (offpeak patronage)

			Augmented Dickey Fuller Test for stationarity[(a)]			KPSS test for nonstationarity[(a)]			
			Null hypothesis: variable is nonstationary			Null hypothesis: variable is stationary			
Variable	**Corridor**	**Time period**	**t-statistic**	**p-value**	**Decision**	**t-statistic**	**p-value**	**Decision**	**Conclusion**
%Δ in offpeak patronage	CPC	2005–Q3 to 2010–Q1	-1.42	0.79	Do not reject null → series is nonstationary	0.44	0.06	Reject null at 10% sig. → series is nonstationary	Nonstationary
%Δ in offpeak patronage	IBY	2005–Q3 to 2010–Q1	-2.15	0.52	Do not reject null → series is nonstationary	0.08	>0.10	Do not reject null → series is stationary	Inconclusive
%Δ in offpeak patronage	KAR	2005–Q3 to 2010–Q1	-3.50	0.06	Do not reject null → series is nonstationary	0.32	>0.10	Do not reject null → series is stationary	Inconclusive
%Δ in offpeak patronage	KHN	2005–Q3 to 2010–Q1	-2.38	0.43	Do not reject null → series is nonstationary	0.12	>0.10	Do not reject null → series is stationary	Inconclusive
%Δ in offpeak patronage	MAI	2005–Q3 to 2010–Q1	-1.80	0.65	Do not reject null → series is nonstationary	0.24	>0.10	Do not reject null → series is stationary	Inconclusive
%Δ in offpeak patronage	MMR	2005–Q3 to 2010–Q1	-1.98	0.58	Do not reject null → series is nonstationary	0.13	>0.10	Do not reject null → series is stationary	Inconclusive
%Δ in offpeak patronage	MTV	2005–Q3 to 2010–Q1	-2.33	0.45	Do not reject null → series is nonstationary	0.26	>0.10	Do not reject null → series is stationary	Inconclusive
%Δ in offpeak patronage	NTP	2005–Q3 to 2010–Q1	-4.24	0.01	Do not reject null → series is nonstationary	0.24	>0.10	Do not reject null → series is stationary	Inconclusive
%Δ in offpeak patronage	STN	2005–Q3 to 2010–Q1	-1.94	0.59	Do not reject null → series is nonstationary	0.11	>0.10	Do not reject null → series is stationary	Inconclusive
%Δ in offpeak patronage	WLN	2005–Q3 to 2010–Q1	-2.73	0.30	Do not reject null → series is nonstationary	0.15	>0.10	Do not reject null → series is stationary	Inconclusive
%Δ in offpeak patronage	WRH	2005–Q3 to 2010–Q1	-2.23	0.48	Do not reject null → series is nonstationary	0.16	>0.10	Do not reject null → series is stationary	Inconclusive

(a) The ADF test incorporated 4 lags and the KPSS test employed a long version of the truncation lag parameter, which had 3 lags.

Table E.7 Stationarity of dependent variable (weekend patronage)

			Augmented Dickey Fuller Test for stationarity[(a)]			KPSS test for nonstationarity[(a)]			
			Null hypothesis: variable is nonstationary			Null hypothesis: variable is stationary			
Variable	**Corridor**	**Time period**	**t-statistic**	**p-value**	**Decision**	**t-statistic**	**p-value**	**Decision**	**Conclusion**
%Δ in offpeak patronage	IBY	2005-Q3 to 2010-Q1	-2.30	0.46	Do not reject null → series is nonstationary	0.13	>0.10	Do not reject null → series is stationary	Inconclusive
%Δ in offpeak patronage	KAR	2005-Q3 to 2010-Q1	-2.34	0.44	Do not reject null → series is nonstationary	0.17	>0.10	Do not reject null → series is stationary	Inconclusive
%Δ in offpeak patronage	KHN	2005-Q3 to 2010-Q1	-2.11	0.53	Do not reject null → series is nonstationary	0.15	>0.10	Do not reject null → series is stationary	Inconclusive
%Δ in offpeak patronage	MAI	2005-Q3 to 2010-Q1	-2.40	0.42	Do not reject null → series is nonstationary	0.21	>0.10	Do not reject null → series is stationary	Inconclusive
%Δ in offpeak patronage	MMR	2005-Q3 to 2010-Q1	-1.74	0.67	Do not reject null → series is nonstationary	0.24	>0.10	Do not reject null → series is stationary	Inconclusive
%Δ in offpeak patronage	STN	2005-Q3 to 2010-Q1	-2.17	0.51	Do not reject null → series is nonstationary	0.19	>0.10	Do not reject null → series is stationary	Inconclusive
%Δ in offpeak patronage	WLN	2005-Q3 to 2010-Q1	-1.73	0.68	Do not reject null → series is nonstationary	0.11	>0.10	Do not reject null → series is stationary	Inconclusive

[(a)] The ADF test incorporated 4 lags and the KPSS test employed long version of the truncation lag parameter, which had 3 lags.

E4.3 Endogeneity issues

In section 2.4.3 we note that endogeneity or 'reverse causation' is another statistical issue that needs to be given careful consideration. In particular, the econometric models adopted in this research project assume that patronage growth is 'caused' by service improvements. However, it is conceivable that transport operators improve service levels as a means of coping with patronage demand.

In the case of the Wellington city bus system endogeneity is unlikely to be a problem because there were no notable service enhancements during the period studied.

E5 Model building process

E5.1 Development of the model for peak weekday patronage

The model building process began with building a general model for peak weekday patronage. This encompassed a broad collection of explanatory variables and key factors.

The general model was modified to take into account the punctuality/congestion problems caused by the combination of timetable rescheduling, driver shortages and the bypass (see table E.2 in section E2.3). As discussed in section 7.4 of the main report, we incorporated the rescheduling impacts into the econometric model by making the assumption that the impact of the rescheduling was temporary; therefore, any impact on patronage that was reversed in the subsequent year was due to rescheduling and any permanent impacts were attributed to the September 2006 fare increase.

Table E.8 shows how the general model was revised to produce a preferred model. The general model produced a fare elasticity estimate for the September 2006 fare increase that was positive, contrary to expectation. The reasons for this are not certain. One possible explanation is that the zone changes accompanying the fare increase actually encouraged patronage.

In model 2, Easter had a positive sign, again countrary to expectation since Easter would be expected to reduce peak-time patronage. This variable was removed, leading to model 3.

Section E4.1 also noted that the correlation between real petrol price movements and the nominal $2.00 petrol price threshold could be making it difficult to distinguish between these two related effects. Therefore, model 4 and model 5 were tested omitting each of these variables in turn.

Despite that testing process, we decided in favour of keeping both variables in (ie model 3). However, the main problem with model 3 was that the diagnostic analysis indicated there was a number of corridors that were undermining the accuracy of the model (see section E6.1). These corridors were removed from the analysis, leading to model 6. In model 6, punctuality/congestion problems were shown to have an incorrect sign so it was removed leading to model 7, the preferred model.

Table E.8 Development of the model for peak weekday patronage[48]

Time trends and explanatory variables		General model	Model 2	Model 3	Model 4	Model 5	Model 6	Model 7 (Preferred)
Time trend	Campus Connection (CPC)	X%	X%	X%	X%	X%	Omitted	
	Island Bay (IBY)	X%	X%	X%	X%	X%	X%	X%
	Karori (KAR)	X%	X%	X%	X%	X%	X%	X%
	Khandallah (KHN)	X%	X%	X%	X%	X%	Omitted	
	Mairangi (MAI)	X%	X%	X%	X%	X%	X%	X%
	Mirimar (MMR)	X%	X%	X%	X%	X%	X%	X%
	Mt Victoria (MTV)	X%	X%	X%	X%	X%	Omitted	
	Newtown Park (NTP)	X%	X%	X%	X%	X%	Omitted	
	Seatoun (STN)	X%	X%	X%	X%	X%	Omitted	
	Wilton (WLN)	X%	X%	X%	X%	X%	X%	X%
	Wrights Hill (WRH)	X%	X%	X%	X%	X%	Omitted	
Punctuality/congestion problems (Feb/Mar 07)		-3%	-2%	-1%	1%	-2%	3%	Implausible sign
Real bus fare (Sep 06)		0.36**	Implausible sign					
Real bus fare (Sep 08)		0.64	-0.12	-0.10	-0.07	-0.37	-0.37	-0.66*
Real petrol price		0.08	-0.05	0.09	0.19**	Omitted to test interaction with $2 threshold	0.19*	0.13*
Nominal $2.00 petrol price threshold		17%***	19%***	8%*	Omitted to test interaction with real petrol price	10%***	3%	4%
Real retail sales (Wellington city)		0.04	0.03	0.04	0.05	0.03	-0.05	-0.04
Employment (Wellington city)		-0.39	-0.10	0.11	0.01	0.23	0.22	0.36
Easter		3%**	3%**	Implausible sign				

48 The time-trends in table E.8 have been removed for confidentiality reasons.

E5.2 Development of the model for offpeak weekday patronage

A general model for offpeak weekday patronage was fitted, similar to that for peak weekday patronage (see section E5.1).

One key issue for offpeak patronage is that the September 2008 fare increase coincided with the introduction of the SuperGold Card in October 2008. Since both events occurred at the same time we were unable to estimate their impacts separately; therefore, the fare elasticity estimates for the 'nominal bus fare (September 2008)/+SuperGold (October 2008)' variable represents the combined effect of both the fare increase and the introduction of SuperGold.

Table E.9 shows how the model for offpeak weekday patronage was refined. The general model was fitted and Easter was found to have an implausible sign so it was removed, leading to model 2. During the next iteration, the 2008 fare increase was removed (again due to implausibility) leading to model 3.

Section E4.1 also noted that the correlation between real petrol price movements and the nominal $2.00 petrol price threshold could be making it difficult to distinguish between these two related effects. Therefore, model 4 and model 5 tested omitting each of these variables in turn. However, we rejected both of these in favour of the model with both real petrol prices and the nominal threshold (ie model 3).

Model 3 was further modified by removing a number of corridors that appeared to undermine the statistical accuracy of the model, as discussed in section E6. This produced model 6 in which the punctuality/congestion problems variable was an incorrect sign, hence it was removed leading to model 7.

Table E.9 Development of the model for offpeak weekday patronage[49]

Time trends and explanatory variables		General model	Model 2	Model 3	Model 4	Model 5	Model 6	Model 7 (preferred)
Time trend	Campus Connection (CPC)	X%	X%	X%	X%	X%	Omitted	
	Island Bay (IBY)	X%	X%	X%	X%	X%	X%	X%
	Karori (KAR)	X%	X%	X%	X%	X%	X%	X%
	Khandallah (KHN)	X%	X%	X%	X%	X%	Omitted	
	Mairangi (MAI)	X%	X%	X%	X%	X%	X%	X%
	Mirimar (MMR)	X%	X%	X%	X%	X%	X%	X%
	Mt Victoria (MTV)	X%	X%	X%	X%	X%	Omitted	
	Newtown Park (NTP)	X%	X%	X%	X%	X%	Omitted	
	Seatoun (STN)	X%	X%	X%	X%	X%	Omitted	
	Wilton (WLN)	X%	X%	X%	X%	X%	X%	X%
	Wrights Hill (WRH)	X%	X%	X%	X%	X%	Omitted	
Punctuality/congestion problems (Feb/Mar 07)		-2%	1%	0%	0%	0%	5%*	Implausible sign
Real bus fare (Sep 06)		-0.12	-0.11	-0.27*	-0.27*	-0.31**	-0.57***	-0.44***
Real bus fare (Sep 08) / +SuperGold (Oct 08)		0.61	0.83‘	Implausible sign				
Real petrol price		0.03	0.24**	0.12*	0.14**	Omitted to test interaction with $2 threshold	0.19***	0.13***
Nominal $2.00 petrol price threshold		17%***	2%	2%	Omitted to test interaction with real petrol price	7%*	-3%	Implausible sign
Real retail sales (Wellington city)		0.03	0.02	0.00	0.01	-0.01	0.11‘	0.11‘
Employment (Wellington city)		-1.70***	-1.49***	-1.26***	-1.25***	-1.01***	-0.32	-0.16
Easter		5%***	Implausible sign					

[49] The time trends in table E.9 have been removed for confidentiality reasons.

E5.3 Development of the model for weekend patronage

A general model for weekend patronage was fitted, similar to that for peak weekday patronage (see section E5.1).

Table E.10 shows that the general model for weekend weekday patronage produced generally plausible findings, except that the real fare 2008 had an implausible sign. This was removed, leading to model 2.

Section E4.1 also noted that the correlation between real petrol price movements and the nominal $2.00 petrol price threshold could be making it difficult to distinguish between these two related effects. Therefore, model 3 and model 4 were tested for these interactions by omitting each of these variables in turn.

Our judgement was that model 2 with both components remained the best model, showing that petrol price impacts reflect the impact of both general petrol price models and the petrol price threshold. However, the diagnostic analysis (see section E6.1) concluded that the removal of a number of corridors would improve the robustness of the general model. These modifications to the general model produced model 5, the preferred model.

Table E.10 Development of the model for weekend patronage[50]

Time trends and explanatory variables		General model	Model 2	Model 3	Model 4	Model 5 (preferred)
Time trend	Island Bay (IBY)	X%	X%	X%	X%	X%
	Karori (KAR)	X%	X%	X%	X%	X%
	Khandallah (KHN)	X%	X%	X%	X%	Omitted
	Mairangi (MAI)	X%	X%	X%	X%	X%
	Mirimar (MMR)	X%	X%	X%	X%	X%
	Seatoun (STN)	X%	X%	X%	X%	Omitted
	Wilton (WLN)	X%	X%	X%	X%	X%
Punctuality/congestion problems (Feb/Mar 07)		-5%	-5%	-4%	-8%‘	-8%‘
Data spike on Sats (Mar 06)		9%’ **	9%’ **	8%’ **	10%’ ***	11% ‘***
Data spike on Suns (Dec 05)		4%	4%	3%	6%	6%
Real bus fare (Sep 06)		-0.05	-0.07	-0.10	0.04	-0.12
Real bus fare (Sep 08)/ +SuperGold (Oct 08)		0.08	Implausible sign			
Real petrol price		0.18’ *	0.17’ **	0.20’ ***	Omitted to test interaction with $2 threshold	0.07
Nominal $2.00 petrol price threshold		3%	3%	Omitted to test interaction with real petrol price	12%’ ***	10%’ *
Real retail sales (Wellington city)		0.07	0.07	0.07	0.09	0.05
Employment (Wellington city)		-0.45‘	-0.44‘	-0.39	-0.33	-0.46‘
Easter		-3%’ *	-3%’ *	-3%’ ***	-1%	-1%

[50] The time trends in table E.10 have been removed for confidentiality reasons.

E6 Diagnostic analysis

E6.1 Overview

The following sections show diagnostic analysis of the preferred models for peak weekday patronage (section E5.1), offpeak weekday patronage (section E5.2) and weekend patronage (section E5.3).

Some of the bus corridors showed problems during certain times:

- The Seatoun (STN) bus corridor showed evidence of an unexplained drop in peak weekday patronage growth rates along with a clustering of residuals both before and after this event.
- The Newtown Park (NTP) bus corridor showed evidence of strong autocorrelation and clustering of residuals for offpeak weekday patronage, suggesting that the model omitted an important explanatory variable or event.
- The Khandallah (KHN) bus corridor showed evidence of an unexplained ‘structural break’ in the residuals for weekend patronage, along with clustering of residuals in offpeak weekday patronage.

We also note that a number of bus corridors did not provide services in the weekend: Seatoun (STN), Newtown Park (NTP), Campus Connection (CPC), Mt Victoria (MTV), and Wrights Hill (WRH).

In light of both of these problems, we decided to exclude the Seatoun (STN), Newtown Park (NTP) and Khandallah (KHN) bus corridors as well as any bus corridors that do not operate on weekends. The following bus corridors were retained:

- Island Bay (IBY)
- Karori (KAR)
- Mairangi (MAI)
- Mirimar (MMR)
- Wilton (WLN).

This approach ensured that we were able to compare ‘like with like’ when comparing weekday peak, weekday offpeak and weekend findings. Section E7 presents findings based on this approach.

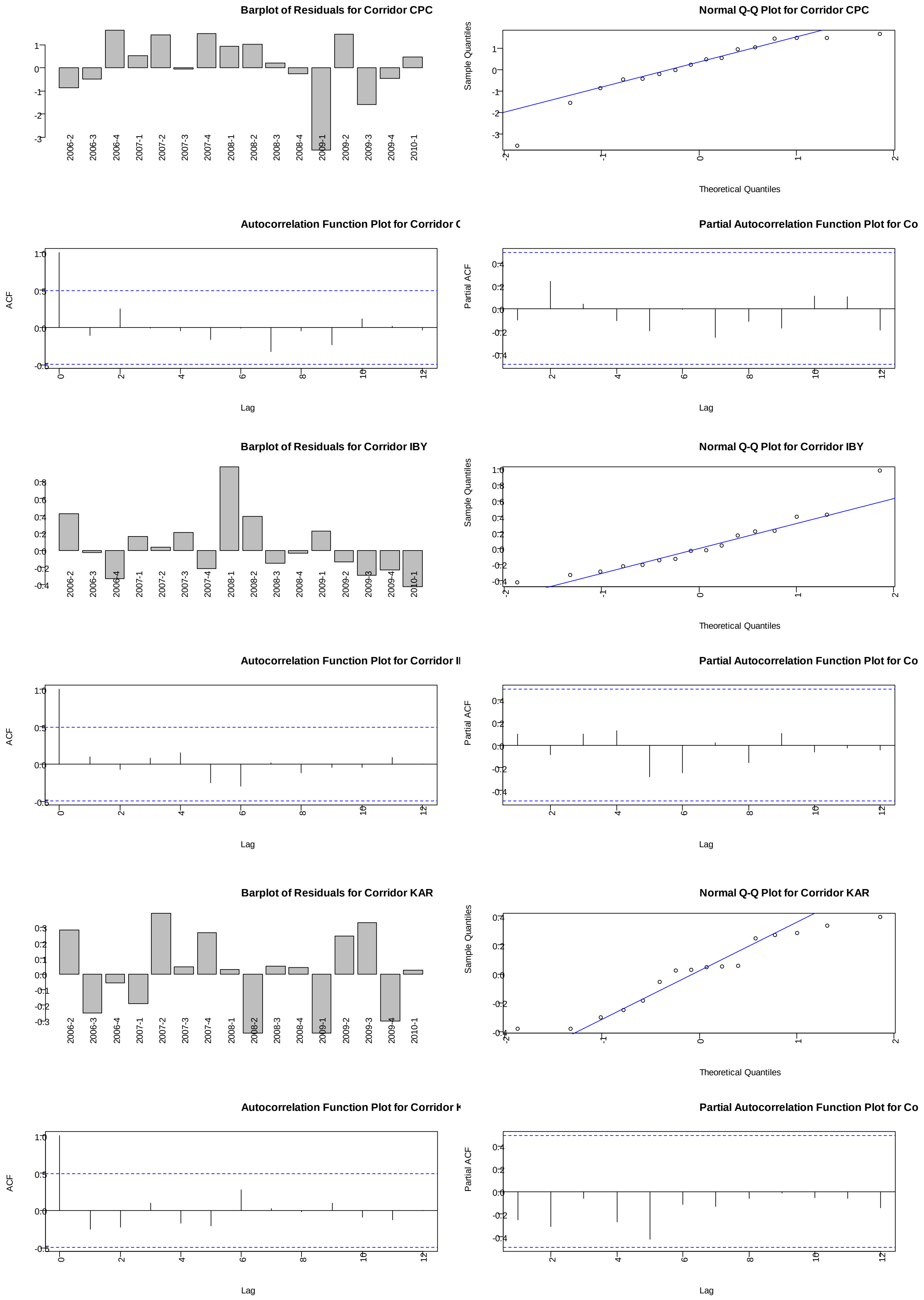
E6.2 Diagnostic analysis for the model for peak weekday patronage

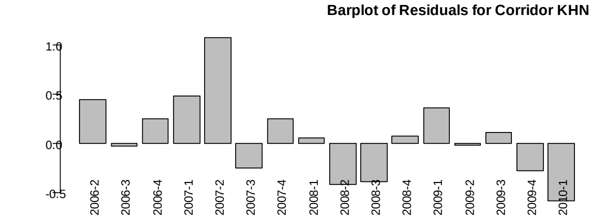
The figures below show diagnostic plots for the residuals from the model 3 used to explain growth in peak weekday patronage as shown in table E.8.

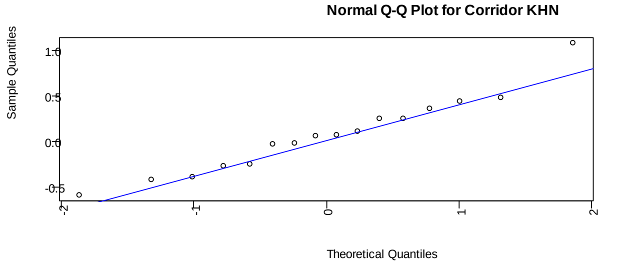
The diagnostic plots show that the residuals for the bus corridors generally conform to key assumptions of normality.

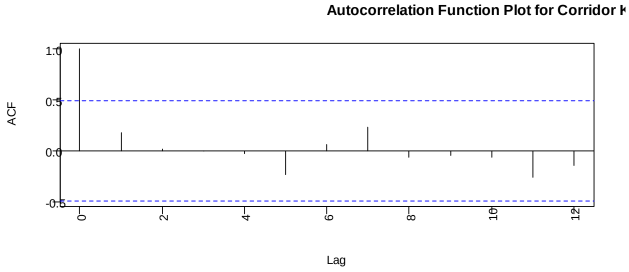
There is minimal evidence of autocorrelation problems; most bus corridors show, at worst, only very mild autcorrelation. The only exception is the Seatoun (STN) corridor which shows evidence of quite serious autocorrelation. The STN corridor shows evidence of a ‘structural break’ or trend shift around 2008-Q4, suggesting that we omitted an important variable that caused a drop in patronage growth around this time.

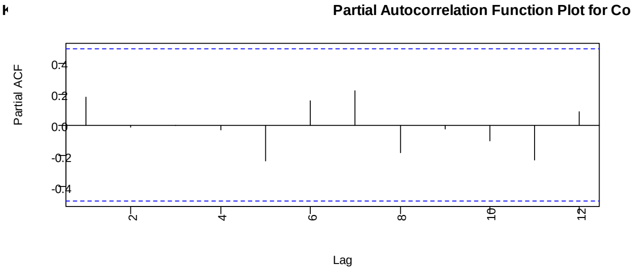
As discussed in section E6.1, the STN corridor was one of the bus corridors omitted from the preferred models.

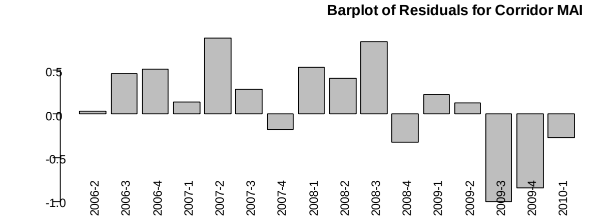

Barplot of Residuals for Corridor CPC
Normal Q-Q Plot for Corridor CPC
Sample Quantiles
Theoretical Quantiles
Autocorrelation Function Plot for Corridor C
Partial Autocorrelation Function Plot for Co
ACF
Partial ACF
Lag
Barplot of Residuals for Corridor IBY
Normal Q-Q Plot for Corridor IBY
Autocorrelation Function Plot for Corridor I
Barplot of Residuals for Corridor KAR
Normal Q-Q Plot for Corridor KAR
Autocorrelation Function Plot for Corridor K
2006-2
2006-3
2006-4
2007-1
2007-2
2007-3
2007-4
2008-1
2008-2
2008-3
2008-4
2009-1
2009-2
2009-3
2009-4
2010-1

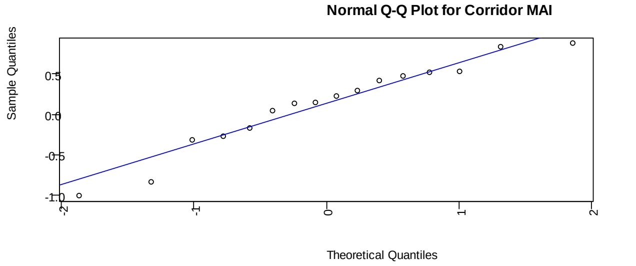

Barplot of Residuals for Corridor KHN

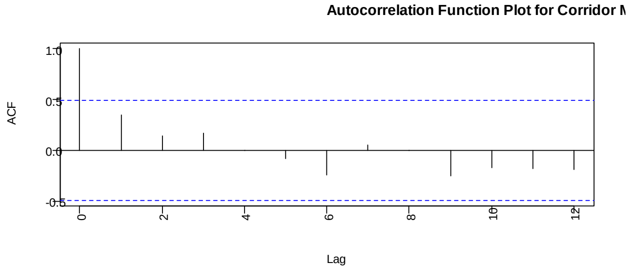

Normal Q-Q Plot for Corridor KHN
Sample Quantiles
Theoretical Quantiles

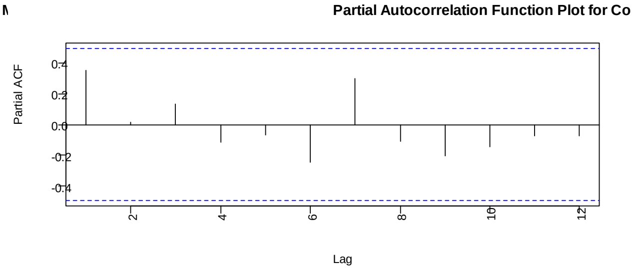

Autocorrelation Function Plot for Corridor K
ACF
Lag

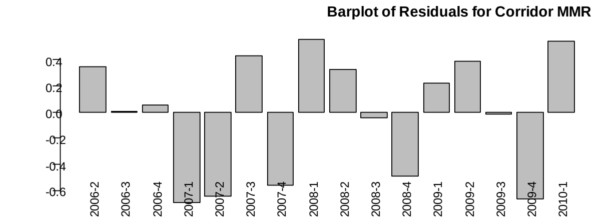

Partial Autocorrelation Function Plot for Co
Partial ACF
Lag

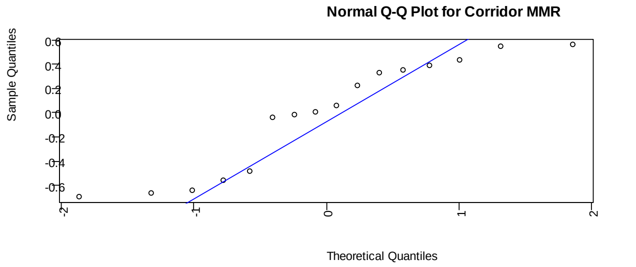

Barplot of Residuals for Corridor MAI

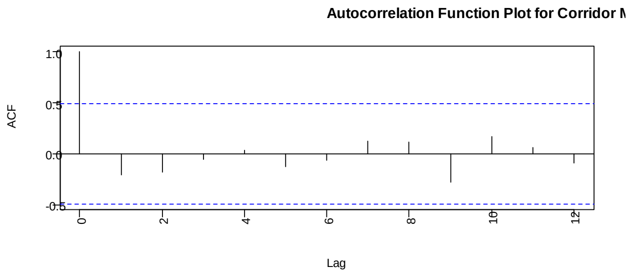

Normal Q-Q Plot for Corridor MAI
Sample Quantiles
Theoretical Quantiles

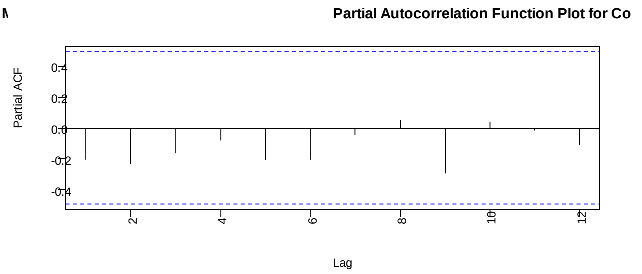

Autocorrelation Function Plot for Corridor M
ACF
Lag

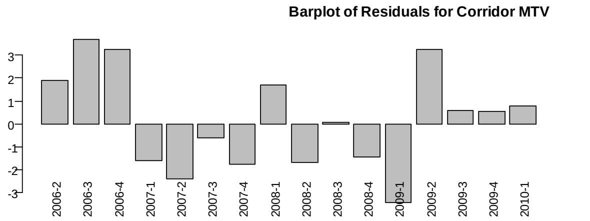

Partial Autocorrelation Function Plot for Co
Partial ACF
Lag

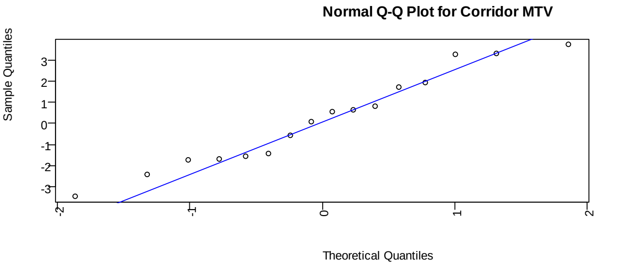

Barplot of Residuals for Corridor MMR

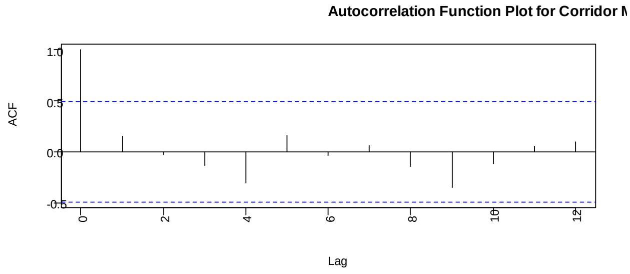

Normal Q-Q Plot for Corridor MMR
Sample Quantiles
Theoretical Quantiles

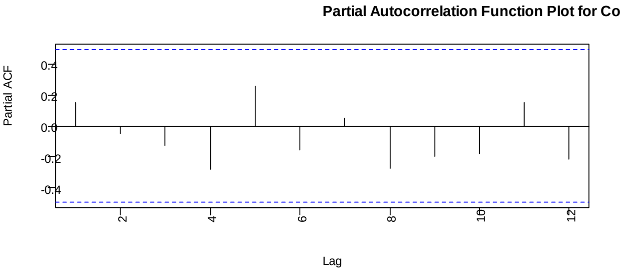

Autocorrelation Function Plot for Corridor M
ACF
Lag

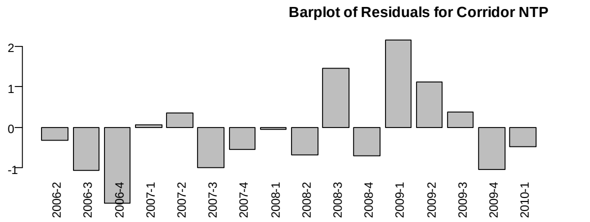

Partial Autocorrelation Function Plot for Co
Partial ACF
Lag

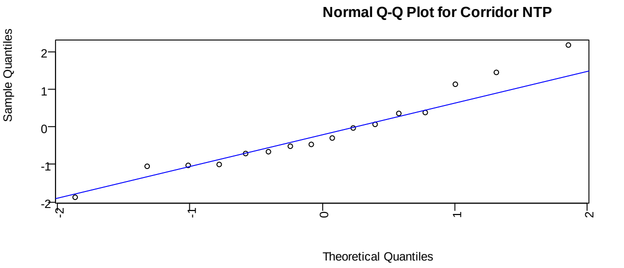

Barplot of Residuals for Corridor MTV

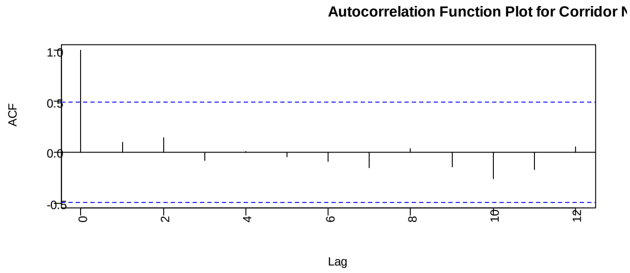

Normal Q-Q Plot for Corridor MTV
Sample Quantiles
Theoretical Quantiles

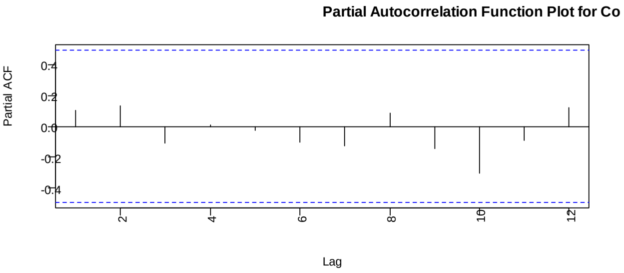

Autocorrelation Function Plot for Corridor M
ACF
Lag

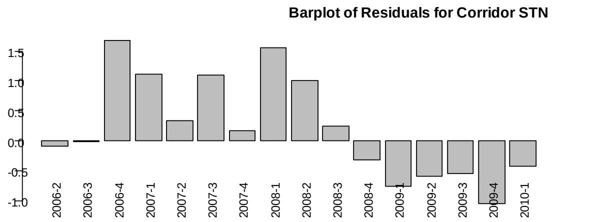

Partial Autocorrelation Function Plot for Co
Partial ACF
Lag

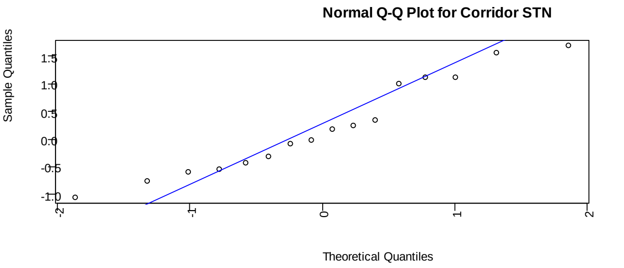

Barplot of Residuals for Corridor NTP

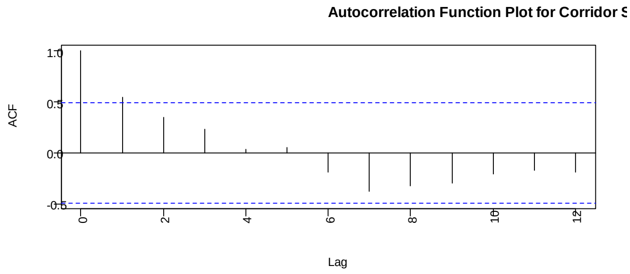

Normal Q-Q Plot for Corridor NTP
Sample Quantiles
Theoretical Quantiles

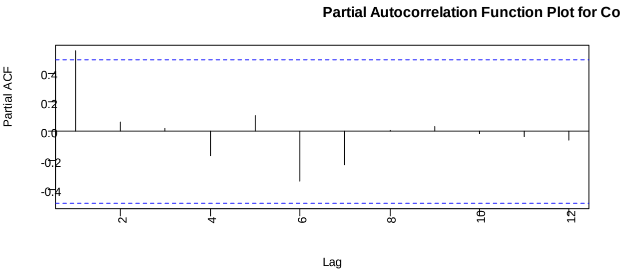

Autocorrelation Function Plot for Corridor N
ACF
Lag

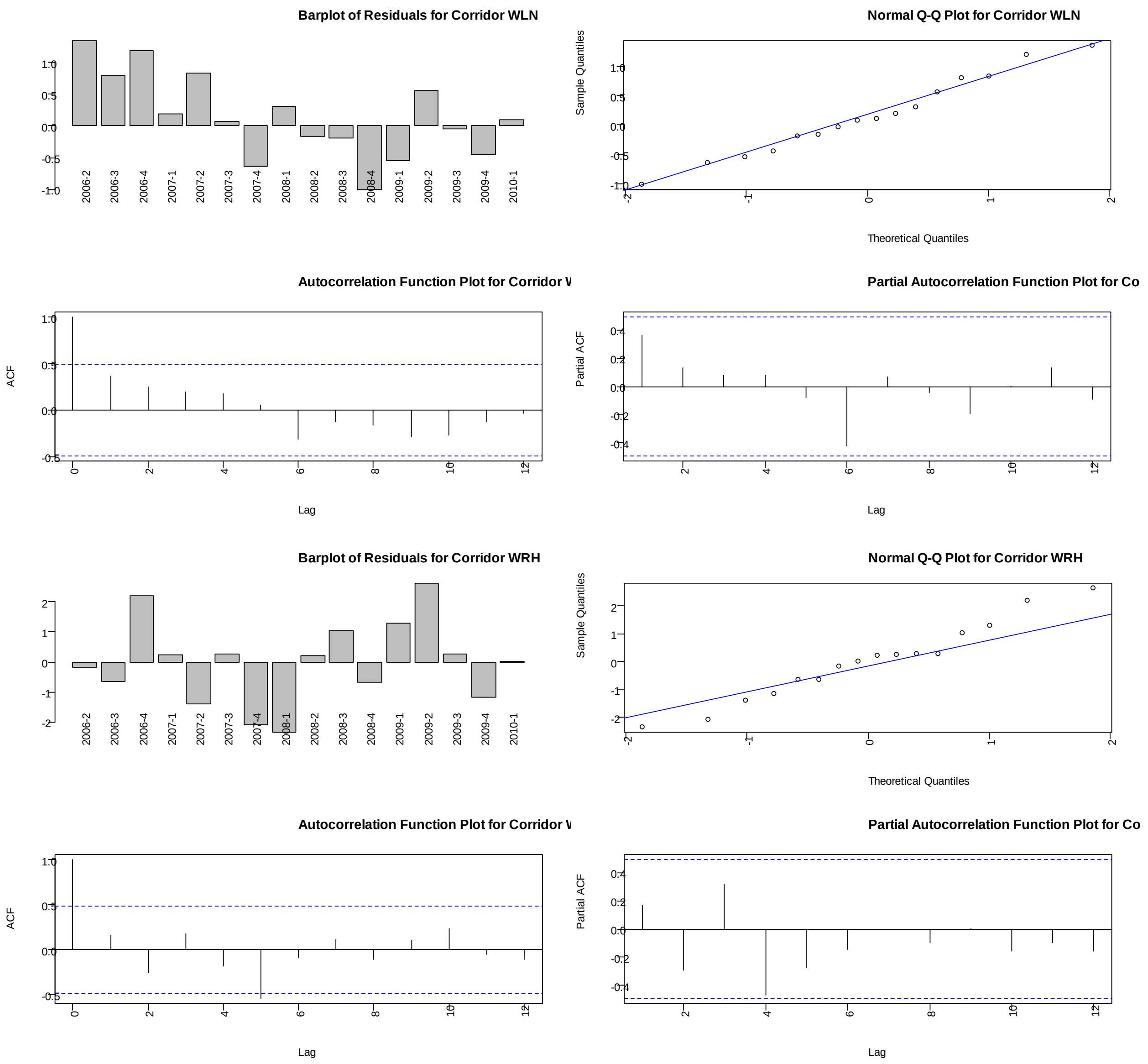

Partial Autocorrelation Function Plot for Co
Partial ACF
Lag


Barplot of Residuals for Corridor STN


Normal Q-Q Plot for Corridor STN
Sample Quantiles
Theoretical Quantiles


Autocorrelation Function Plot for Corridor S
ACF
Lag


Partial Autocorrelation Function Plot for Co
Partial ACF
Lag

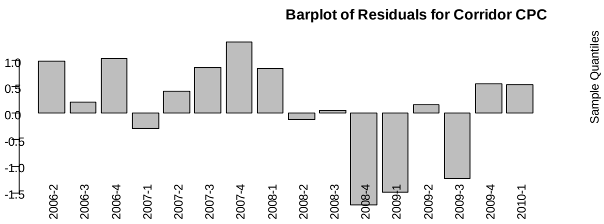


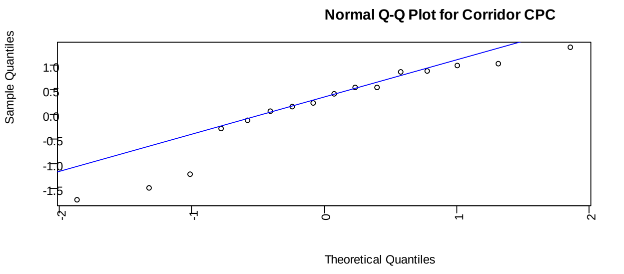
E6.3 Diagnostic analysis for the model for offpeak weekday patronage

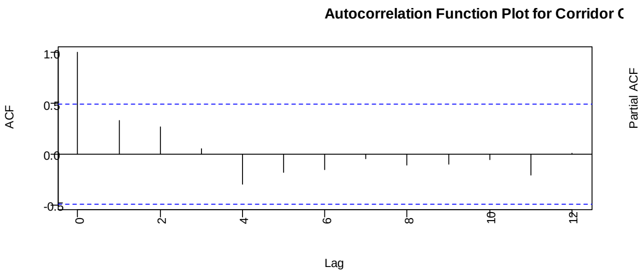
The figures below show diagnostic plots for the residuals from model 3 used to explain growth in offpeak weekday patronage in table E.9.

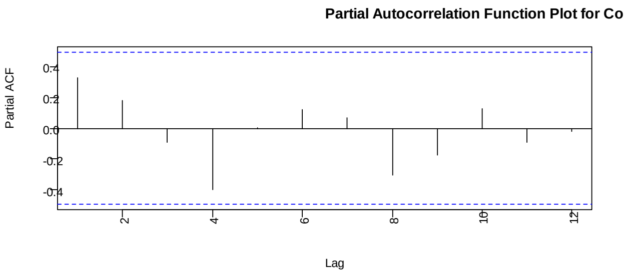
The diagnostic plots show that the residuals for the bus corridors generally conform to key assumptions of normality.There is minimal evidence of autocorrelation problems; most bus corridors show, at worst, only very mild autcorrelation. The most notable exception is the Newtown Park (NTP) corridor which shows evidence of a 'strucural break' in 2009-Q2 along with autocorrelation and clustering of residuals. The Campus Connection (CPC) corridor also shows evidence of a 'structural break' in 2008-Q4 but this does not appear as concerning. The KHN corridor also shows evidence of clustering of residuals.

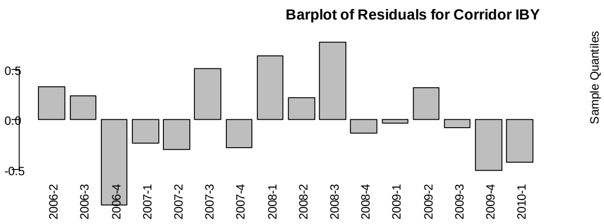
As noted in section E6.1, the NTP corridor, the CPC corridor and the KHN corridor were among those excluded from the preferred models.

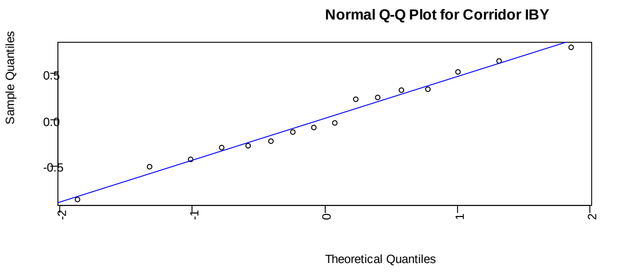

Barplot of Residuals for Corridor CPC

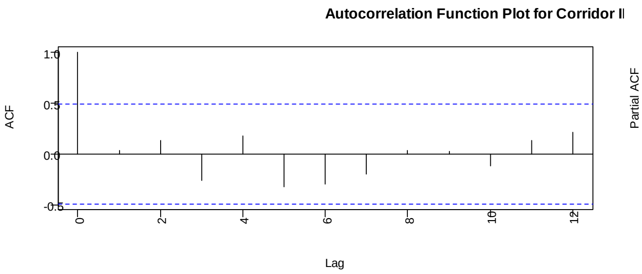

Normal Q-Q Plot for Corridor CPC
Sample Quantiles
Theoretical Quantiles

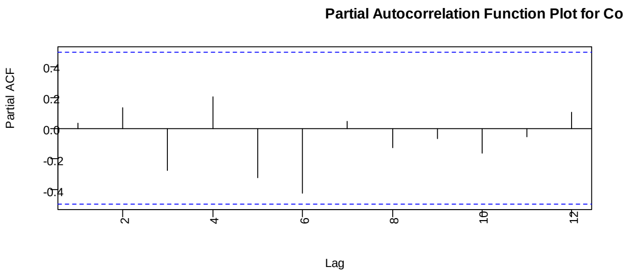

Autocorrelation Function Plot for Corridor C
ACF
Lag

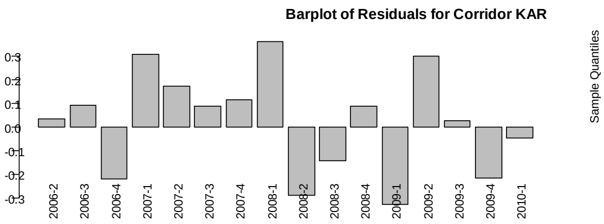

Partial Autocorrelation Function Plot for Co
Partial ACF
Lag

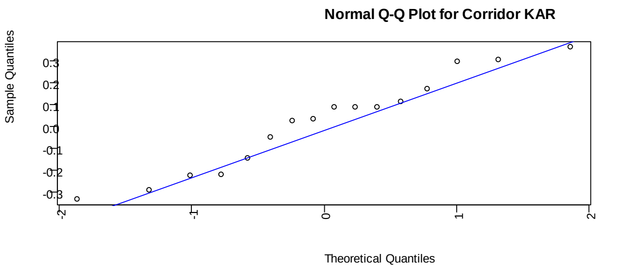

Barplot of Residuals for Corridor IBY

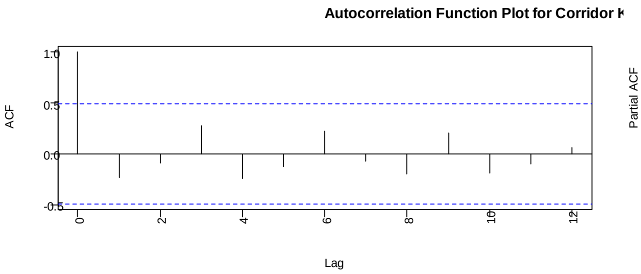

Normal Q-Q Plot for Corridor IBY
Sample Quantiles
Theoretical Quantiles

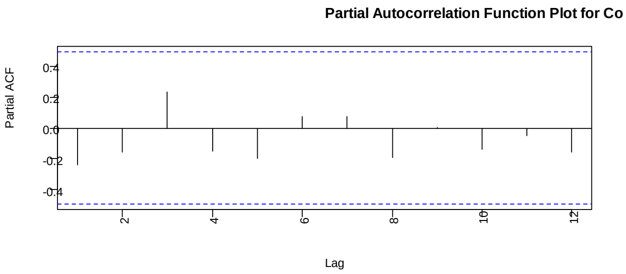

Autocorrelation Function Plot for Corridor I
ACF
Lag

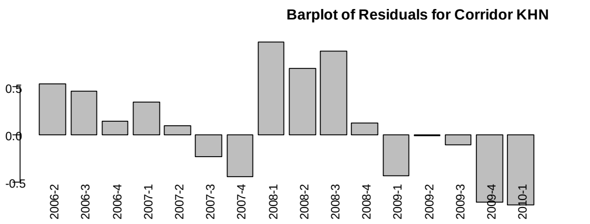

Partial Autocorrelation Function Plot for Co
Partial ACF
Lag

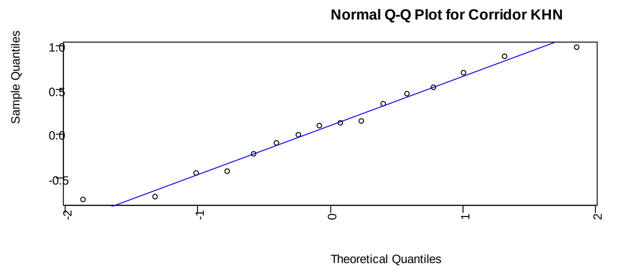

Barplot of Residuals for Corridor KAR

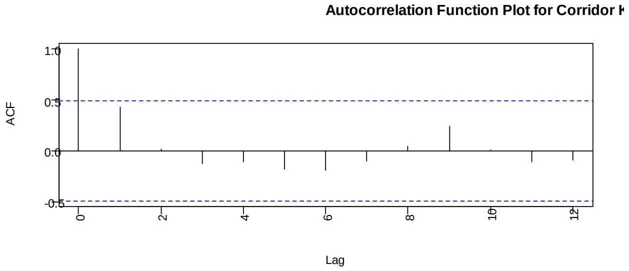

Normal Q-Q Plot for Corridor KAR
Sample Quantiles
Theoretical Quantiles

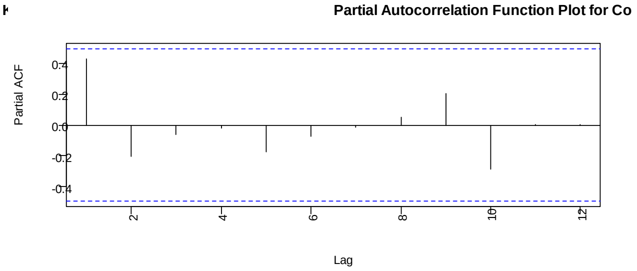

Autocorrelation Function Plot for Corridor K
ACF
Lag

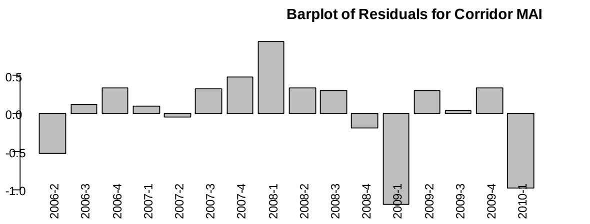

Partial Autocorrelation Function Plot for Co
Partial ACF
Lag

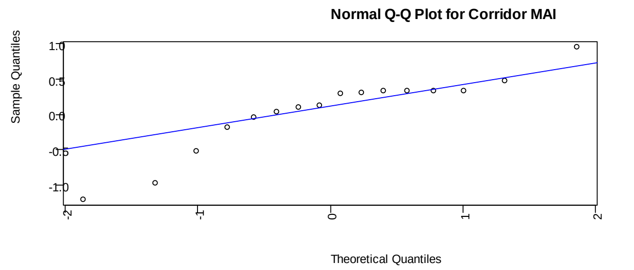

Barplot of Residuals for Corridor KHN

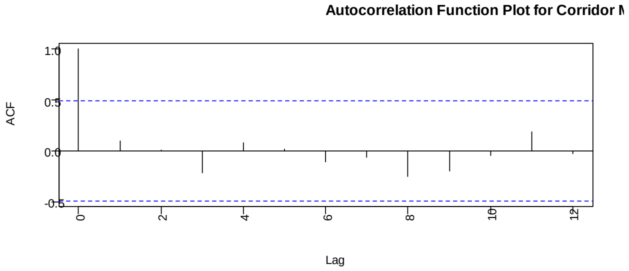

Normal Q-Q Plot for Corridor KHN
Sample Quantiles
Theoretical Quantiles

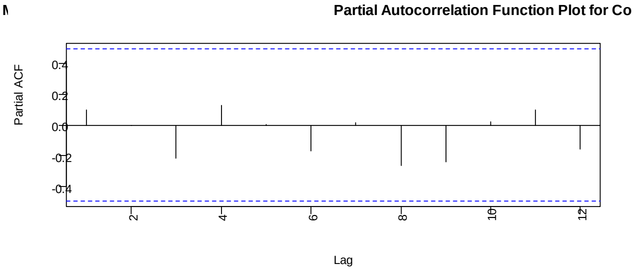

Autocorrelation Function Plot for Corridor K
ACF
Lag

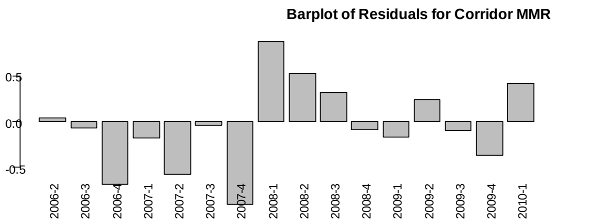

Partial Autocorrelation Function Plot for Co
Partial ACF
Lag

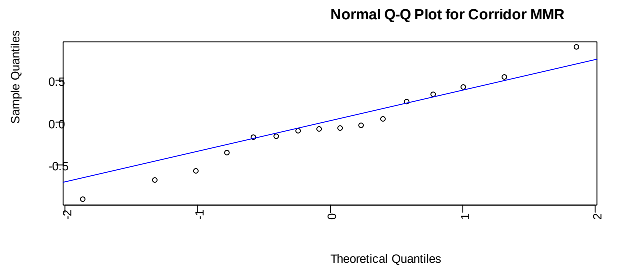

Barplot of Residuals for Corridor MAI

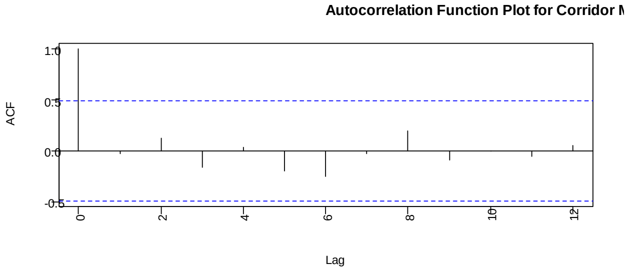

Normal Q-Q Plot for Corridor MAI
Sample Quantiles
Theoretical Quantiles

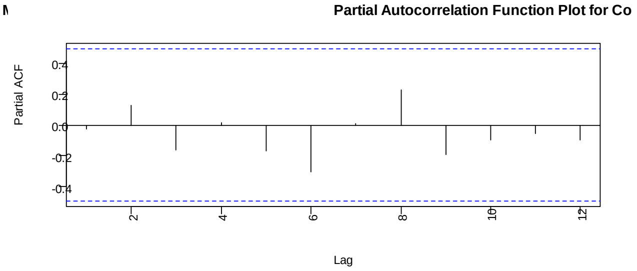

Autocorrelation Function Plot for Corridor M
ACF
Lag

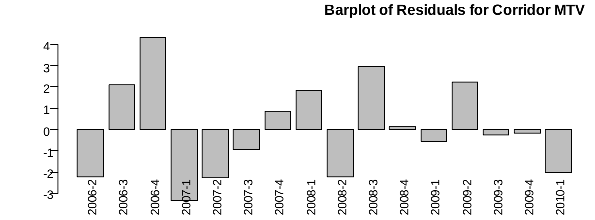

Partial Autocorrelation Function Plot for Co
Partial ACF
Lag

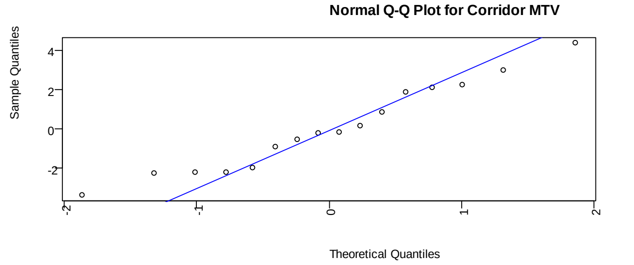

Barplot of Residuals for Corridor MMR

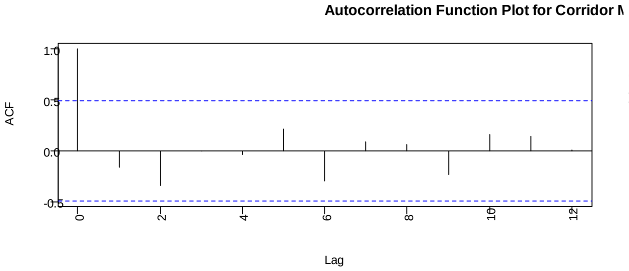

Normal Q-Q Plot for Corridor MMR
Sample Quantiles
Theoretical Quantiles

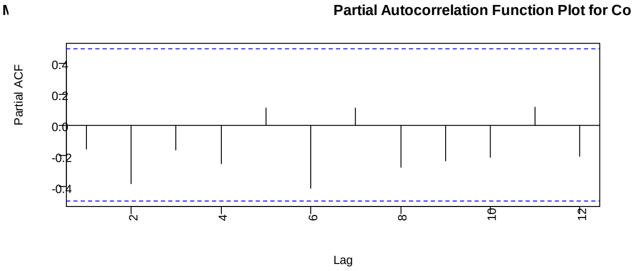

Autocorrelation Function Plot for Corridor M
ACF
Lag

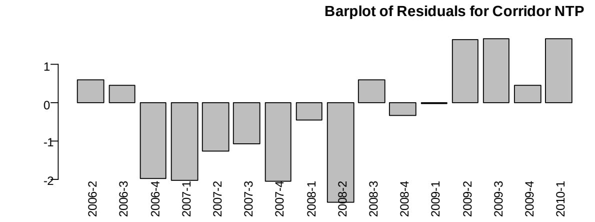

Partial Autocorrelation Function Plot for Co
Partial ACF
Lag

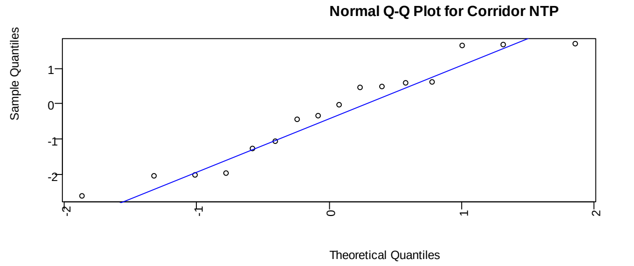

Barplot of Residuals for Corridor MTV

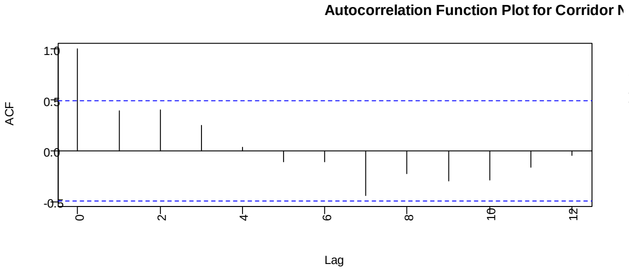

Normal Q-Q Plot for Corridor MTV
Sample Quantiles
Theoretical Quantiles

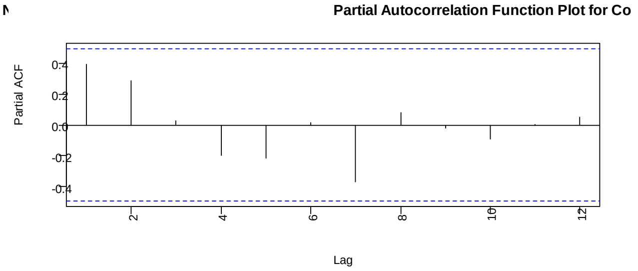

Autocorrelation Function Plot for Corridor N
ACF
Lag

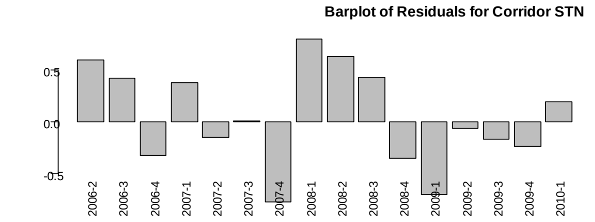

Partial Autocorrelation Function Plot for Co
Partial ACF
Lag

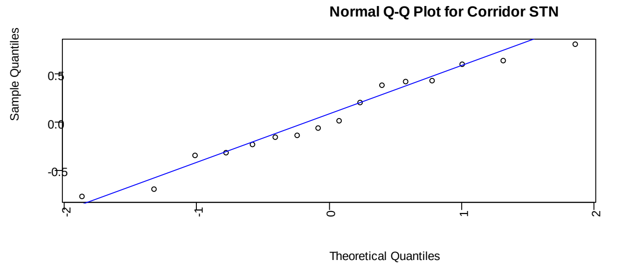

Barplot of Residuals for Corridor NTP

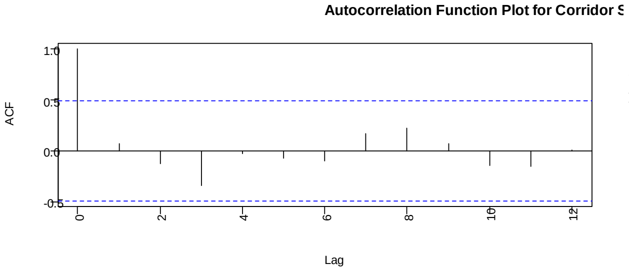

Normal Q-Q Plot for Corridor NTP
Sample Quantiles
Theoretical Quantiles

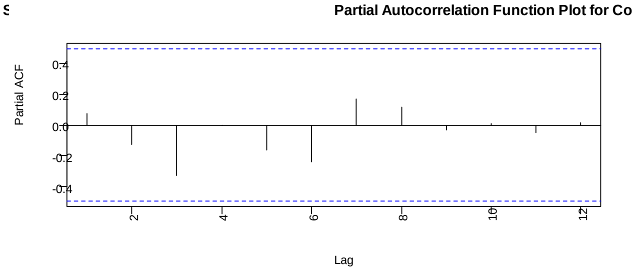

Autocorrelation Function Plot for Corridor N
ACF
Lag

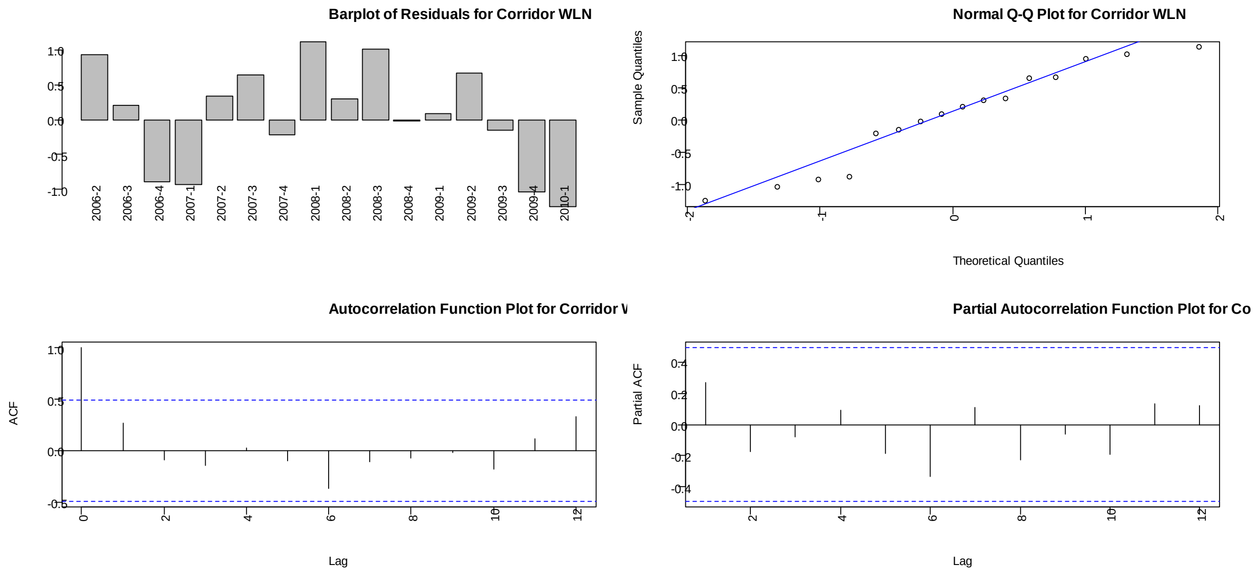

Partial Autocorrelation Function Plot for Co
Partial ACF
Lag

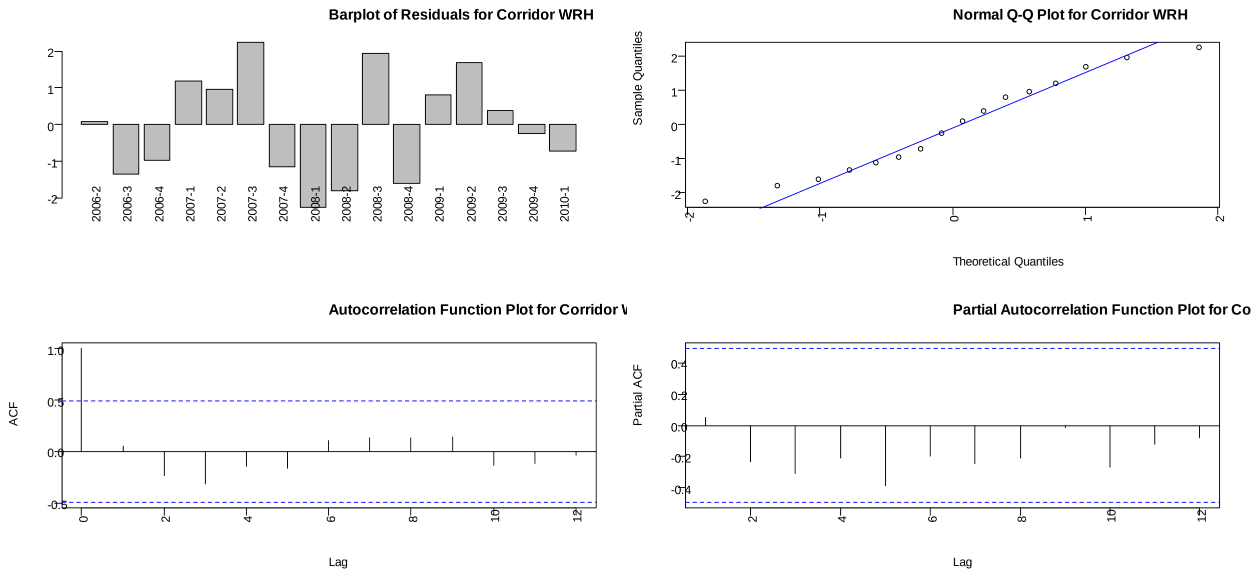

Barplot of Residuals for Corridor STN


Normal Q-Q Plot for Corridor STN
Sample Quantiles
Theoretical Quantiles


Autocorrelation Function Plot for Corridor S
ACF
Lag


Partial Autocorrelation Function Plot for Co
Partial ACF
Lag





E6.4 Diagnostic analysis for the model for weekend patronage

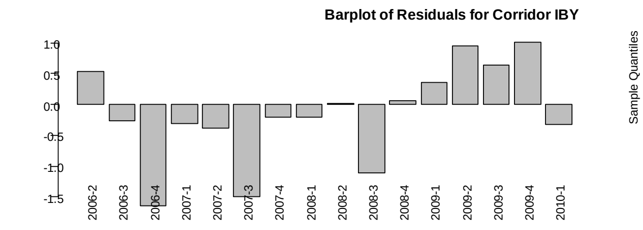
The figures below show diagnostic plots for the residuals from model 2used to explain growth in weekend patronage in table E.10.

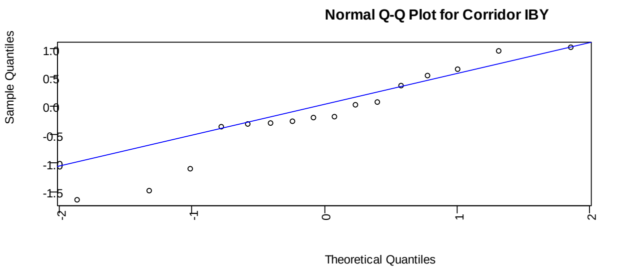
The diagnostic plots show that the residuals for the bus corridors generally conform to key assumptions of normality.

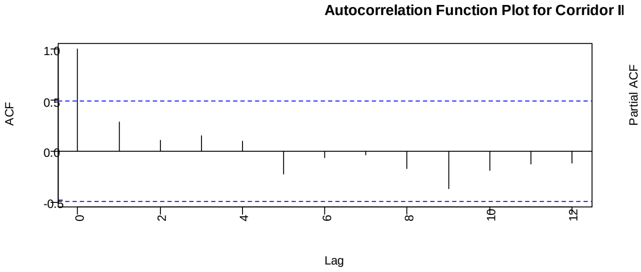
There are a few bus corridors that exhibit autocorrelation or other patterns in the residuals, hence suggesting a failure to explain weekend growth sufficiently:

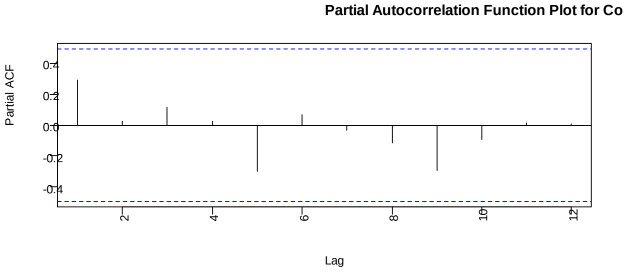
- The most problematic bus corridor is Khandallah (KHN) which shows evidence of a 'structural break' in 2008-Q3. Prior to this date, most residuals are positive and after this date they are all negative.
- Island Bay (IBY) and Mairangi (MAI) both show a cluster of positive residuals from, respectively, 2009-Q2 and 2009-Q2 onwards, suggesting there were unexpected jumps in patronage in 2009-Q2 that the model was unable to explain.

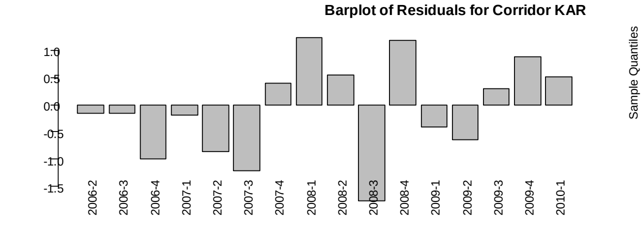
As discussed in section E6.1, the KHN corridor was excluded from the preferred models.

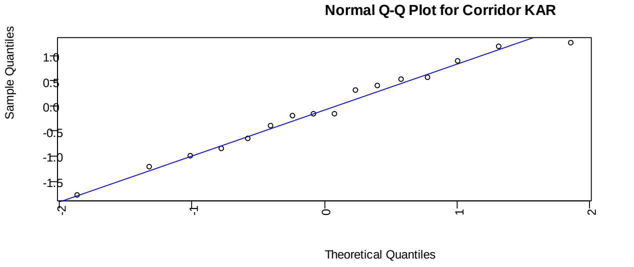

Barplot of Residuals for Corridor IBY

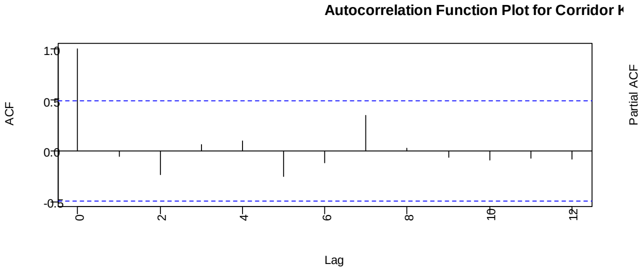

Normal Q-Q Plot for Corridor IBY
Sample Quantiles
Theoretical Quantiles

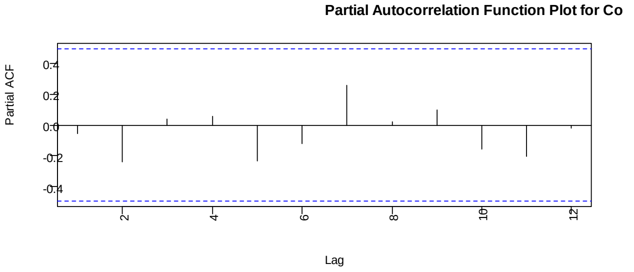

Autocorrelation Function Plot for Corridor I
ACF
Lag

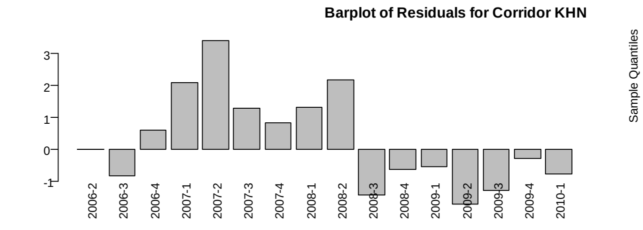

Partial Autocorrelation Function Plot for Co
Partial ACF
Lag

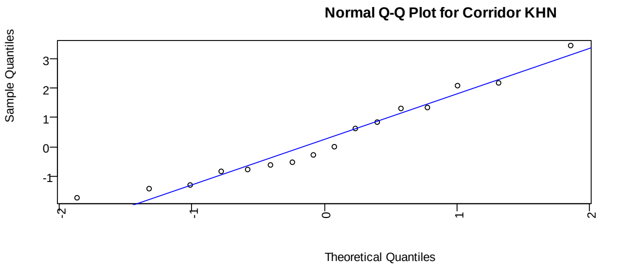

Barplot of Residuals for Corridor KAR

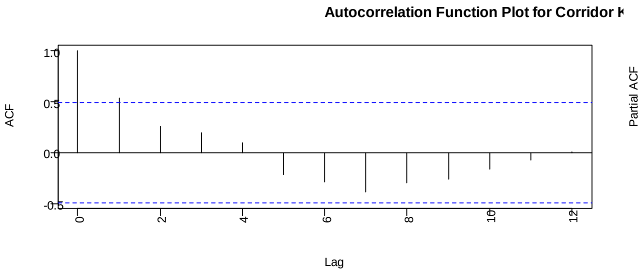

Normal Q-Q Plot for Corridor KAR
Sample Quantiles
Theoretical Quantiles

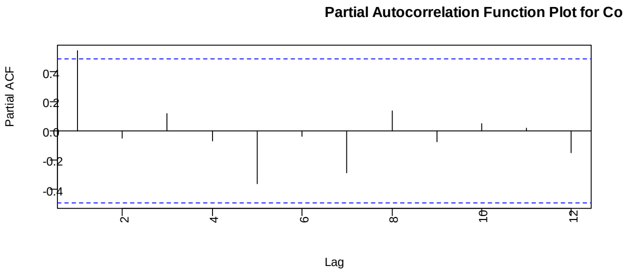

Autocorrelation Function Plot for Corridor K
ACF
Lag

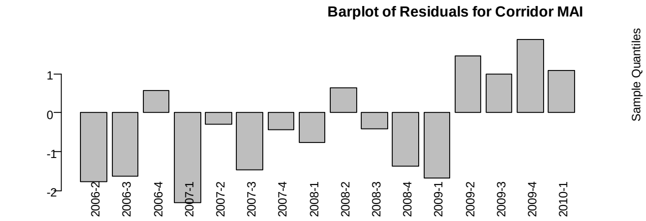

Partial Autocorrelation Function Plot for Co
Partial ACF
Lag

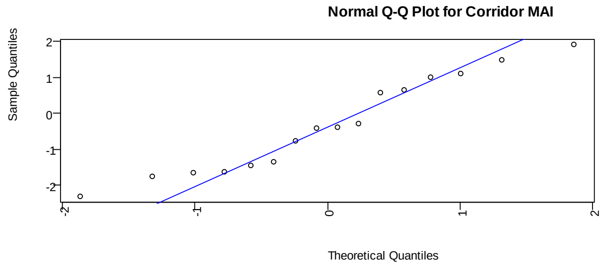

Barplot of Residuals for Corridor KHN

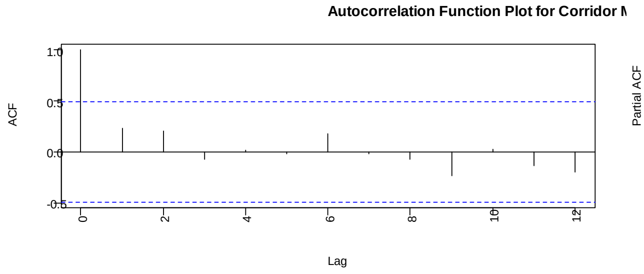

Normal Q-Q Plot for Corridor KHN
Sample Quantiles
Theoretical Quantiles

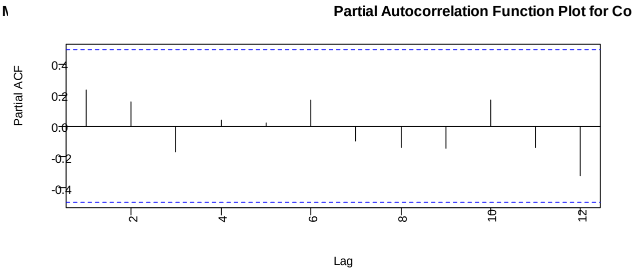

Autocorrelation Function Plot for Corridor K
ACF
Lag

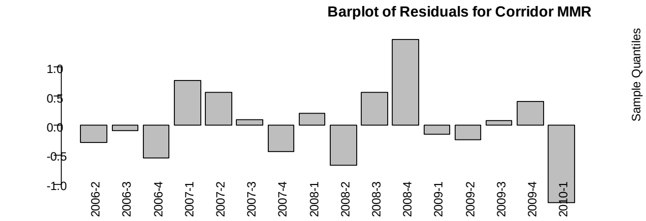

Partial Autocorrelation Function Plot for Co
Partial ACF
Lag

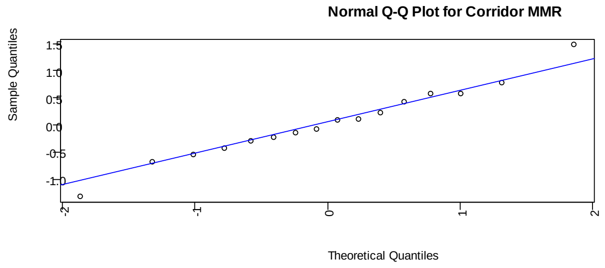

Barplot of Residuals for Corridor MAI

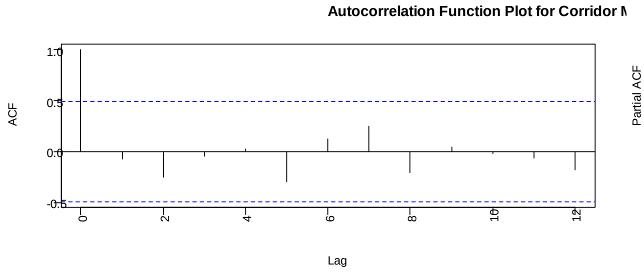

Normal Q-Q Plot for Corridor MAI
Sample Quantiles
Theoretical Quantiles

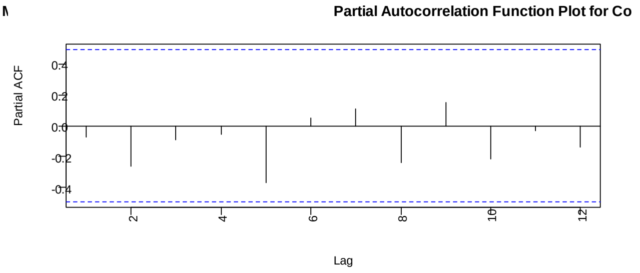

Autocorrelation Function Plot for Corridor M
ACF
Lag

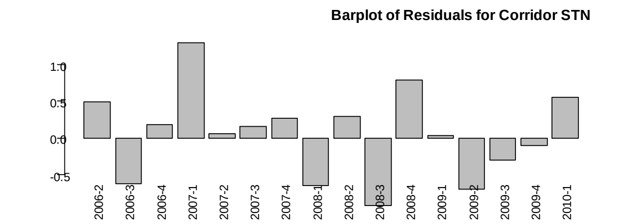

Partial Autocorrelation Function Plot for Co
Partial ACF
Lag

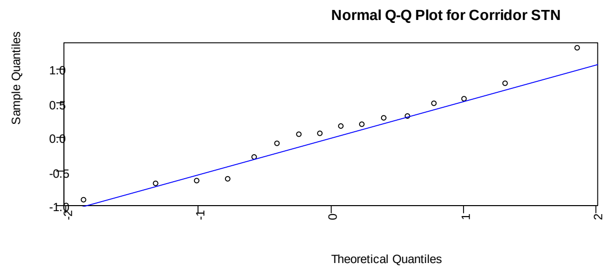

Barplot of Residuals for Corridor MMR

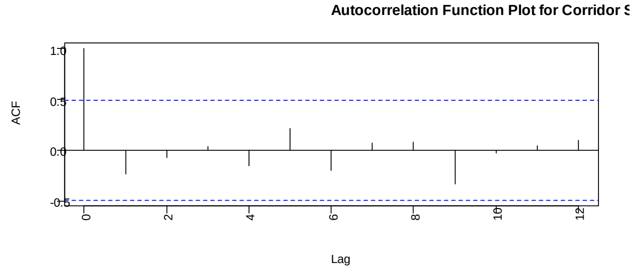

Normal Q-Q Plot for Corridor MMR
Sample Quantiles
Theoretical Quantiles

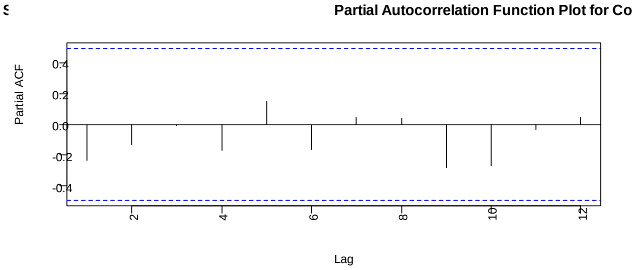

Autocorrelation Function Plot for Corridor M
ACF
Lag

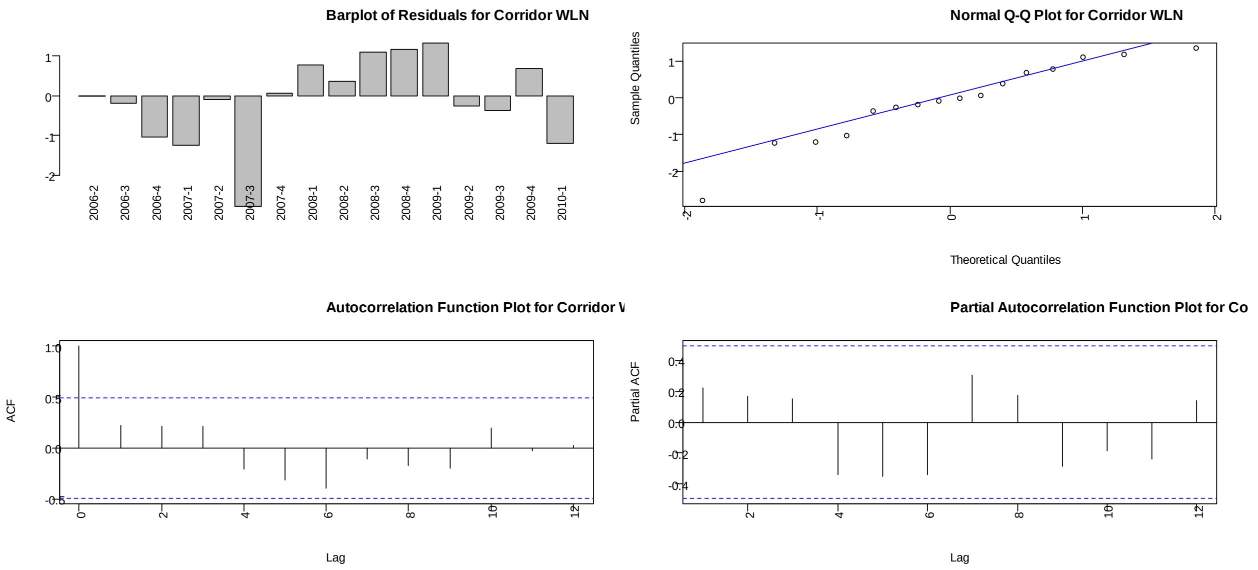

Partial Autocorrelation Function Plot for Co
Partial ACF
Lag


Barplot of Residuals for Corridor STN


Normal Q-Q Plot for Corridor STN
Sample Quantiles
Theoretical Quantiles


Autocorrelation Function Plot for Corridor S
ACF
Lag


Partial Autocorrelation Function Plot for Co
Partial ACF
Lag



E7 Estimates and findings

This section presents the coefficients estimated using our econometric panel data model.

Table E.11 below shows our estimates for the impact of economic variables, broken down into peak weekday, interpeak weekday, evening weekday and weekend.

Table E.11 Estimates of coefficients for economic variables

Economic variables	Weekday		Weekend
	Peak	Offpeak	
Real bus fare (Sep 06)	Removed due to implausible sign	-0.44*** (-0.57, -0.31)	-0.12 (-0.60, 0.36)
Real bus fare (Sep 08)/+SuperGold (Oct 08)	-0.66* (-1.23, -0.10)	Removed due to implausible sign	Removed due to implausible sign
Real petrol price	0.13* (0.02, 0.24)	0.13*** (0.06, 0.21)	0.07 (-0.05, 0.20)
Nominal $2.00 petrol price threshold	4% (-1%, 9%)	Removed due to implausible sign	10%* (1%, 18%)
Real retail sales (Wellington city)	-0.04 (-0.19, 0.10)	0.11‘ (-0.01, 0.24)	0.05 (-0.06, 0.17)
Employment (Wellington city)	0.36 (-0.09, 0.81)	-0.16 (-0.60, 0.27)	-0.46‘ (-0.96, 0.04)

Note for symbols of statistical significance: *** → 0.1%, ** → 1%, * → 5%, ‘ →10%

The key findings from table E.11 are:

- As discussed in section E3.1, our graphical analysis of the data concluded that the September 2006 fare increase had a different impact from the September 2008 fare increase. We therefore chose to model these two fare increases as separate events. Our fare elasticity estimates for these events reflected the same themes observed via graphical analysis[51]:

- The September 2006 fare increase had an impact on both offpeak weekday patronage and weekend patronage with respective fare elasticities of about -0.4 and -0.1. However, the fare increase had no discernible impact on peak-time patronage; one possible explanation for this is that the fare increases were accompanied by a simplification of the fare structure that may have been more appealing to commuters.
- The September 2008 fare increase had an impact on peak weekday patronage with a fare elasticity of -0.4. The impact of the fare increase on offpeak weekday and weekend patronage was indiscernible. It seems highly likely that the negative impact of the fare increase on offpeak weekday and weekend patronage was cancelled out by the introduction of the SuperGold Card, providing free offpeak travel during these times[52].

- The impact of real retail sales on patronage growth was found to be close to zero but was retained in the table for the interest of readers.
- Employment had a positive association with peak patronage and a negative association with offpeak weekday and weekend patronage. However, we note that these associations are not statistically significant.

Table E.12 shows the impact of miscellaneous events on bus patronage growth.

Table E.12 Impacts of miscellaneous events on patronage growth

Miscellaneous events	Weekday		Weekend
	Peak	Offpeak	
Rescheduling/driver-shortage/bypass (Feb/Mar 07)	Removed due to implausible sign	Removed due to implausible sign	-8%‘ (-16%, 1%)
Data spike on Sats (Mar 06)	Removed due to implausible sign	Removed due to implausible sign	11%’ *** (5%, 16%)
Data spike on Suns (Dec 05)	Removed due to implausible sign	Removed due to implausible sign	6% (-2%, 13%)
Easter	Removed due to implausible sign	Removed due to implausible sign	-1% (-3%, 1%)

[51] A Steering Group member put forward the hypothesis that the increase in cash fares relative to the cost of 10-trip tickets/monthly tickets may have contributed to the differences observed between the 2006 fare increase and the 2008 fare increase, with increases in cash fares having a disproportionate impact on offpeak travel. However, our analysis of ticket sales data contradicts this hypothesis:

- During the 2006 fare increase, cash fares actually went up less than 10-trip and monthly tickets, and yet the main loss of patronage was during offpeak times.
- During the 2008 fare increase, cash fares went up while monthly tickets remained the same, and yet the main loss of patronage was during peak times.

[52] A peer reviewer also suggested that the 2008 fare increase of ‘only’ 8% was much smaller than the 2006 fare increase of 20%. This may also explain why the offpeak response to the 2008 fare increase was relatively muted. Further research in the future could examine whether smaller fare increases are associated with lower fare elasticities.

The key findings from table E.12 are:

- The punctuality/congestion problems in February 2007 did not have a discernible impact on weekday patronage; the impact on weekend patronage was negative and statistically significant. That said, due to a lack of data, we had to assume the punctuality/congestion problems had the same impact across all bus corridors – this assumption may not be accurate.
- Our examination of monthly patronage data concluded there were erroneous spikes in weekend 'patronage'. We have not identified the reasons for these but they could be due to any combination of data problems, the timing of holidays, weekend events or unusual weather. We controlled for these using the 'data spike' dummy variables shown in table E.12.
- Our attempts to control for the impact of Easter produced incorrect signs in the case of weekday patronage so they were dropped. The model predicts that Easter has a small negative impact on weekend patronage, which is plausible, but this estimate is not statistically significant.

We also examined time trends but these are not shown for confidentiality reasons. In general, the time trends for both peak and offpeak weekday patronage are close to zero; this suggests that the model is explaining weekday patronage growth reasonably well.

In contrast, the time trends for weekend patronage are positive, suggesting some factors are driving weekend patronage that we have been unable to incorporate into the modelling process. We have more confidence in the estimates and findings for the weekday models than we do for the weekend models.

Appendix F: Econometric analysis of patronage growth on the Hamilton city bus system

F1 Introduction

In section 8.4 of the main report we presented our conclusions regarding the contribution of explanatory variables to Hamilton City bus patronage growth over the five-year period from 2005–Q2 to 2010–Q1. Then in section 8.5 we presented our findings in regard to elasticities and other estimates for the explanatory variables.

These conclusions and findings are based on a thorough econometric methodology[53] that helps us understand as much as we can about what is driving patronage growth at a corridor level. We then bundled data from the bus corridors together and used an econometric tool (called a panel data model) to estimate what is driving bus patronage across the Hamilton city bus system.

The following sections show how the econometric methodology was applied to analysis of Hamilton city bus patronage, and describe the analyses underlying our conclusions and findings.

- *F2 Data collection and data manipulation* – the analytical process begins with data collection. The data then has to be checked and manipulated into a form suitable for econometric analysis.
- *F3 Graphical analysis* – we believe it is important to look at the data and make sense of it intuitively before proceeding onto econometric analysis. In section F3 we look at patronage growth along each of the bus route groups and seek to explain and understand any trends or anomalies in the data. The observations here feed into the models tested in sections F4 to F7.
- *F4 Data analysis* – there are a number of statistical problems that can potentially undermine the validity of the econometric analysis. (These problems are technically referred to as multicollinearity, spurious regression and endogeneity.) In section F4 we show that we have examined the data for presence of these problems and have responded accordingly where there is evidence of a problem.
- *F5 Model building process* – the process of building models for patronage growth involves looking at the data and fitting a general model that explains the patterns in the data as well as possible. We then investigate the contribution of the explanatory variables in the general model, removing those that look suspect or indeterminate, and whittling the model down to its core components. Section F5 describes the process by which each of the initial models was whittled down into preferred models.
- *F6 Diagnostic analysis* – the preferred model will still not be statistically valid unless the residuals of the model meet certain criteria. In section F6 we show our examination of the residuals of each individual line, in which we look for evidence of autocorrelation, non-normality or omitted variables.
- *F.7 Final model findings* – in section F7 we show the estimates produced using the final models.

[53] See chapter 2 of the main report for presentation and explanation of the econometric methodology.

F2 Data collection and data manipulation

F2.1 Patronage data

The Waikato Regional Council provided the following data on patronage (excluding SuperGold Card patronage)[54] by route:

- peak weekday patronage (before 9am, 3pm to 6pm) for the seven years from July 2003 to June 2010
- offpeak weekday patronage (9am to 3pm, after 6pm) for the six years from July 2004 to June 2010
- Saturday and Sunday patronage (9am to 3pm, after 6pm) for the six years from July 2004 to June 2010.

As discussed in section 8.4 of the main report, the existence of new routes and route restructuring complicates econometric analysis. Therefore, for the purposes of this seminal piece of research, we chose to focus on routes that meet the following criteria:

- The route existed throughout the six-year period.
- The route was not in the 'catchment area' of any of the new routes, and was hence unaffected by the introduction of any of the new routes.

Throughout the seven-year period covered by these analyses, there have been 34 routes but it made sense to group some of these routes together into route groups because they were not truly independent. For example, the introduction of the Pukete Direct (PD) service most definitely had an impact on the Pukete (1) service. These route groups are shown in tables F.1 and F.2.

Table F.1 shows the route groups that meet the 'selection route' criteria shown above, along with key events within each of those route groups.

Table F.1 'Selected routes' that were used in further stages of analysis

Route group	Individual route group members	Notes on key events
1+PD	1 – Pukete PD – Pukete Direct	The Pukete Direct was introduced in July 2008 Sunday Services introduced in September 2008
2+SD	2 – Silverdale SD – Silverdale Direct	The Silverdale Direct was introduced in February 2009 Sunday Services introduced in September 2008
3+DD+8[55]	3 – Dinsdale DD – Dinsdale Direct 8 – Frankton	The Dinsdale Direct was introduced in July 2008 Sunday Services introduced in September 2008
4	4 – Flagstaff	Sunday Services introduced in September 2008
6	6 – Mahoe	
7	7 – Glenview	Sunday Services introduced in September 2008
9	9 – Nawton	Offpeak frequency doubled from hourly to half-hourly in October 2006 (estimated date) Sunday services introduced in September 2008
10	10 – Hilcrest	

[54] Note that patronage, in this case, excludes SuperGold passengers.

[55] Note that the Dinsdale Direct (DD) has been grouped with both the Dinsdale (3) and Frankton (8) because it follows a route that overlaps with the catchment areas of both of those routes.

Route group	Individual route group members	Notes on key events
11	11 – Fairfield	Sunday services introduced in September 2008
12	12 – Fitzroy	Offpeak frequency doubled from (almost) hourly to half-hourly in February 2007
14	14 – Claudelands	
26	26 – Bremworth	Offpeak frequency doubled from (almost) hourly to half-hourly in September 2006 (estimated date)

Table F.2 shows the route groups that failed to meet 'selection route' criteria shown because of new routes and route restructuring that would have complicated econometric analysis. These routes could be included in an extension of this research.

Table F.2 Routes that were omitted from further analysis due to complicating factors

Route group	Individual route group members	Notes on complicating factors
O	Orbiter	The Orbiter was not introduced until July 2006
CBD	CBD shuttle	The CBD shuttle was not introduced until April 2008
16+RD+16EC+69	16 – Rototuna 17 – Hamilton East Uni 69 – Unitech 16 – Eastern Circular	The catchment areas for these routes overlap a lot The Unitech (69) was restructured in February 2007, renamed as the Hamilton East Uni (17) and significant route changes were made The Eastern Circular (16) was removed in February 2007 and replaced by the Hamilton East Uni (17) and the Rototuna (16)
5+CD+RD+16+30	5 - Chartwell CD – Chartwell Direct 16 – Rototuna RD – Rototuna Direct 30 – Northerner	The catchment areas for these routes overlap a lot The Northerner (30) experienced extensive route changes in July 2005 The Charwell Direct (CD) was introduced in February 2006 and it had a clear impact on Chartwell (5) patronage The Rototuna (16) was introduced in February 2007 The Chartwell Direct was replaced by the Rototuna Direct (RD) in July 2008. (This also involved a route change that added another 2.5km and coincided with the connection of the CBD shuttle to the Orbiter).
13+15+17	13 – University 15 – Ruakura 17 – Hamilton East Uni	The catchment areas for these routes overlap a lot The Ruakura (15) was introduced in February 2006 The Hamilton East Uni (17) was introduced in February 2007
18+55	18 – Te Rapa 55 – City Express	There is some overlap between these two routes The City Express (55) was introduced in February 2009

F2.2 Service change data

The key service changes associated with each of the 'selected route' groups are shown in table F.3. These service changes were compiled from timetables, promotional materials and other documentation provided by the Waikato Regional Council. In some cases we had to make 'educated guesses' about the nature and timing of service changes based on the available information.

We extracted the total number of trips before and after each service change from timetables provided by the Waikato Regional Council. These were used to estimate the % change in trips associated with service changes, and were later used to estimate the service elasticities presented in sections F.5 and F.7.

Table F.3 Description of service changes and routes affected

Service change		Date/s	Time of day affected	Routes affected											
				1+1(PD)	2+2(SD)	3+3(DD)+8	4	6	7	9	10	11	12	14	26
A	There were major timetable changes on route 26: • Weekday offpeak frequency went from (almost) half-hourly to a regular half-hourly service • A few extra peak services were added • Mon–Wed evening hours were extended (see D below).	Sep 06	Offpeak weekday Peak weekday												✓
B	There were major timetable changes on route 9: • Offpeak frequency was doubled from hourly to half-hourly • A few extra peak services were added • Mon–Wed evening hours were extended (see D below).	Oct 06	Offpeak weekday Peak weekday							✓					
C	There were major timetable changes on route 12: • Weekday offpeak frequency went from (almost) half-hourly to a regular half-hourly service • Mon–Wed evening hours were extended (see D below). • Services added to the Saturday to address gaps during the lunch-time period and to provide more regular services (see E below).	Feb 07	Offpeak weekday, Peak weekday, Saturday										✓		
D	Mon–Wed evening hours were extended from ~6.15pm to ~7.45pm (outbound) and ~5:45pm to ~7:15pm (inbound)	Sep 06													✓
		Oct 06	Offpeak weekday	✓	✓	✓	✓	✓	✓	✓	✓			✓	
		Feb 07	Offpeak weekday									✓	✓		
E	Services added to address gaps during the lunch-time period and to provide more regular services.	Feb 07	Offpeak weekday	✓		✓		✓	✓	✓		✓		✓	
		Feb 07	Saturdays	✓		✓		✓	✓	✓		✓	✓	✓	✓

Service change		**Date/s**	**Time of day affected**	**Routes affected**											
				1+1(PD)	**2+2(SD)**	**3+3(DD)+8**	**4**	**6**	**7**	**9**	**10**	**11**	**12**	**14**	**26**
F	Services were added to make evening services more regular.	Feb-07	Off-peak weekday	✓		✓		✓	✓	✓		✓		✓	
G	Pukete Direct (PD) was introduced to supplement the Pukete (1). This service is only provided during peak times and only goes to limited stops.	Jul-08	Peak weekday	✓											
H	Silverdale Direct (SD) was introduced to supplement the Silverdale (2). This service is only provided during peak times and only goes to limited stops	Feb-09	Peak weekday		✓										
I	Dinsdale Direct (DD) was introduced to supplement the Dinsdale (3) and arguably also the Frankton (8). This service is only provided during peak times and only goes to limited stops	Jul-08	Peak weekday			✓									
J	Sunday services were introduced based on the same timetable as the pre-existing Saturday services	Sep-08	Sundays	✓	✓	✓	✓		✓	✓		✓		✓	
K	Mon–Thur hours were extended from ~7:45pm to 9:45 pm (outbound) and ~ 7:15pm to ~10:15pm (inbound)	Feb-09	Off-peak weekday	✓		✓			✓	✓					
M	Weekday morning hours were extended from ~6.50am to ~6:20am (inbound) and from ~7:20am to ~6:50am (outbound)	Feb-09	Off-peak weekday	✓		✓			✓	✓					
N	Weekend hours were extended in the morning: ~7.50am to ~6.50am (inbound); ~8.20am to ~7.20am (outbound). Weekend hours also extended in the evening: ~5.45pm to ~6.45pm (inbound); ~6.15pm to ~7.15pm (outbound)	Feb-09	Saturday, Sunday	✓		✓			✓	✓					

F2.3 Other data

We collected and incorporated data on a number of explanatory variables: fares, petrol prices, retail sales and employment. Where applicable, these variables were then adjusted for inflation and hence the rest of the report refers to them as real fares, real petrol prices and real retail sales.

The retail sales and employment data reflect economic activity within the 'Hamilton city' territorial authority, which seems appropriate since we are only focusing on Hamilton city bus routes.

We also collected data on cars licensed by territorial authority, but after examination we found evidence of substantial corruption in the data so it was discarded.

In section 2.2.2 of the main report, we explained why we decided against incorporating population statistics into the econometric analyses. In general, we have doubts about the statistical robustness of findings produced using population statistics because they are low frequency (ie data is only annual) low accuracy (ie data is only an estimate), exhibit low variance (ie populations exhibit steady growth rates over time) and could only be obtained for broad geographical regions (ie territorial authorities).

Ideally, econometric modelling should control for the impact of key historical events. Table F.4 shows key events that we considered and, in most cases, incorporated into the analyses. There was no standardised documentation of these events. Therefore, as with service changes (see section F2.2) we had to make 'educated guesses' about the timing of a few of these events (ie introduction of electronic ticketing) based on the documentation made available to us.

Table F.4 Miscellaneous events

Event	Months affected	Quarters affected	Notes relating to event
Electronic ticketing introduced	Apr 04	2004–Q2	Electronic ticketing appears to have been introduced in April 2004. Prior to April 2004, it appears that a cash system was employed with 10-trip concession booklets. The new electronic tickets were priced at the same rate as the 10-trip tickets; however, cash tickets became about 11% more expensive to encourage a shift to use of electronic tickets.
Introduction of two-hour free transfer	Oct 06	2006–Q4	A two-hour free transfer appears to have been introduced in October 2006. This enabled passengers with unlimited transfers free on any Hamilton city bus service within two hours of purchase.
An advertising campaign with free bus ride coupons.	Oct 06	2006–Q4	Free bus ride coupons were provided in newspapers in October 2006 and they expired at the end of October 2006.
Fare increases	Feb 07, May 08, Apr 09, Dec 09,	2007–Q1, 2008–Q2, 2009–Q2, 2009–Q4	Based on our analysis of timetables and other data from the Waikato Regional Council, we have ascertained that there were fare increases in February 2007, May 2008, April 2009 and December 2009. We did not have data on average fare increases so we used the adult BUSIT single fare as a proxy for all these fares.
Hamilton V8 races 2008 and 2009	Apr 08 and Apr 09	2008–Q2 and 2009–Q2	The main impact of the races would have been on weekend patronage but weekday patronage may also have been affected somewhat. There was a massive spike in weekend patronage during the April 2008 races.
Crossing of the $2.00 nominal petrol price threshold	May 08 through Aug 08	2008–Q3	During the period from 22 May 2008 through to 13 Aug 2008 (roughly corresponding with 2008–Q3) the nominal price of regular petrol crossed the $2.00 threshold. There is reason to believe that the crossing of this threshold may have been a key trigger for behavioural

Event	Months affected	Quarters affected	Notes relating to event
			change. (However, is important to note that the impact of thresholds like the $2.00 mark is not concrete – it may reflect a number of other issues around the same time (eg media attention on 'peak oil') and may very well have changed as people have become accustomed to higher petrol prices.)
Introduction of SuperGold Card	Oct 08	2008–Q3 through to 2009–Q2	The SuperGold Card was introduced in Oct 08, providing free off-peak and weekend travel for persons over 65. Note that a key limitation of the route-level patronage data provided by the Waikato Regional Council is that it excludes SuperGold patronage; therefore, the introduction of SuperGold should in theory cause a decrease in route-level patronage.
Easter holidays	March or April depending on calendar	Q1 or Q2 depending on calendar	The Easter holidays occur sometimes in March and sometimes in April, depending on the calendar at the time. This can affect patronage because the timetables are more limited and because patrons are on holiday and hence less likely to use the buses for transportation.

Two key events not mentioned in table F.4 are the completion of the introduction of real-time information (RTI) and a new inner city bus exchange. Unfortunately, we were unable to obtain dates for these events. However, we suspect that any effect they had on patronage may be difficult to discern.

F3 Graphical analysis

F3.1 Key themes from graphical analysis

This section presents the key themes drawn out from a graphical analysis of all bus route groups selected for econometric analysis. See sections F3.2 to F3.4 for discussion of specific route groups within each time period (ie peak weekday, offpeak weekday, weekend).

The key themes from graphical analysis are:

- The introduction of SmartCard ticketing in 2004–Q2 did not have a discernible impact on patronage. If there had been a discernible impact on patronage then we would have seen a jump in patronage through quarters 2004–Q3, 2004–Q4 and 2005–Q1; this jump was not observed.
- There is evidence of a 'jump' in patronage in 2006–Q4, which continued to a lesser extent in 2007–Q1. As a general rule, this 'jump' had both a temporary and a permanent component:
  - The temporary component of the jump should most plausibly be attributed to the free ticket promotion in October 2006 (see table F.4).
  - The permanent component of the jump can be explained by a combination of various factors[56]:

[56] We also considered the hypothesis that the Orbiter service introduced in July 2006 contributed to growth in patronage; in theory, the Orbiter could have had a flow-on impact on patronage on certain routes. However, we dismiss this hypothesis as of low relevance because a) the 'jump' did not occur until 2006–Q4 whereas the Orbiter was introduced in July 2006 and b) the Orbiter exhibited gradual growth from July 2006 onwards whereas the observed 'jumps' in patronage were quite sudden.

- A free two-hour transfer was also introduced in October 2006 (see table F.4). We anticipate that this may have encouraged a permanent boost to patronage because it effectively lowered the cost of travel for people making trips of a short duration.
- The free ticket promotion may have also had a permanent impact on patronage by encouraging people who had previously avoided the Hamilton bus system, to now use it.
- Additional off-peak services were introduced in February 2007, to improve the regularity of services[57]. There were minor improvements to lunchtime and evening services on most routes. There was also a doubling of frequency on route 9 (October 2006), route 12 (February 2007) and 26 (September 2006). We see evidence from the graphical analysis that these changes to the offpeak weekday timetable had a flow-on 'network effect' on both peak patronage and weekend patronage.

- Most routes exhibited a temporary jump in patronage in 2008–Q2 (most likely due to the April 2008 V8 races) and 2008–Q3 (most likely due to nominal petrol prices crossing the $2.00 mark).
- The impacts of both petrol prices and fares appear to be difficult to discern. However, most of the routes show a decline in patronage from about 2009–Q1 onwards, and it seems reasonable to attribute this to a combination of falling petrol prices, rising fares and economic recession.
- The introduction of Sunday services in September 2008 had a roughly one-for-one impact on patronage, and this pattern was shown consistently across all routes. When Sunday services were introduced they followed the same timetable as the pre-existing Saturday services; therefore, the number of trips offered in the weekend roughly doubled. Patronage roughly doubled in response to these. This consistent relationship between Sunday service provision and patronage growth is shown clearly – see figures F.26–29, F.31–32 and F.34.[58]
- A selection of routes experienced an extension of weekend hours in February 2009 (ie 2009–Q1). These extensions did not have a discernible impact on patronage on any of the routes.

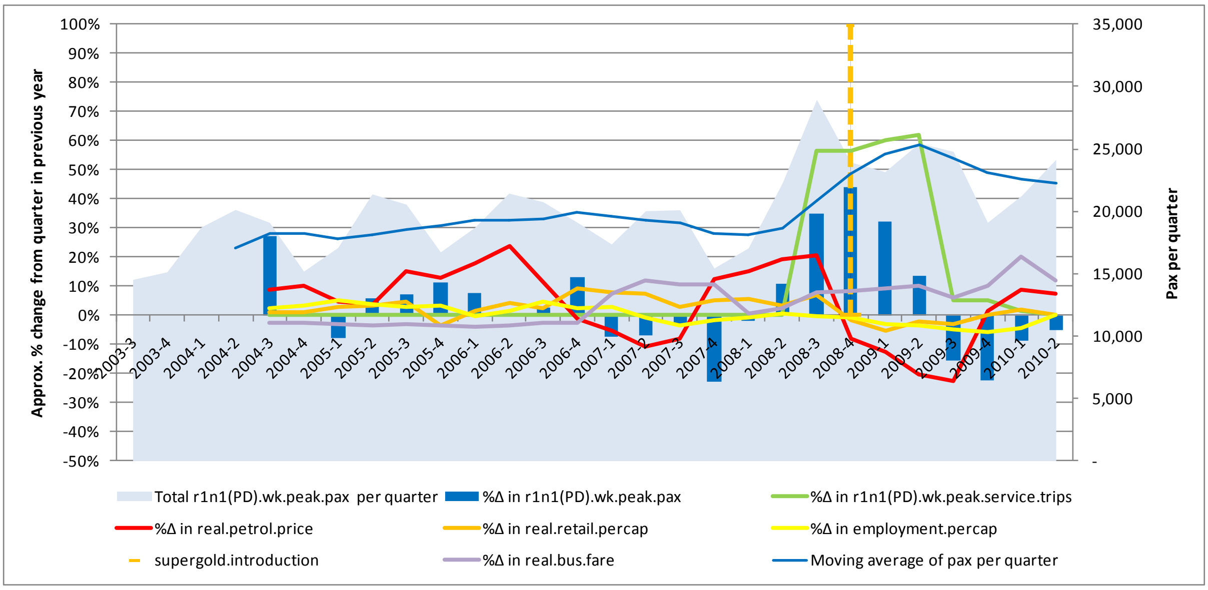
F3.2 Graphical analysis of peak data

This section provides figures plotting peak patronage and growth in peak patronage through time, for each route group, and compares that to growth in explanatory variables, including service trips, real bus fares and real petrol prices.

[57] We note that, according to this explanation, patronage on routes 2, 4, and 10 would have been unaffected by most service changes (see table F.10). This may explain why routes 1, 2, 4 and 10 showed muted or negligible permanent 'jumps' in patronage around 2006–Q4.

[58] Note, however, that the growth figures shown in the figures provided are actually log-changes, not conventional percentage changes. With small numbers this difference is of no consequence eg a 10% growth in trips can be expressed as $\ln(1.1/1.0) = 0.095 = 9.5\% \approx 10\%$. But with large numbers there can be a discrepancy eg a doubling of trips is expressed as $\ln(2/1) = 0.693 = 69.3\%$ which is quite different from the conventional 100%.

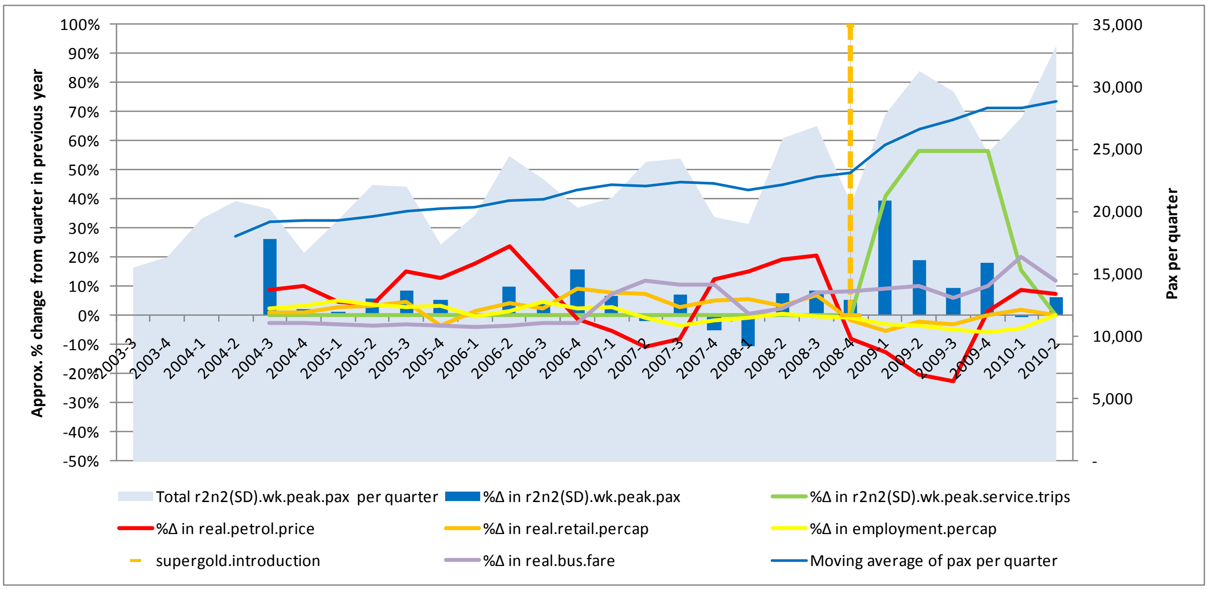
Figure F.1 Route group 1+1(PD) – analysis of peak-time patronage growth



Key observations from graphical analysis of the Pukete (1) and the Pukete Direct (PD) are:

- The introduction of the Pukete Direct in 2008-Q3 had a clear impact on patronage growth.
- The additional morning services added in 2009-Q1 do not appear to have had a positive impact on patronage growth.
- Patronage seemed to spike up by 10% in 2006-Q4 and then reversed in 2007-Q4. It is possible that this was due to promotional free bus tickets handed out in October 2006.
- Patronage was also unusually low in 2003-Q3 and this expressed itself in the 25% jump in patronage in 2004-Q3. The reasons for this are not clear but it could be a data issue, given that the data series started in 2003-Q3.

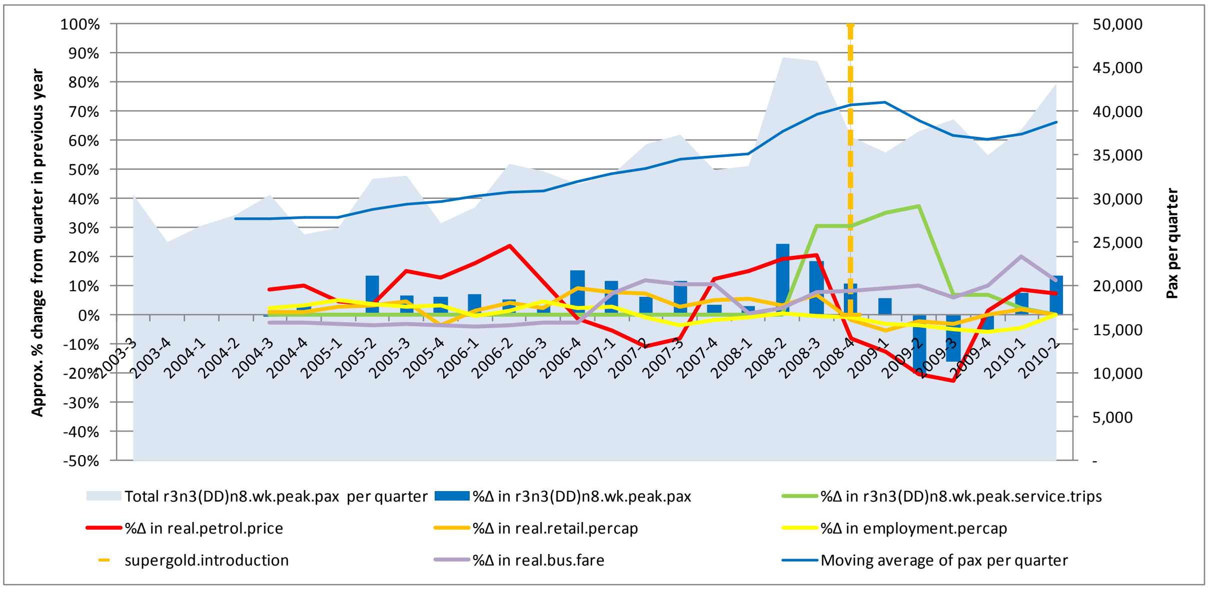
Figure F.2 Route group 2+2(SD) – analysis of peak-time patronage growth



Key observations from graphical analysis of the Silverdale (2) and the Silverdale Direct (PD) are:

- The introduction of the Silverdale Direct in 2009-Q1 had a discernible impact on patronage growth.
- Patronage seemed to spike up by 10% in 2006-Q4 and then reversed in 2007-Q4. It is possible that this was due to promotional free bus tickets handed out in October 2006.
- Patronage was also unusually low in 2003-Q3 and this expressed itself in the 25% jump in patronage in 2004-Q3. The reasons for this are not clear but it could be a data issue, given that the data series started in 2003-Q3.

Figure F.3 Route group 3+3(DD)+8 – analysis of peak-time patronage growth

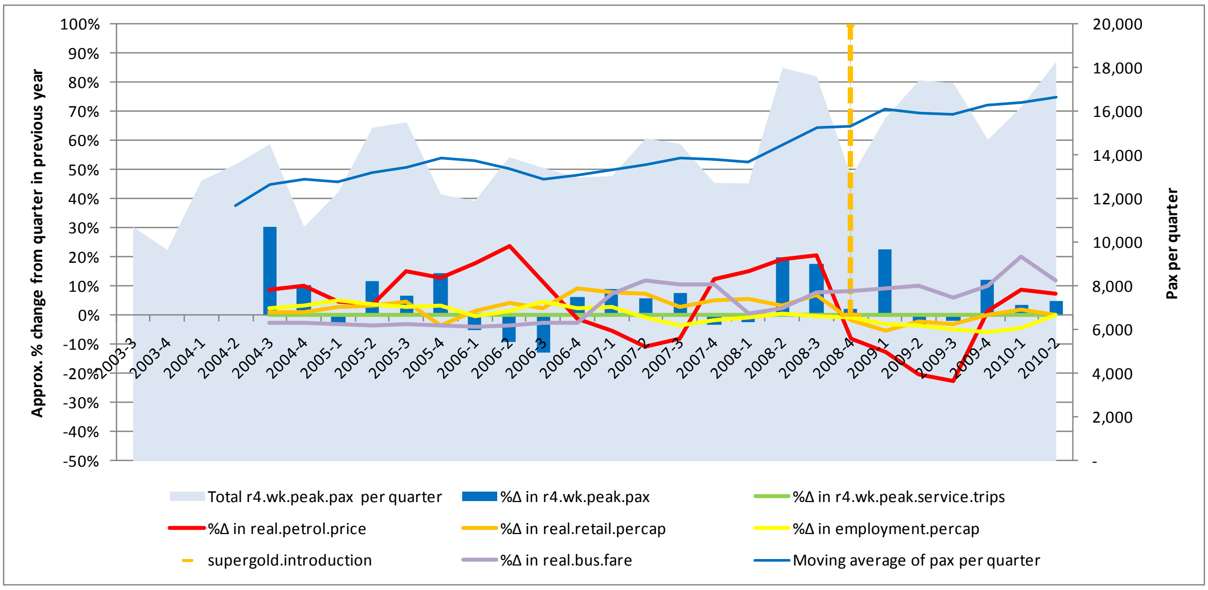


Key observations from graphical analysis of the Dinsdale (3), the Dinsdale Direct (PD) and the Frankton (8)[59]. are:

- The introduction of the Dinsdale Direct in 2008-Q3 does not appear to have had a discernable impact on patronage.
- Patronage seemed to jump up permanently by about 10% in 2006-Q4.
- There was a temporary spike in patronage in 2008-Q2 of about 20%; this can probably be attributed to the April 2008 v8 races.
- There was a temporary spike in patronage in 2008-Q3 of about 15%; this probably occurred because petrol prices rose above the $2.00 threshold.

[59] We note that the Dinsdale Direct has been grouped with both route 3 and route 8 because it follows a path that crosses both of these catchment areas.

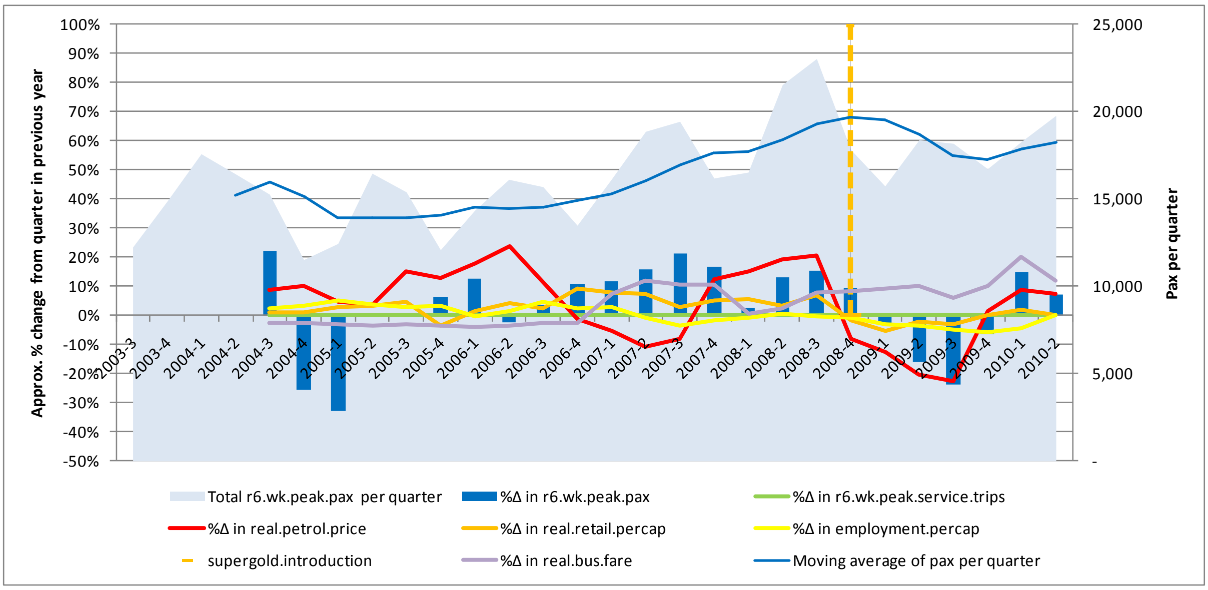
Figure F.4 Route group 4 – analysis of peak-time patronage growth



Key observations from graphical analysis of the Flagstaff (4) are:

- Patronage increased permanently by about 5% in 2006-Q4.
- Again, the spikes in patronage in 2008-Q2 and 2008-Q3 can probably be attributed to the April 2008 V8 races and the crossing of the $2.00 petrol price threshold.
- There were no service changes, so any patronage trends exhibited on this route must be attributed to non-service related explanatory variables.
- Patronage jumped in 2009-Q1 for unexplained reasons.

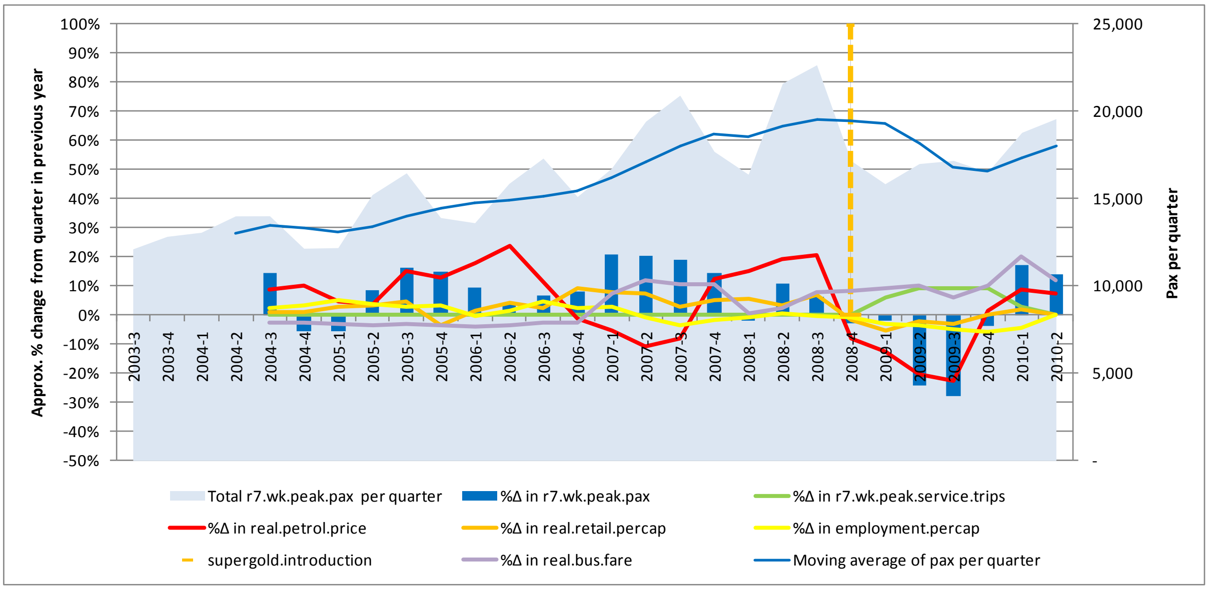
Figure F.5 Route group 6 – analysis of peak-time patronage growth



Key observations from graphical analysis of the Mahoe (6) are:

- Patronage growth was negative in 2004-Q4 and 2005-Q1 – this appears to have been due to unusually high patronage levels in 2003-Q4 and 2004-Q; the reasons for this unusually high patronage have not been explained.
- There was also an unusual spurt in patronage growth that started in 2006-Q4, despite the absence of any peak-time service improvements on this route. The most likely explanations for this are a combination of a free-ticket promotion in October 2006 and service improvements in February 2007 to improve the regularity of off-peak weekday services around lunchtime and in the evening.
- Again, the spikes in patronage in 2008-Q2 and 2008-Q3 can probably be attributed to the April 2008 V8 races and the crossing of the $2.00 petrol price threshold.

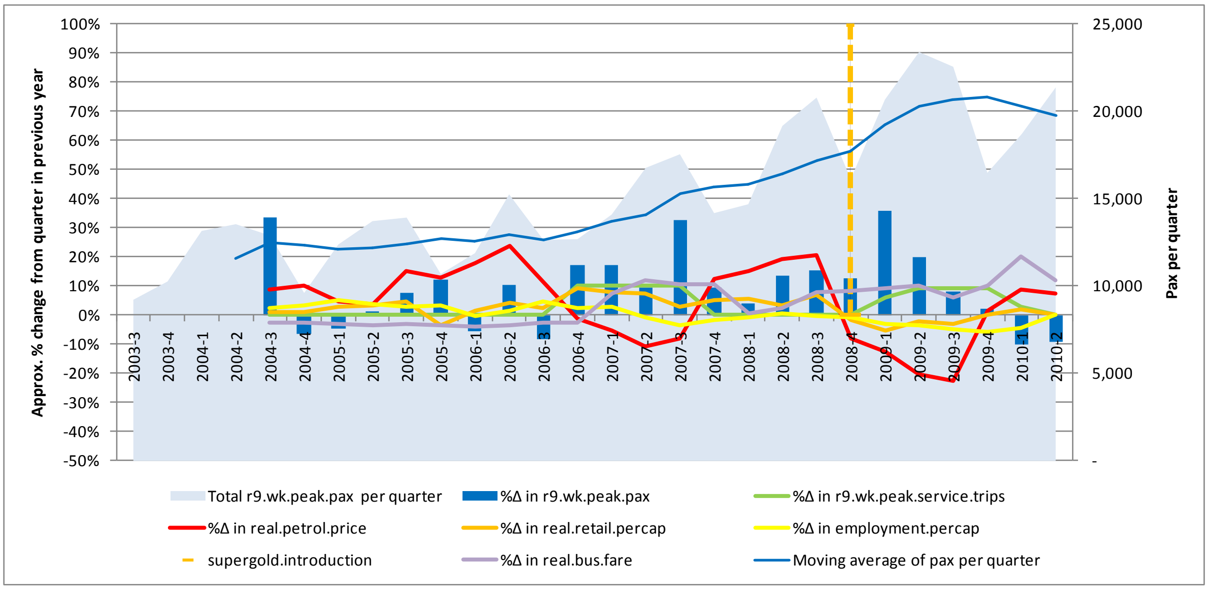
Figure F.6 Route group 7 – analysis of peak-time patronage growth



Key observations from graphical analysis of the Glenview (7) are:

- There was also an unusual spurt in patronage growth that started in 2007-Q1, despite the absence of any peak-time service improvements on this route. The most likely explanations for this are service improvements in February 2007 to improve the regularity of off-peak weekday services around lunchtime and in the evening.
- Again, the spikes in patronage in 2008-Q2 and 2008-Q3 can probably be attributed to the April 2008 V8 races and the crossing of the $2.00 petrol price threshold.
- The extra peak-time services, introduced in 2009-Q1 had an indiscernible impact on peak-time patronage.

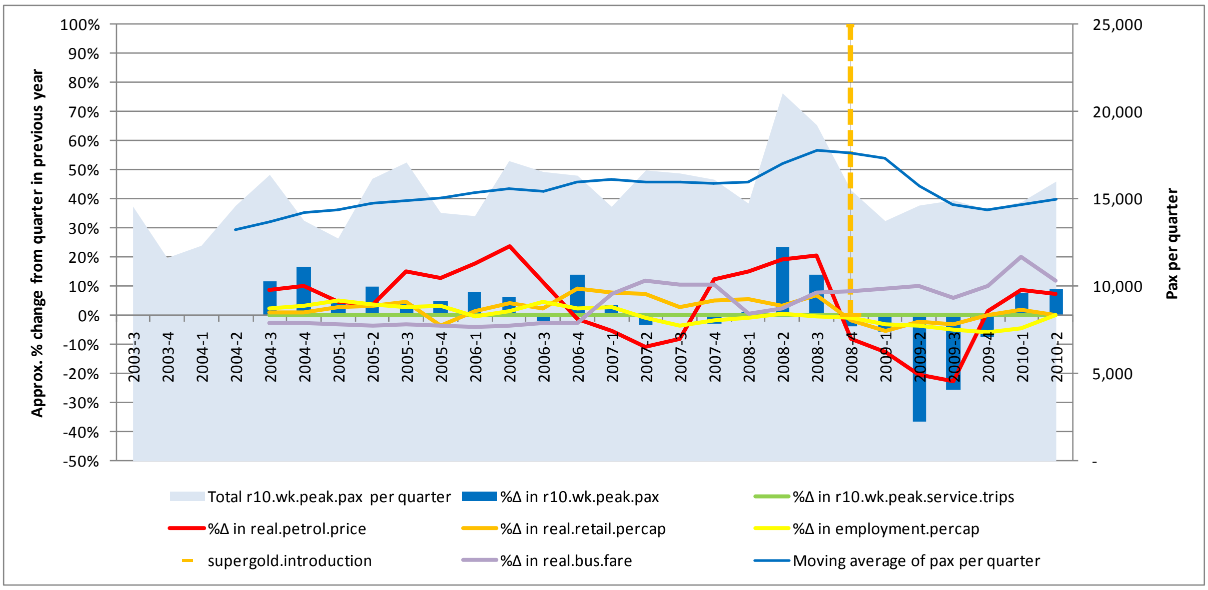
Figure F.7 Route group 9 – analysis of peak-time patronage growth



Key observations from graphical analysis of the Nawton (9) are:

- There was also an unusual spurt in patronage growth that started in 2006–Q4. We note that there were major time table changes in October 2006, including a doubling of inter-peak frequency and additional peak-time services. Other factors include, as with previous routes discussed, a free-ticket promotion in October 2006 and service improvements in February 2007 to improve the regularity of off-peak weekday services around lunchtime and in the evening.
- There was another growth spurt around 2009–Q1. This may be related to the additional peak services added in February 2009, but we cannot be sure.

Figure F.8 Route group 10 – analysis of peak-time patronage growth

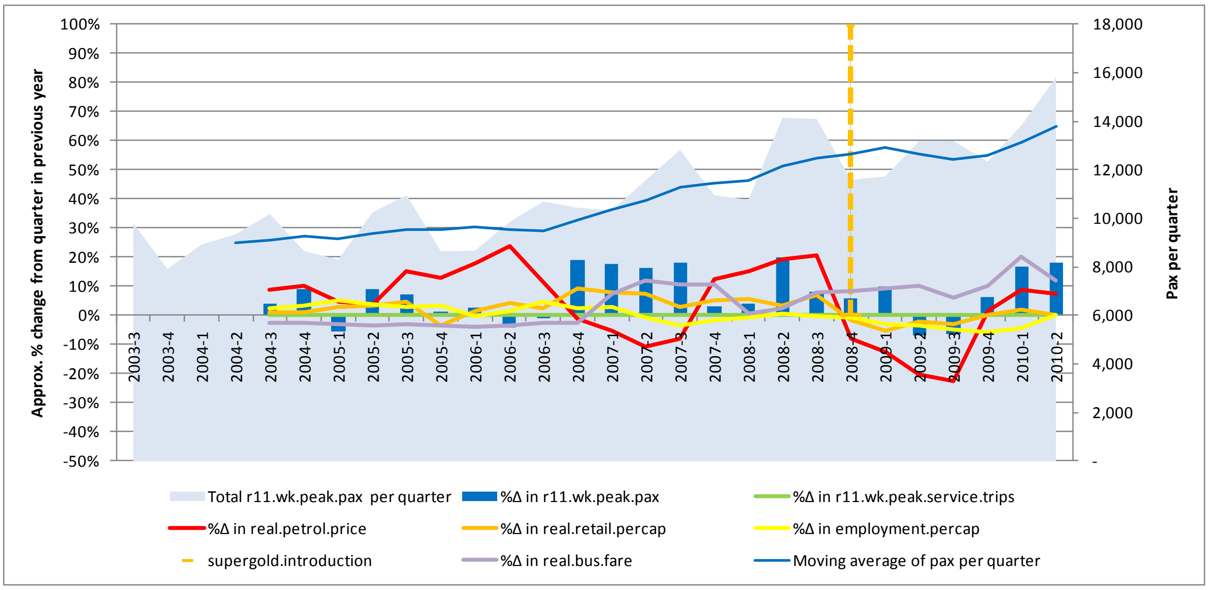


Key observations from graphical analysis of the Hilcrest (10) are:

- This route is of particular interest because there were no peak-time service changes during this whole period. There were also limited changes to off-peak service changes.

- There was a temporary spike in patronage in 2006-Q4, most likely due to the free ticket promotion, but there was not the 10% to 20% growth in peak patronage seen on other routes during the period from 2006-Q4 to 2007-Q4. This suggests that the growth in peak patronage seen on other routes is due to service improvements to off-peak weekday services around lunchtime and in the evening.
- As with other routes, there was a spike in patronage in 2008-Q2 and 2008-Q3, which was most likely due to the April 2008 V8 races and the crossing of the $2.00 petrol price thresholds. The drops in patronage in 2009-Q2 and 2009-Q3 (relative to the previous year) most likely occurred because the April 2009 V8 races did not generate as much patronage and petrol prices had fallen back below $2.00 by this point.

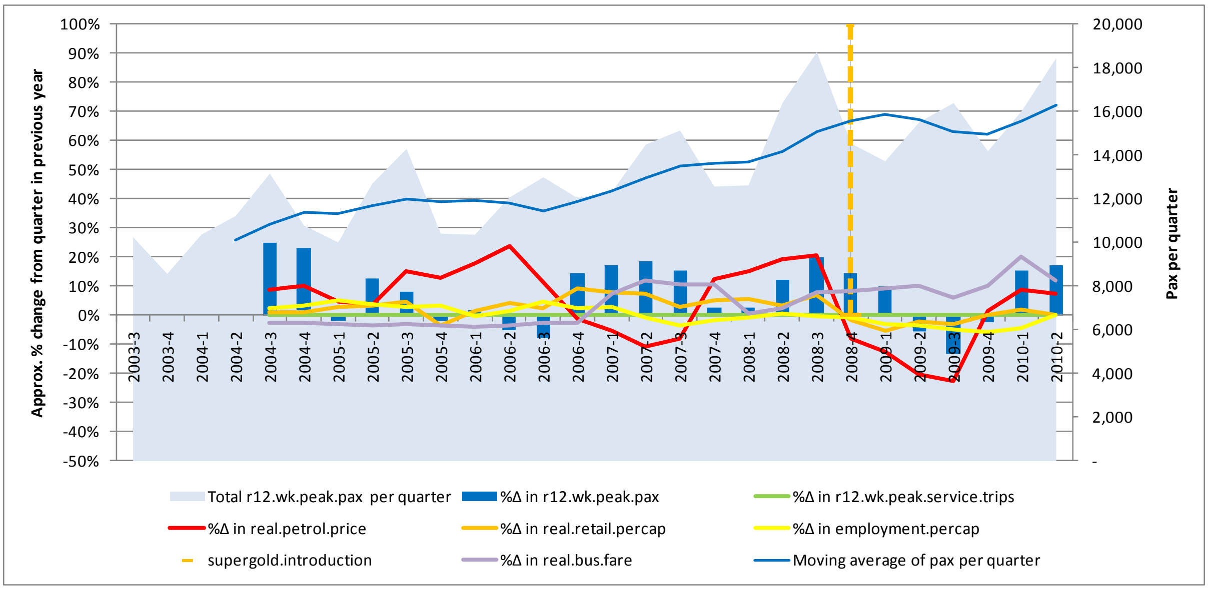
Figure F.9 Route group 11 – analysis of peak-time patronage growth



Key observations from graphical analysis of the Fairfield (11) are:

- There is appears to be a clear jump in patronage in 2006-Q4. We suspect that this was a combination of the impact of the free-ticket promotion in October 2006 and service improvements in February 2007 to improve the regularity of off-peak weekday services around lunchtime and in the evening
- The spike in patronage in 2008-Q2 can probably be attributed to the April 2008 V8 races.

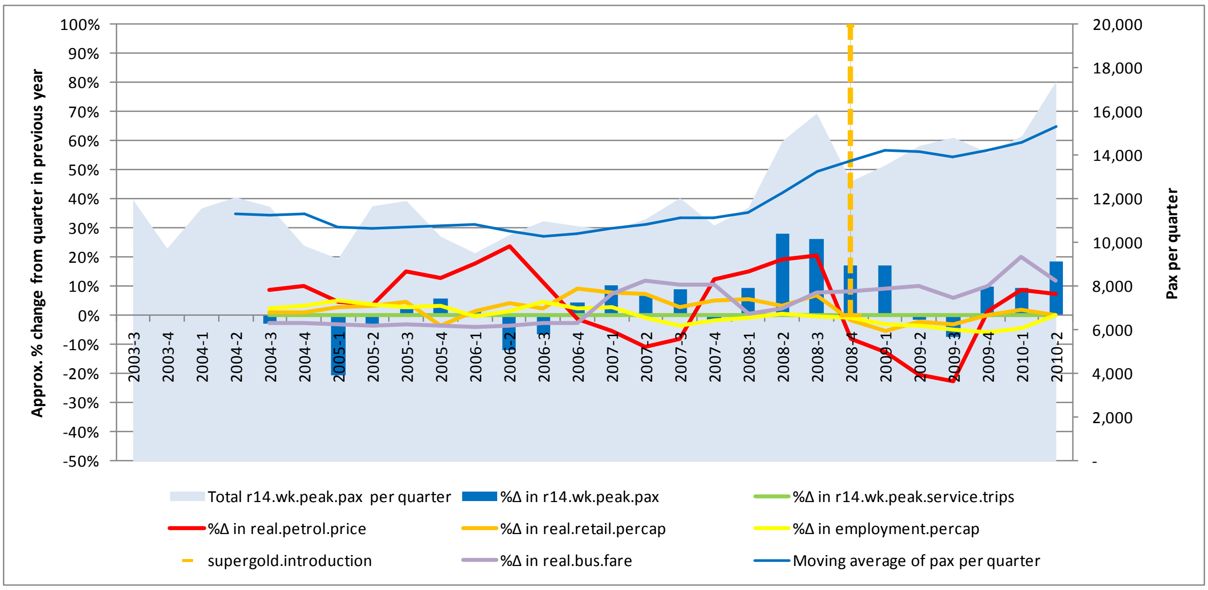
Figure F.10 Route group 12 – analysis of peak-time patronage growth



Key observations from graphical analysis of the Fitzroy (12) are:

- There was unusually high patronage growth in 2004-Q3 and 2004-Q4. The reasons for this are not clear, but appear to be related to unusually low patronage the year before, in 2003-Q3 and 2003-Q4.
- There appears to be a clear jump in patronage in 2006-Q4. We suspect that this was actually a combination of the impact of the free-ticket promotion in October 2006 and service improvements in February 2007 to improve the regularity of off-peak weekday services around lunchtime and in the evening.
- As with other routes, there was a spike in patronage in 2008-Q2 and 2008-Q3, which was most likely due to the April 2008 V8 races and the crossing of the $2.00 petrol price thresholds.

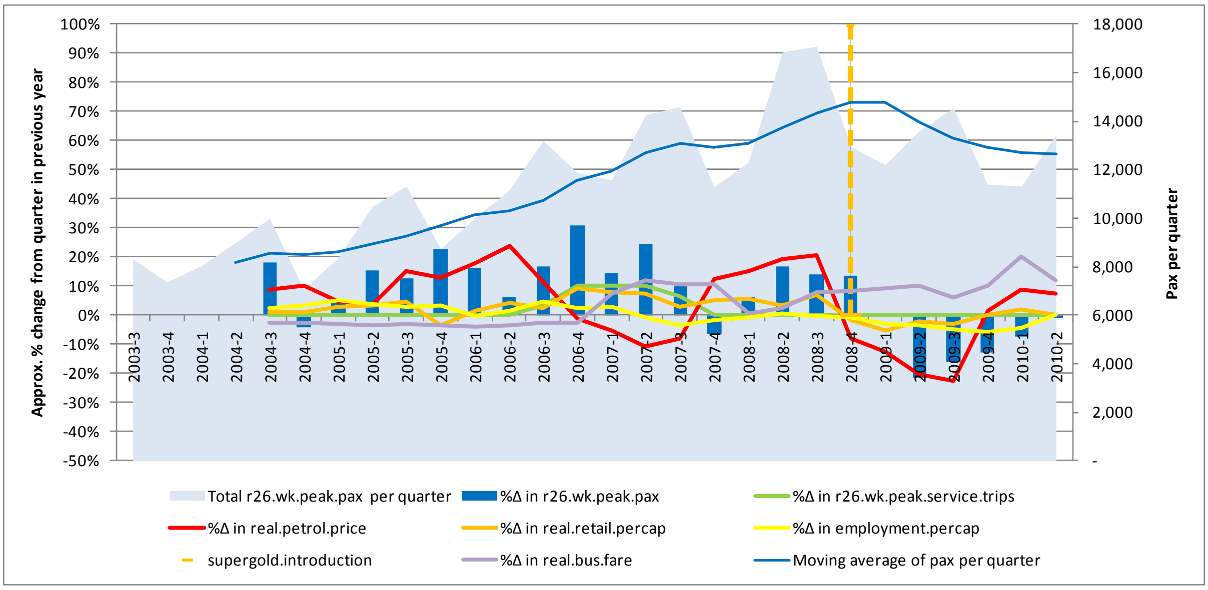
Figure F.11 Route group 14 – analysis of peak-time patronage growth



Key observations from graphical analysis of the Claudelands (14) are:

- This route is of particular interest because, like route 10, there were no peak-time service changes during this whole period. There were also limited changes to off-peak service changes.
- Again, there was not the 10% to 20% growth in peak patronage seen on other routes during the period from 2006-Q4 through to 2007-Q4. This suggests that the growth in peak patronage seen on other routes was due to service improvements to off-peak weekday services around lunchtime and in the evening.
- As with other routes, there was a spike in patronage in 2008-Q2 and 2008-Q3, which was most likely due to the April 2008 V8 races and the crossing of the $2.00 petrol price thresholds.

Figure F.12 Route group 26 – analysis of peak-time patronage growth



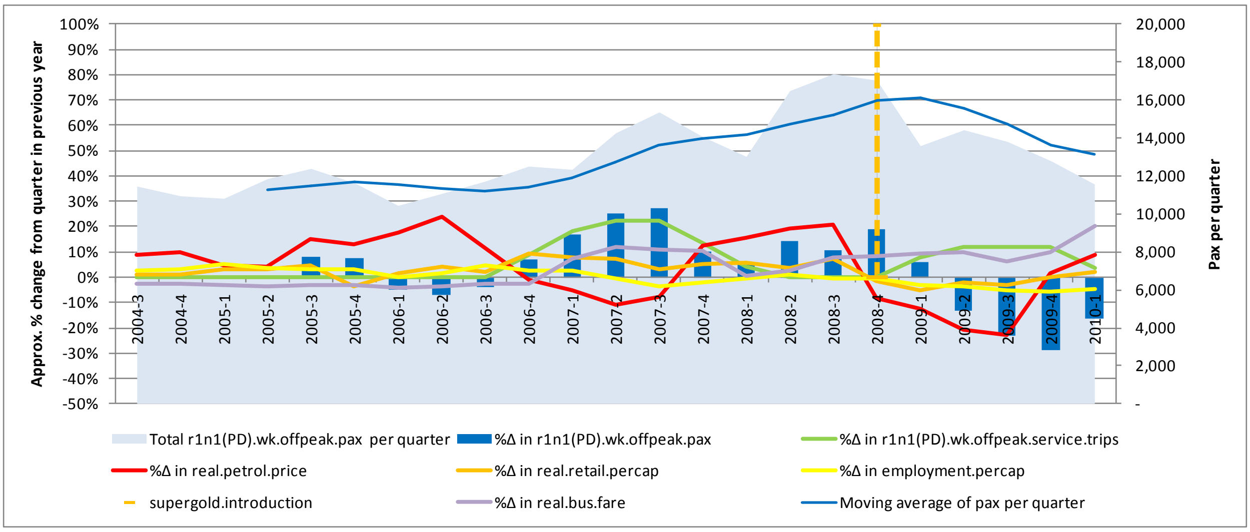
Key observations from graphical analysis of the Bremworth (26) are:

- This route shows unusually high patronage growth throughout its history, although the growth appears to have ceased from 2009 onwards, most likely due to a combination of falling petrol prices and economic recession.
- The patronage growth spurt from 2006-Q3 onwards was most likely related to significant off-peak service improvements (including a doubling of inter-peak frequency) in September 2006.
- As with other routes, there was a spike in patronage in 2008-Q2 and 2008-Q3, which was most likely due to the April 2008 V8 races and the crossing of the $2.00 petrol price thresholds.

F3.3 Graphical analysis of offpeak data

This section provides figures plotting off-peak patronage and growth in off-peak patronage through time, for each route group, and compares that to growth in explanatory variables, including service trips, real bus fares and real petrol prices.

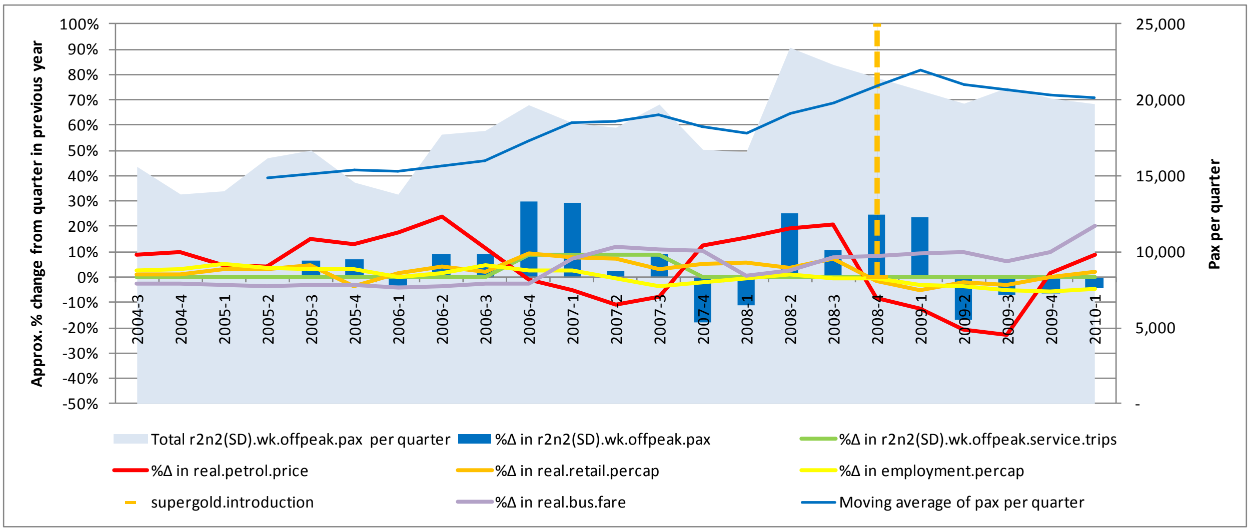
Figure F.13 Route group 1 – analysis of off-peak patronage growth



Key observations from graphical analysis of the Pukete (1) are:

- Patronage showed a spurt of growth from about 2006–Q4 and this growth spurt can be plausibly linked to a combination of the free ticket promotion and service improvements at the time. There was both an extension of evening hours in October 2006 and additional services in February 2007 to improve the regularity of services around lunchtime and in the evenings.
- The further extension of evening hours in 2009–Q1 did not have a discernible impact on patronage.
- There has been very negative growth since 2009–Q2 and the reasons for this are not clear, but could be related to economic recession and/or falling petrol prices.

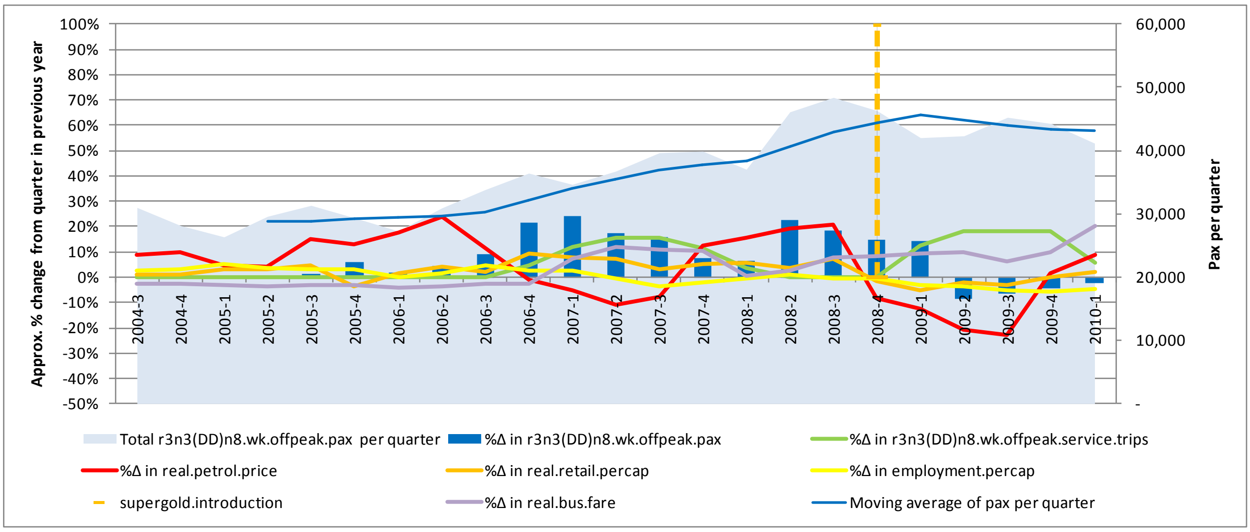
Figure F.14 Route group 2 – analysis of off-peak patronage growth



Key observations from graphical analysis of the Silverdale (2) are:

- Patronage exhibited a growth spike of about 30% in 2006–Q4 and 2007–Q1. This growth was mostly temporary and appears to have reversed the following year.
- There was an extension of evening hours in October 2006. This did not have a discernible impact on patronage growth.

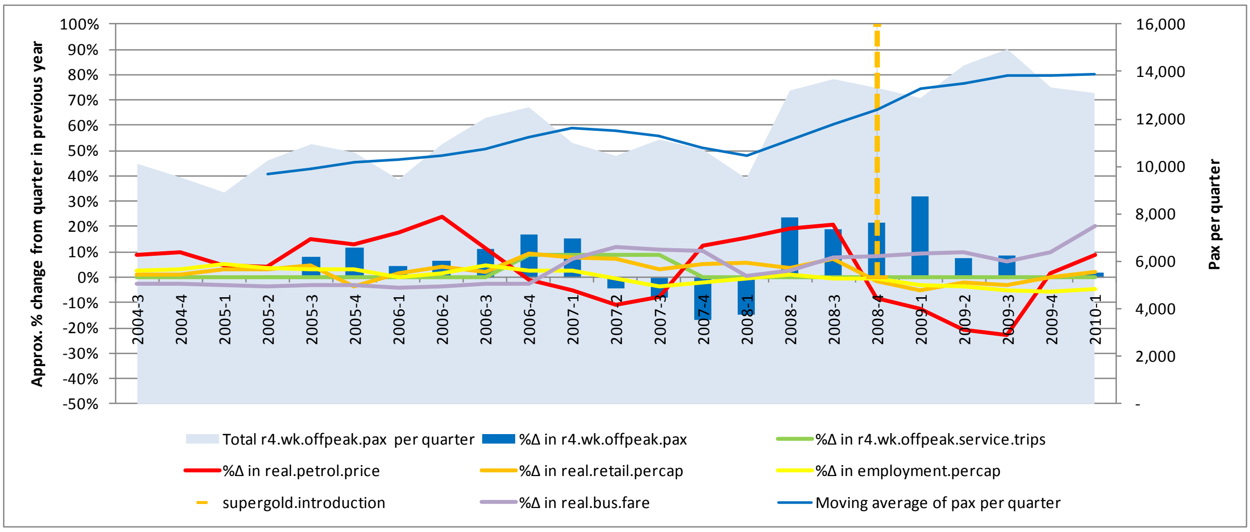
Figure F.15 Route group 3+8 – analysis of off-peak patronage growth



Key observations from graphical analysis of the Dinsdale (3) and the Frankton (8) are:

- Patronage exhibited a growth spike of about 20% in 2006-Q4 and 2007-Q1.
- Some of the growth from 2006-Q3 to 2007-Q4 can be plausibly linked to a combination of the free two-hour transfer and service improvements at the time. There was both an extension of evening hours in October 2006 and additional services in February 2007 to improve the regularity of services around lunchtime and in the evenings.
- The further extension of evening hours in 2009-Q1 did not have a discernible impact on patronage.

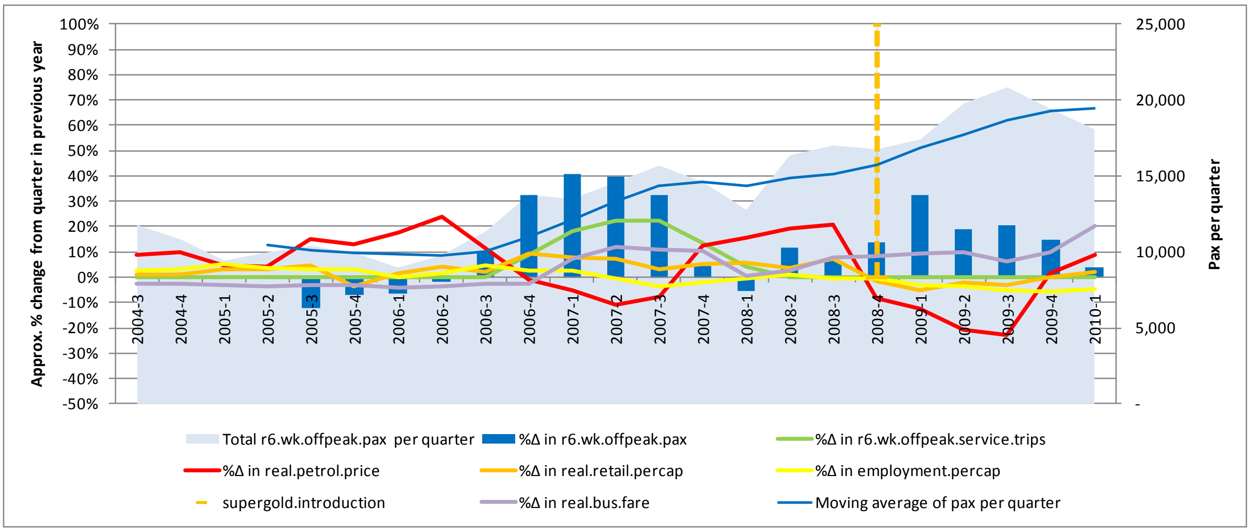
Figure F.16 Route 4 (Flagstaff) – analysis of off-peak patronage growth



Key observations from graphical analysis of the Flagstaff (4) are:

- Patronage exhibited a growth spike of about 15% in 2006-Q4 and 2007-Q1. This could potentially be linked to the extension of evening hours in October 2006.
- There appears to be a permanent jump in patronage, of about 15%, around 2008-Q2, but the reasons for this are not clear.
- The further extension of evening hours in 2009-Q1 did not have a discernible impact on patronage.

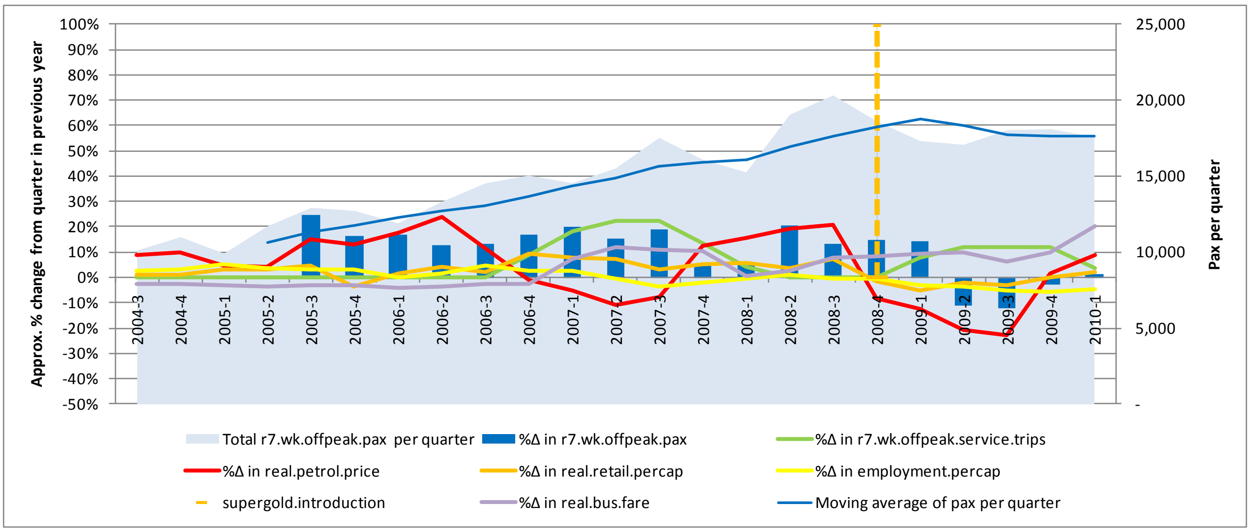
Figure F.17 Route group 6 – analysis of off-peak patronage growth



Key observations from graphical analysis of the Mahoe (6) are:

- Some of the growth from 2006-Q3 to 2007-Q4 can be plausibly linked to a combination of the free two-hour transfer and service improvements at the time. There was both an extension of evening hours in October 2006 and additional services in February 2007 to improve the regularity of services around lunchtime and in the evenings.
- Patronage growth also became quite high again from about 2009-Q1.

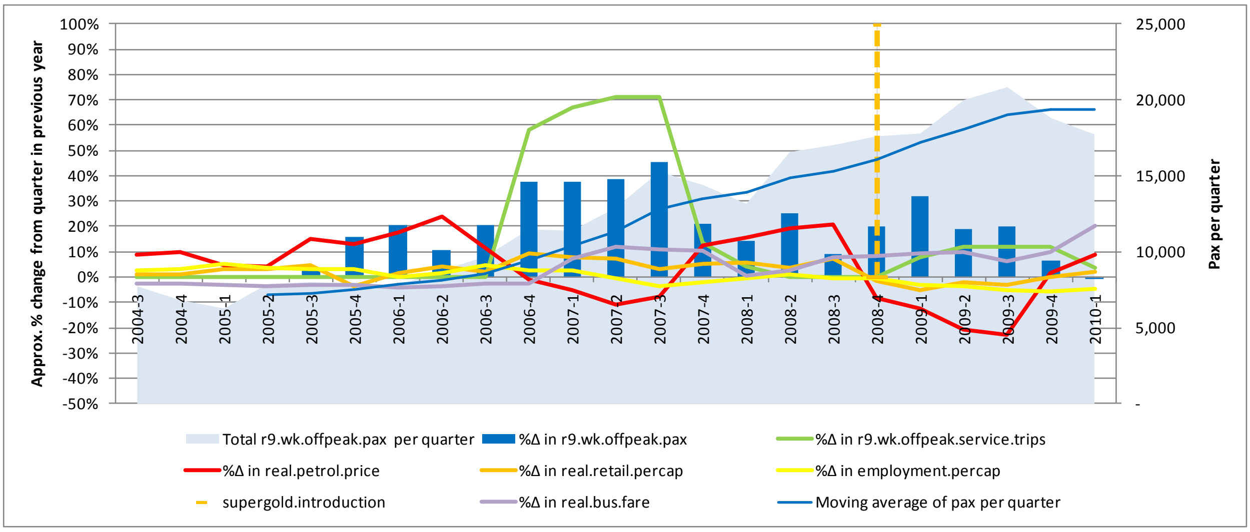
Figure F.18 Route group 7 – analysis of off-peak patronage growth



Key observations from graphical analysis of the Glenview (7) are:

- This route has had unusually high growth throughout its history.
- Some of the growth from 2006-Q3 to 2007-Q4 can be plausibly linked to a combination of the free two-hour transfer and service improvements at the time. There was both an extension of evening hours in October 2006 and additional services in February 2007 to improve the regularity of services around lunchtime and in the evenings.
- Patronage seemed to jump up permanently by about 10% in 2008-Q2.

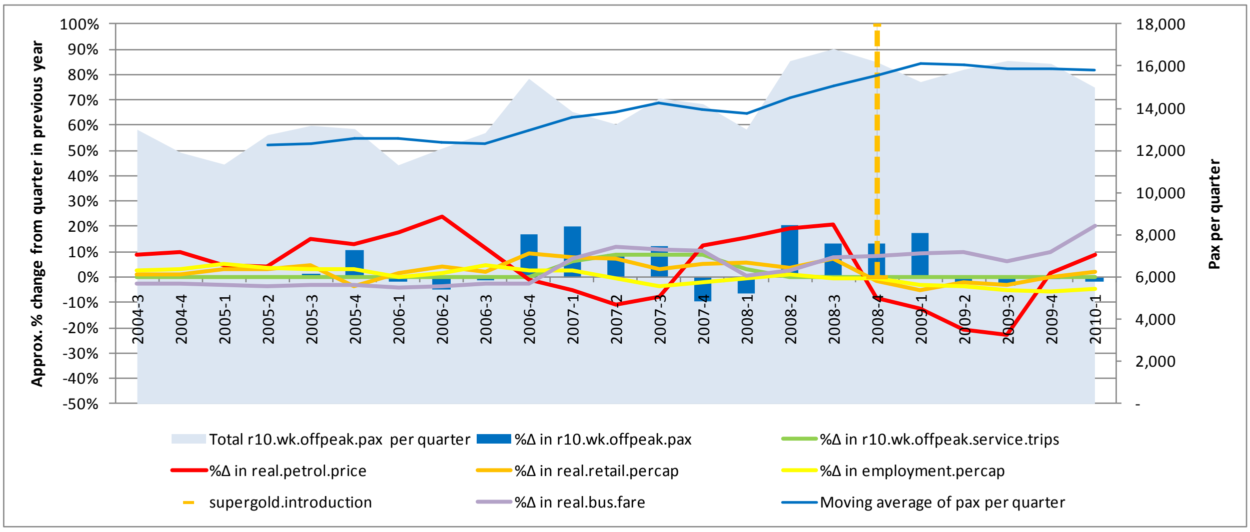
Figure F.19 Route group 9 – analysis of off-peak patronage growth



Key observations from graphical analysis of the Nawton (9) are:

- This route has had unusually high growth throughout its history.
- Interpeak frequency was doubled from hourly to half-hourly in October 2006 (estimated date). More services were added in February 2007 to improve the regularity of services around lunchtime and in the evenings. There was a clear patronage response to some combination of these service improvements. As in other cases, the free two-hour transfer probably played a role.
- The extension of evening hours in 2009-Q1 did not have a discernible impact on patronage.

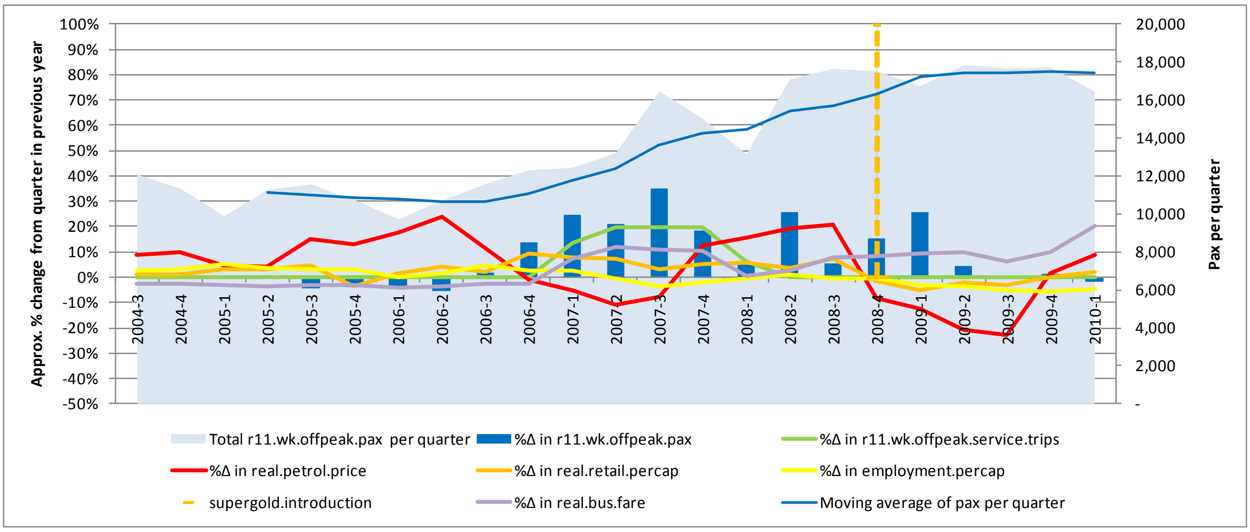
Figure F.21 Route group 10 – analysis of off-peak patronage growth



Key observations from graphical analysis of the Hilcrest (10) are:

- Patronage exhibited a growth spike of about 20% in 2006-Q4 and 2007-Q1. This growth was mostly temporary and appears to have reversed the following year.
- Patronage seemed to jump up permanently by about 10% in 2008-Q2.

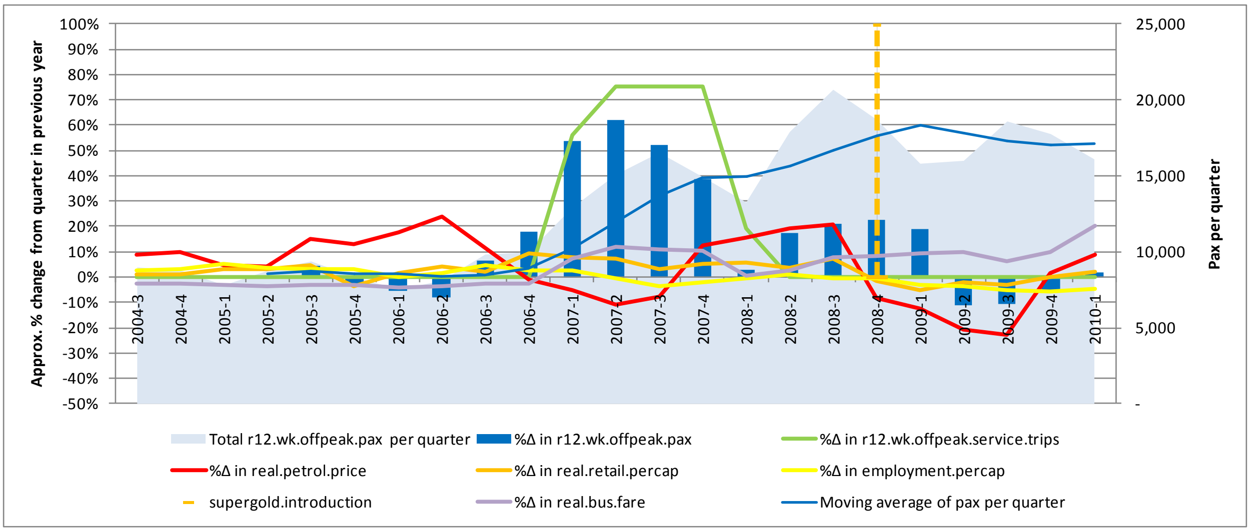
Figure F.22 Route group 11 – analysis of off-peak patronage growth



Key observations from graphical analysis of the Fairfield (11) are:

- Some of the growth from 2006-Q3 to 2007-Q4 can be plausibly linked to a combination of the free two-hour transfer and service improvements at the time. There was both an extension of evening hours in October 2006 and additional services in February 2007 to improve the regularity of services around lunchtime and in the evenings.

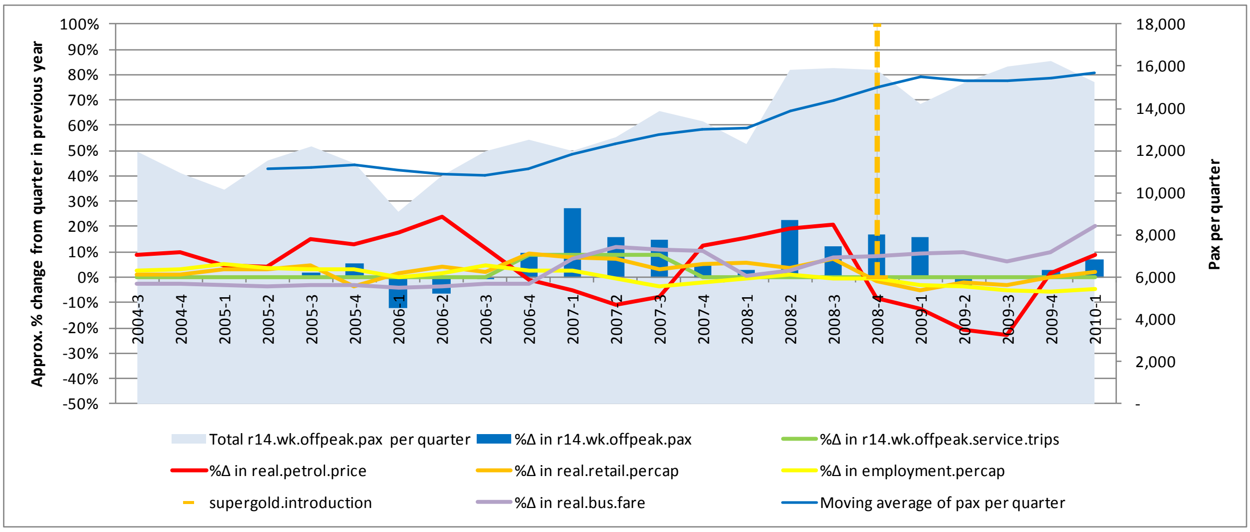
Figure F.23 Route group 12 – analysis of off-peak patronage growth



Key observations from graphical analysis of the Fitzroy (12) are:

- Interpeak frequency was doubled from (almost) hourly to half-hourly in October 2006. In addition, there was also an extension of evening hours (from 6.15pm to 7.45pm Mon-Wed, matching Thur-Fri). These service enhancements, perhaps in combination with the free two-hour transfer, have had a clear impact on patronage growth.
- Patronage seemed to jump up permanently by about 15% in 2008-Q2.

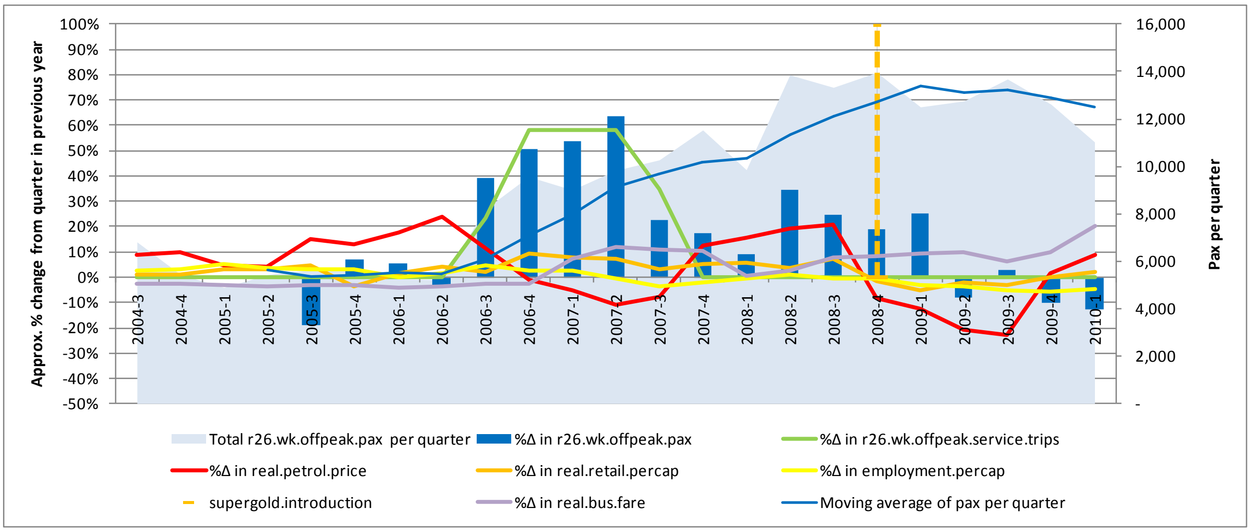
Figure F.24 Route group 14 – analysis of off-peak patronage growth



Key observations from graphical analysis of the route Fairfield (14) are:

- Some of the growth from 2006-Q4 to 2007-Q4 can be plausibly linked to an extension of evening hours in October 2006.
- Patronage seemed to jump up permanently by about 15% in 2008-Q2.

Figure F.25 Route group 26 – analysis of off-peak patronage growth



Key observations from graphical analysis of the route Bremworth (26) are:

- Interpeak frequency was doubled from (almost) hourly to half-hourly in September 2006 (estimated date). In addition, there was also an extension of evening hours (from 6.16pm to 7.46pm Mon-Wed). These service enhancements, perhaps in combination with the free two-hour transfer, have had a clear impact on patronage growth.
- Patronage seemed to jump up permanently by about 15% in 2008-Q2.

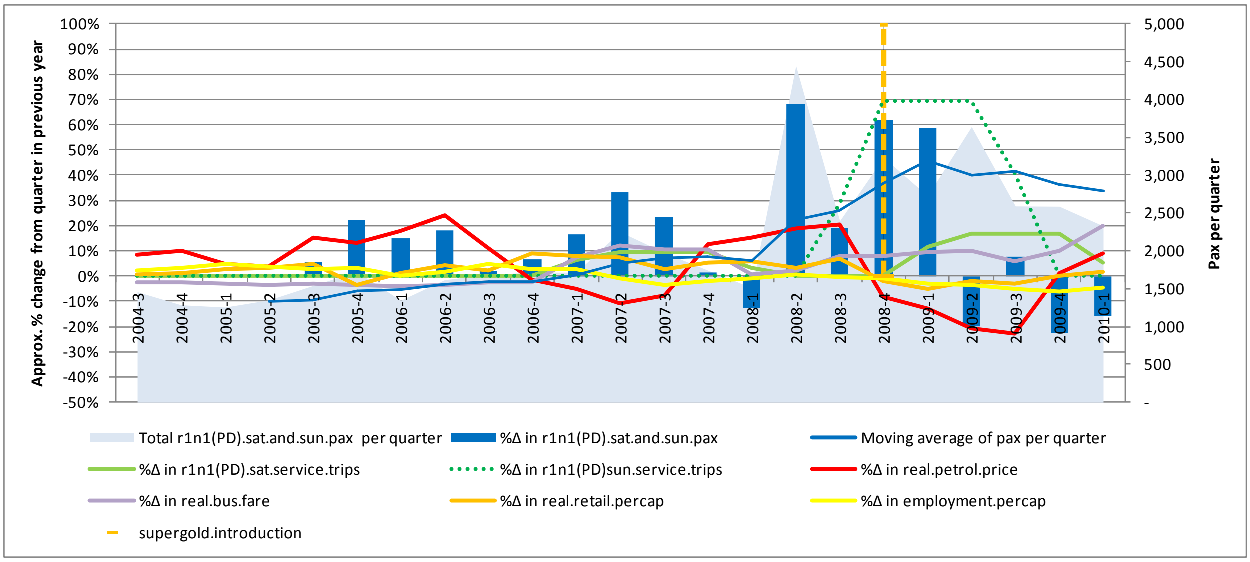
F3.4 Graphical analysis of weekend data

This section provides figures plotting weekend patronage[60] through time (in levels and year-on-year growth) for each route group, and compares that to growth in explanatory variables (service trips, real bus fares, real petrol prices etc). The key themes observed are:

- The introduction of the free two-hour transfer (estimated date 2006–Q4) seems to have had a pronounced impact on weekend patronage. This is plausible given that this initiative essentially halves the cost of a short-duration return trip, and a number of weekend trips could feasibly fit into this category (eg shopping trips, trips to a cafe, etc). That said, the 'jumps' observed in 2006–Q4 differ by routes:
  - Routes 1, 2, 4 showed only minor increases in weekend patronage.
  - Routes 3 and 8 showed a 30% increase in weekend patronage (although this was accompanied by minor improvements to the Saturday timetable).
  - Route 6 showed a 40% increase in weekend patronage (although this was accompanied by minor improvements to the Saturday timetable and major improvements to weekday timetables).
  - Route 7 showed a 20% increase in weekend patronage (although this was accompanied by minor improvements to the Saturday timetable).
  - Route 9 showed a 40% increase in weekend patronage (although this was accompanied by minor improvements to the Saturday timetable and major improvements to weekday timetables).
  - Route 10 showed a 10% to 30% increase in weekend patronage.
  - Route 11 showed a 30% increase in weekend patronage (although this was accompanied by minor improvements to the Saturday timetable and major improvements to weekday timetables).
  - Route 12 showed a 20% to 70% increase in weekend patronage (although this was accompanied by minor improvements to the Saturday timetable and major improvements to weekday timetables).
  - Route 14 showed a 30% increase in weekend patronage.
- The introduction of the April 2008 V8 races caused a dramatic increase in weekend patronage during 2008–Q2, generally in the range of 50% to 90%.
- The continuation of the April 2009 V8 races was associated with a drop in weekend patronage for 2009–Q2. This was because, even though weekend patronage was high during the 2009 races it was not as high as during the 2008 races; therefore, we generally see a drop in weekend patronage when we estimate the growth between 2008–Q1 and 2009–Q2. Routes 6 and 10 are good illustrations of this phenomenon.
- The introduction of Sunday services in 2008–Q3 on selected 'key routes' had about a 1-to-1 impact on weekend patronage.

[60] We note that there were often different numbers of Saturdays and Sundays in a given quarter. To adjust for this, we added together average Saturday patronage in a given quarter and average Sunday patronage in a given quarter. The resulting measure can be thought of as average patronage per weekend. As would be expected, this measure roughly doubled when Sunday services were introduced.

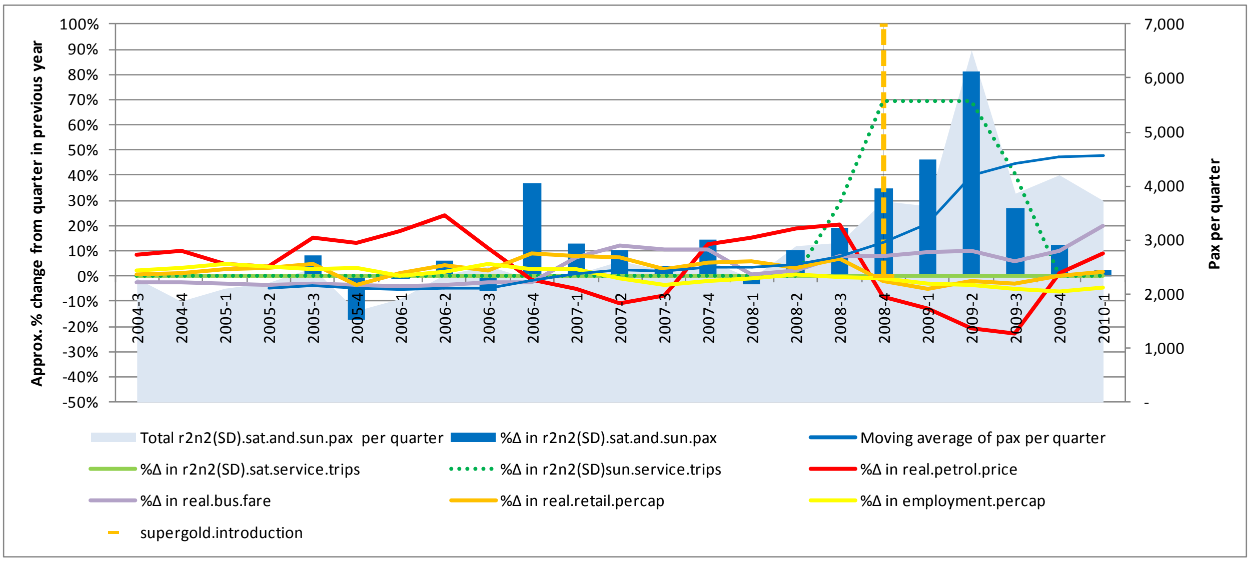
Figure F.26 Route 1 – analysis of weekend patronage growth



Key observations from graphical analysis of the Pukete (1) are:

- Additional services were added on weekends in 2007–Q1 to ensure a more regular service during the lunchtime period. There was an increase in patronage growth around this time; however, this was a relatively minor timetable change so one should be cautious about attributing causation. The introduction of the free two-hour transfer may have also played a role.
- It is clear that the April 2008 V8 races had a positive impact on weekend patronage in 2008–Q2. Weekend patronage increased by about 70%.
- It is also clear that, by comparison, the April 2009 V8 races did not generate as much weekend patronage. Weekend patronage decreased by 20% in this quarter, despite the introduction of weekend services that would otherwise have increased weekend patronage by about 50%.
- There is a clear 1-to-1 relationship between trip growth due to the introduction of Sunday services (in 2008–Q3) and patronage growth.
- The extension of weekend hours in 2009–Q1 did not have a discernible impact on patronage.

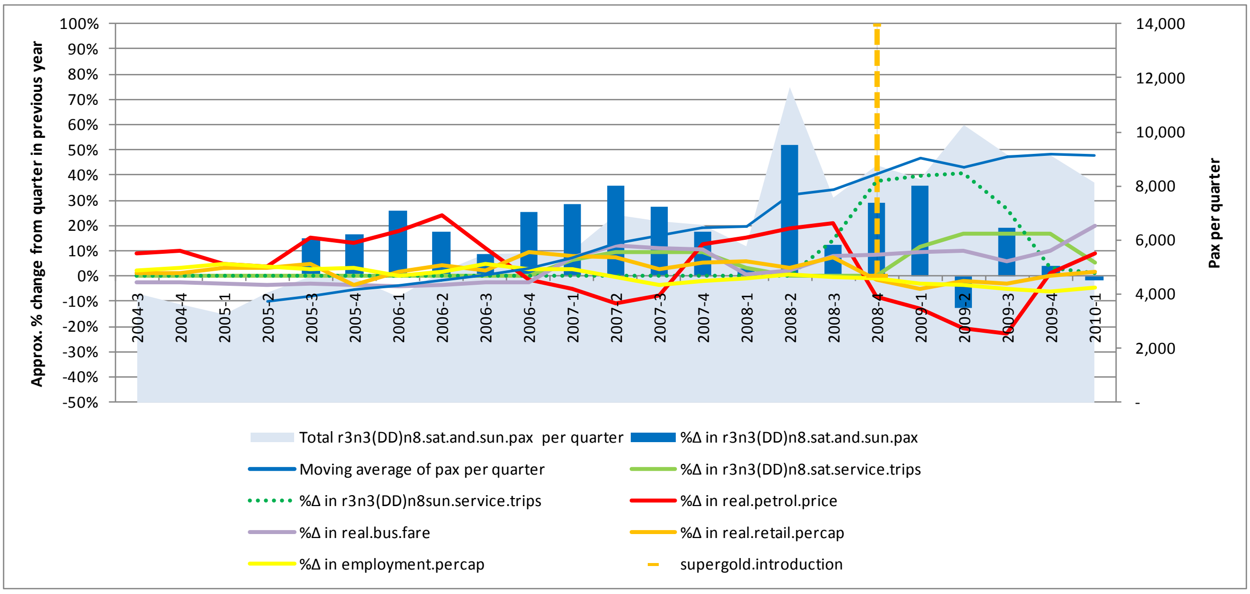
Figure F.27 Route 2 – analysis of weekend patronage growth



Key observations from the graphical analysis of the Silverdale (2) are:

- Other than the introduction of Sunday services in 2008-Q3, there were no service changes on this route during the whole period. Patronage growth was reasonably stable as well, with an unusual spike in 2006-Q4.
- Interestingly, this is the only route where the April 2008 V8 races did not appear to have an impact on patronage in 2008-Q2; however, there is evidence that the April 2009 V8 races contributed to the higher than usual spike in patronage in 2009-Q2.
- There is a clear 1-to-1 relationship between trip growth due to the introduction of Sunday services (in 2008-Q3) and patronage growth.

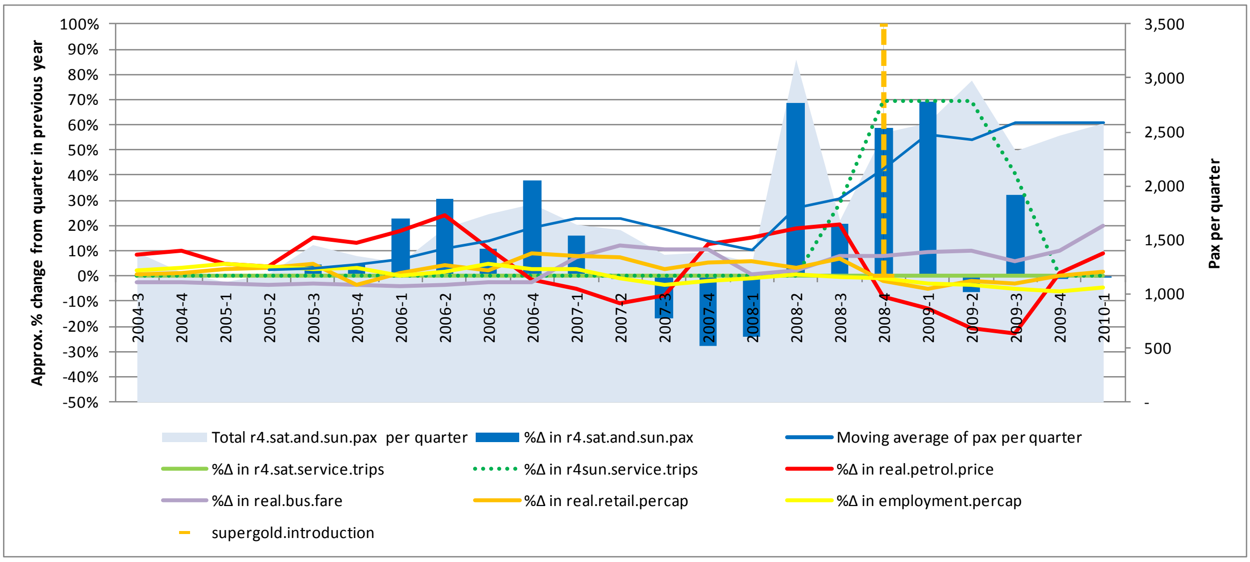
Figure F.28 Routes 3 and 8 – analysis of weekend patronage growth



Key observations from the graphical analysis of the Dinsdale (3) and the Frankton (8) are:

- Growth in patronage was quite high in the period from 2005-Q3 to 2006-Q2 and the reasons for this are not clear, although rising petrol prices may have played a role.
- There was a permanent jump in patronage by about 20% to 30% in 2006-Q4. The provision of additional services on weekends in 2007-Q1 to ensure a more regular service around lunchtime may have played a role but it is not obvious. The introduction of a free two-hour transfer may have also played a role.
- It is clear that the April 2008 V8 races had a positive impact on weekend patronage in 2008-Q2, causing it to be 70% higher than usual. However, the weekend patronage associated with the April 2009 V8 races was much lower, hence we see zero growth associated with 2009-Q2.
- There is a clear 1-to-1 relationship between trip growth due to the introduction of Sunday services (in 2008-Q3) and patronage growth.
- The extension of weekend hours in 2009-Q1 did not have a discernible impact on patronage.

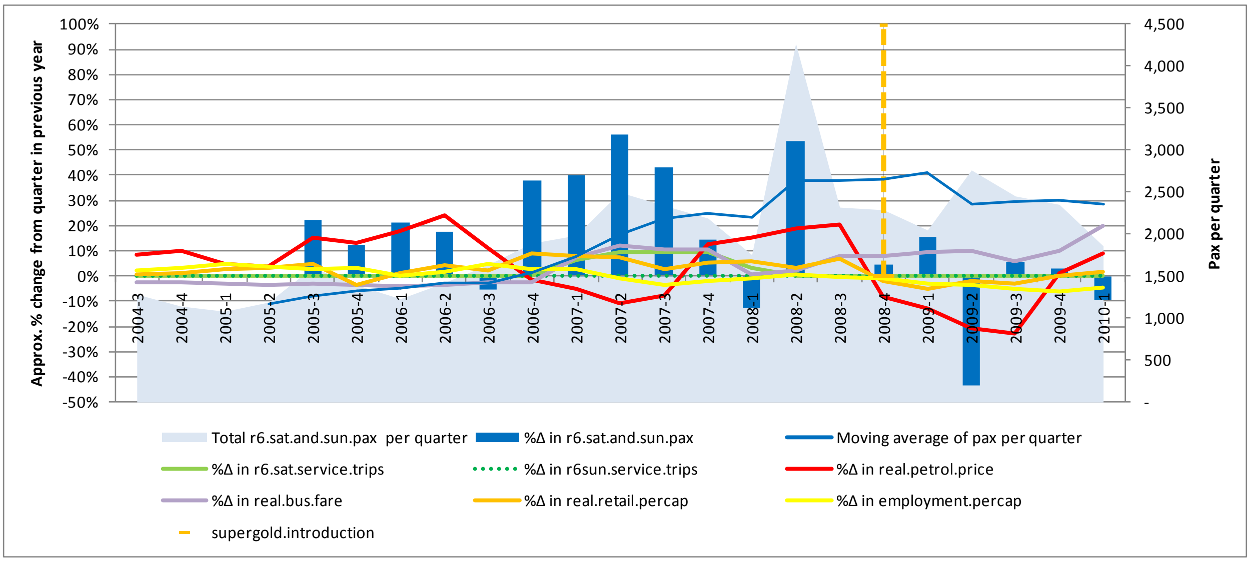
Figure F.29 Route 4 (Flagstaff) – analysis of weekend patronage growth



Key observations from the graphical analysis of the Flagstaff (4) are:

- It is clear that the April 2008 V8 races had an impact on patronage in 2008-Q2.
- There is a clear 1-to-1 relationship between trip growth due to the introduction of Sunday services (in 2008-Q3) and patronage growth.
- Unlike previous routes, there was no patronage growth spurt around the 2006-Q4/2007-Q1 mark. This could be due to the fact that this route did not benefit from service improvements to give greater frequency around lunchtime.

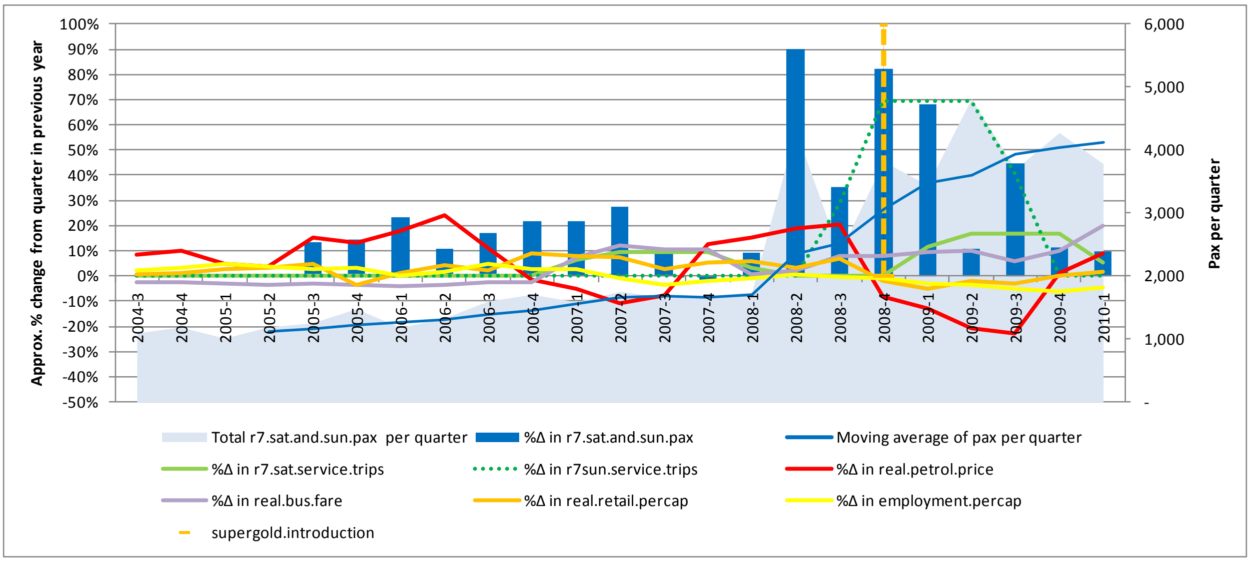
Figure F.30 Route 6 (Mahoe) – analysis of weekend patronage growth



Key observations from the graphical analysis of the Mahoe (6) are:

- There was a large jump in patronage in 2006-Q4. Patronage jumped permanently in that quarter by about 40%. The reasons for this are not clear. There were minor service additions to the Saturday timetable in 2007-Q1, to ensure there were regular services around lunchtime. An examination of historical timetables suggests no other changes. It seems, again, that the introduction of the two-hour free transfer played a role.
- It is clear that the April 2008 V8 races had an impact on weekend patronage in 2008-Q2, but it was reversed the next year because the April 2009 V8 races did not generate as much weekend patronage.

Figure F.31 Route 7 (Glenview) – analysis of weekend patronage growth

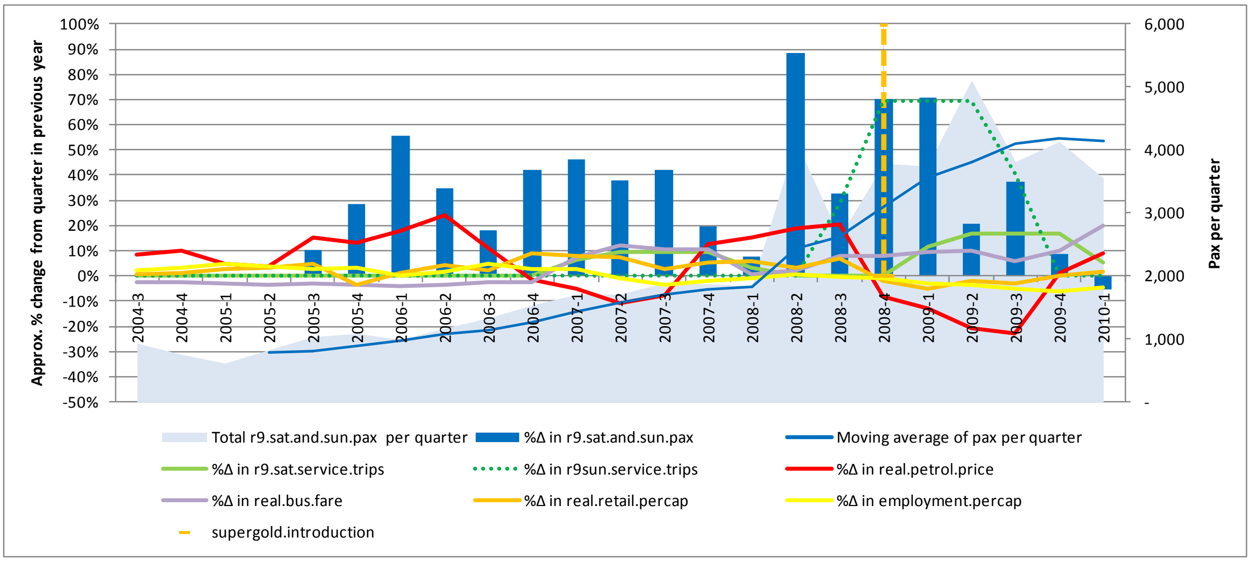


Key observations from the graphical analysis of the Glenview (7) are:

- There was a permanent jump in patronage in 2006-Q3/2006-Q4 by about 20%. Again, the reasons for this are not clear but the introduction of the free two-hour transfer may have played a role. There were minor service additions to the Saturday timetable in 2007-Q1, to ensure regular services around lunchtime. An examination of historical timetables suggests no changes other than that.

- It is clear that the April 2008 V8 races had an impact on patronage in 2008-Q2.
- There is a clear 1-to-1 relationship between trip growth due to the introduction of Sunday services (in 2008-Q3) and patronage growth.
- There was an extension of weekend services in 2009-Q1; however, that extension of hours did not appear at first glance to have had much impact on patronage growth.

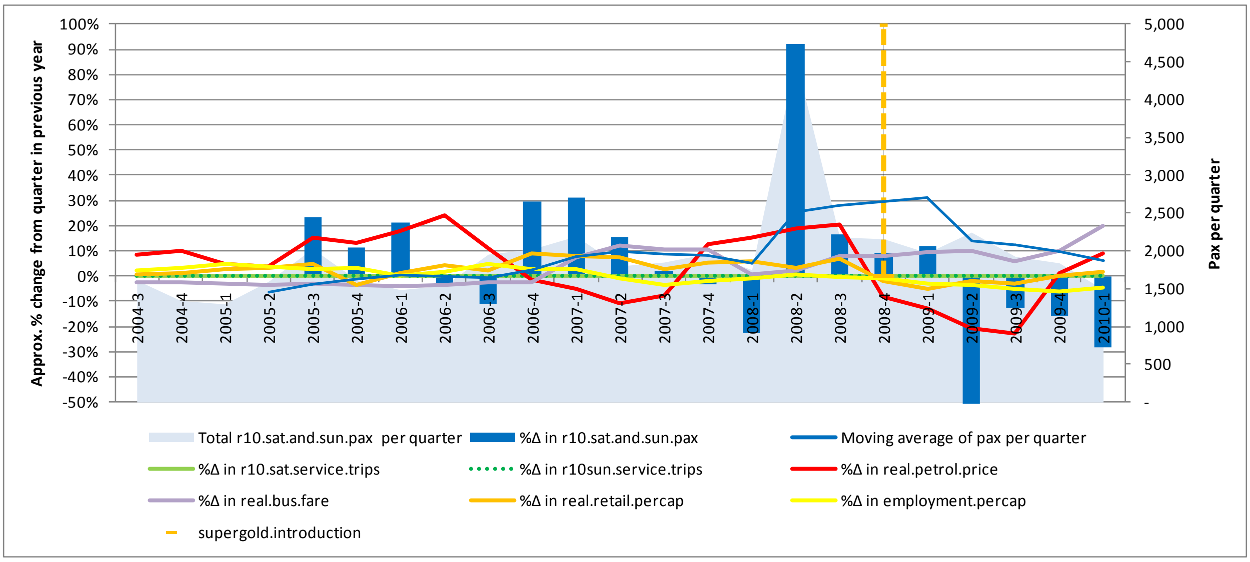
Figure F.32 Route 9 (Nawton) – analysis of weekend patronage growth



Key observations from the graphical analysis of the Nawton (9) are:

- There was a permanent jump in patronage in 2006-Q4 by about 20%. Again, the reasons for this are not clear but the introduction of the free two-hour transfer may have played a role. There were minor additions to the Saturday timetable in 2007-Q1, to ensure regular services around lunchtime. We estimate from examination of timetables that there was a doubling of weekday interpeak service frequency around 2006-Q4, and this could have had a 'flow-on' impact on *weekend* patronage.
- It is clear that the April 2008 V8 races had an impact on weekend patronage in 2008-Q2, but it was reversed (to some extent) the next year during the April 2009 V8 races.
- There is a clear 1-to-1 relationship between trip growth due to the introduction of Sunday services (in 2008-Q3) and patronage growth.
- There was an extension of weekend services in 2009-Q1; however, that extension of hours did not appear at first glance to have had much impact on patronage growth.

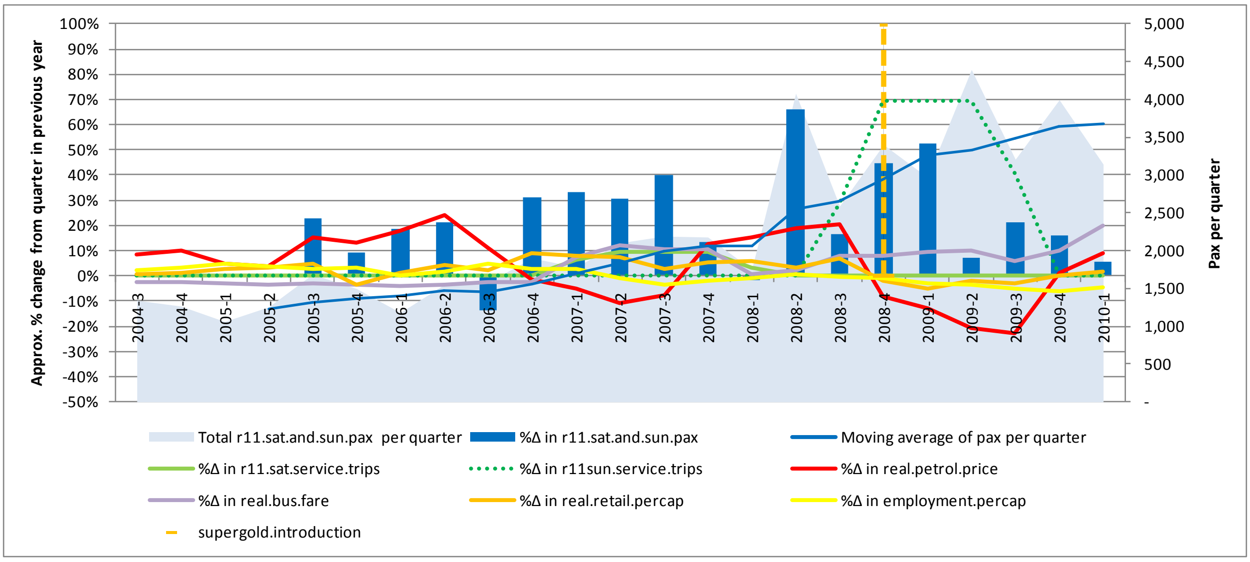
Figure F.33 Route 10 (Hilcrest) – analysis of weekend patronage growth



Key observations from the graphical analysis of the Hilcrest (10) are:

- It is clear that the April 2008 V8 races had an impact on patronage in 2008-Q2, and this was reversed the next year because the April 2009 V8 races did not generate as much weekend patronage.
- There were no service changes on this route during the whole period. Despite this, there appears to have been a growth spurt of about 30% in 2006-Q4 (although it became muted, probably by the fare increase, halfway through 2007-Q1). Again, the free two-hour transfer may have played a role.

Figure F.34 Route 11 (Fairfield) – analysis of weekend patronage growth

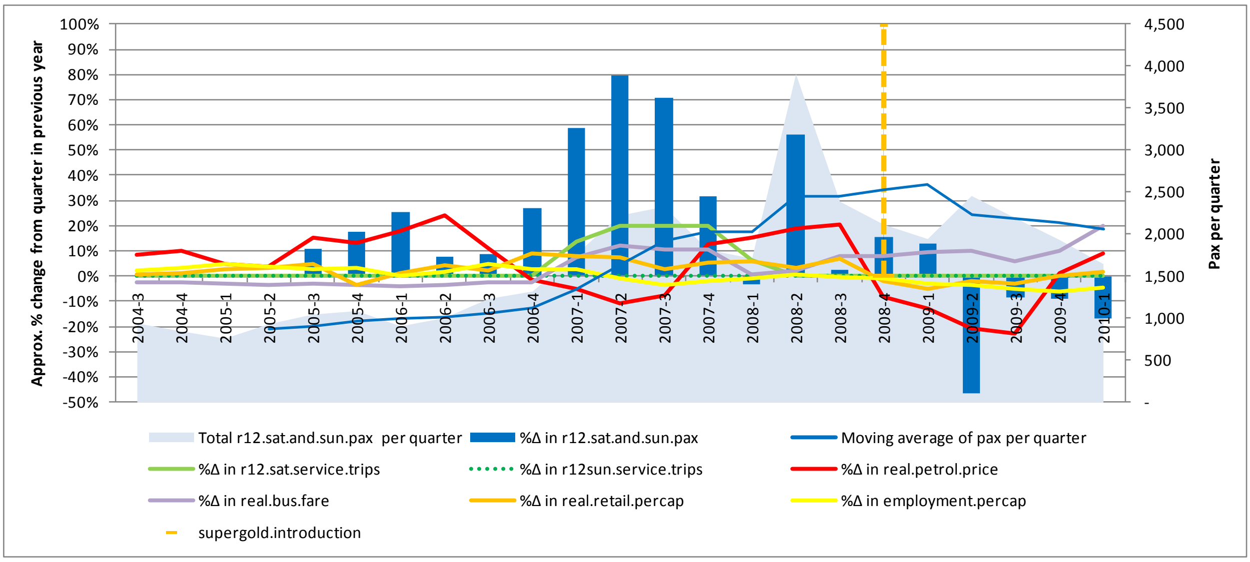


Key observations from the graphical analysis of the Fairfield (11) are:

- There was a permanent jump in patronage in 2006-Q4 by about 30%. Again, the reasons for this are not clear but the two-hour free transfer most likely contributed. There were minor additions to the Saturday timetable in 2007-Q1, to ensure regular services around lunchtime. There was an extension of weekday evening hours that could potentially have had a 'flow-on' impact on weekend patronage, but this also occurred in 2007-Q1 and hence post-dated the jump in 2006-Q4.

- It is clear that the April 2008 V8 races had an impact on patronage in 2008–Q2.
- There is a clear 1-to-1 relationship between trip growth due to the introduction of Sunday services (in 2008–Q3) and patronage growth.

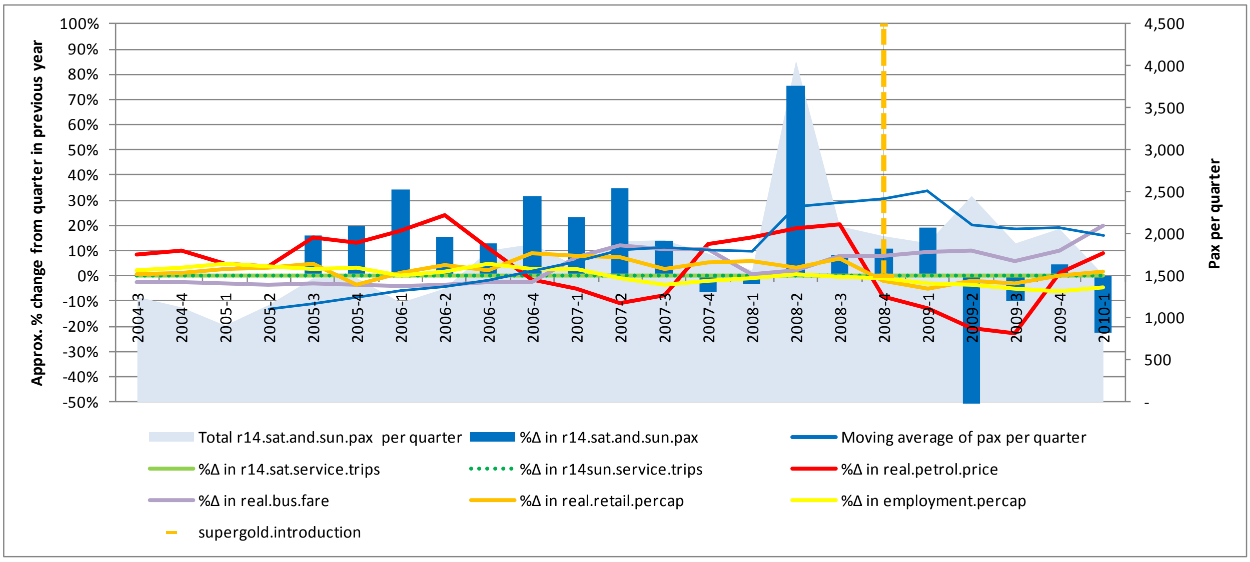
Figure F.35 Route 12 (Fitzroy) – analysis of weekend patronage growth



Key observations from the graphical analysis of the Fitzroy (12) are:

- There was a permanent jump in patronage in 2006–Q4 by about 20% and then again in 2007–Q1 by another 50%. Again, the reasons for this are not clear but the two-hour free transfer may have played a role. There were minor additions to the Saturday timetable in 2007–Q1, to ensure regular services around lunchtime. However, the main service change at this time was a doubling of weekday service frequency from half-hourly to hourly, and an extension of weekday evening services. It appears that these service changes had a 'flow-on' impact on weekend patronage.
- It is clear that the April 2008 V8 races had an impact on patronage in 2008–Q2, but this was reversed the next year because the April 2009 V8 races did not generate as much weekend patronage.

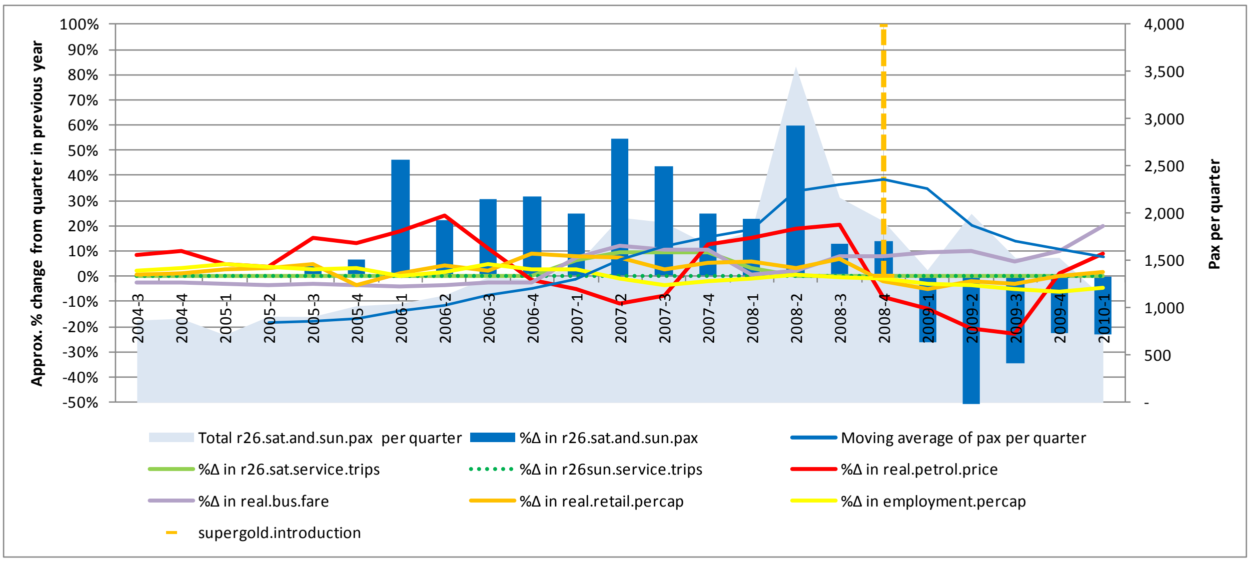
Figure F.36 Route 14 (Claudelands) – analysis of weekend patronage growth



Key observations from the graphical analysis of the Claudelands (14) are:

- It is clear that the April 2008 V8 races had an impact on patronage in 2008-Q2, but this was reversed the next year because the April 2009 V8 races did not generate as much weekend patronage.
- There were no service changes on this route during the whole period. Despite this, there appears to have been a growth spurt of about 30% in 2006-Q4, possibly caused by the free two-hour transfer.

Figure F.37 Route 26 (Bremworth) – analysis of weekend patronage growth



Key observations from the graphical analysis of the Bremworth (26) are:

- There was consistent growth in patronage from 2006-Q1 through to 2008-Q4. The reasons for this are not clear.
- There were minor additions to the Saturday timetable in 2007-Q1, to ensure regular services around lunchtime. However, a more important factor may be the significant improvement to weekday off-peak services in 2006-Q3; weekday off-peak frequency was doubled from hourly to half-hourly and evening hours were extended. This may have had a 'flow-on' impact on weekend patronage.
- It is clear that the April 2008 V8 races had an impact on patronage in 2008-Q2, but this was reversed the next year because the April 2009 V8 races did not generate as much weekend patronage.
- There were no service changes on this route during this whole period. Despite this, there appears to have been a growth spurt of about 30% in 2006-Q4.

F4 Data analysis

F4.1 Multicollinearity analysis

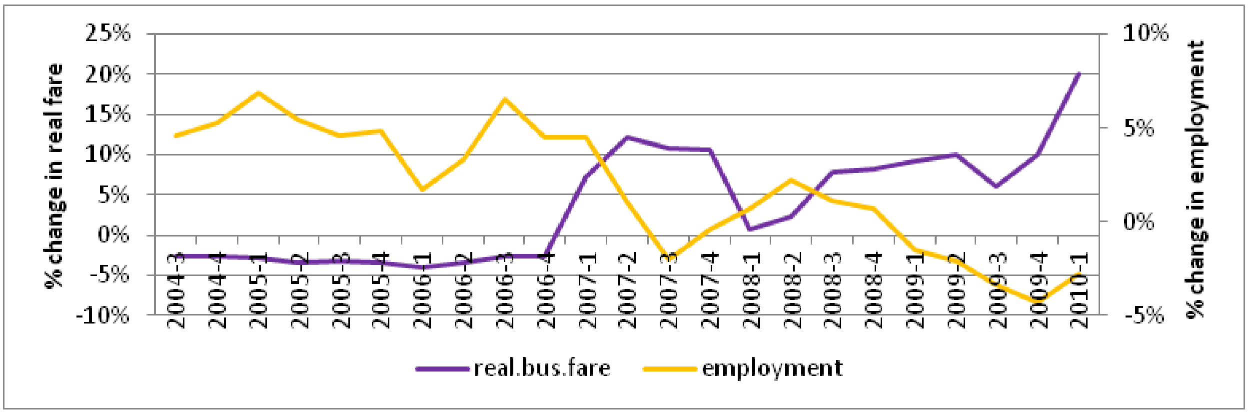
As noted in section 2.4.1 of the main report, high correlations between explanatory variables can make econometric estimation difficult. This section uses correlation tables to examine the extent to which such correlations might be problematic.

Tables F.5 to F.7 show all the correlations between explanatory variables corresponding to the period from 2005-Q2 to 2010-Q1.

The introduction of the SuperGold Card has strong correlations with various economic variables including real petrol prices (-0.7) and real retail sales (-0.7).

There is a very high negative correlation between employment and real bus fare (-0.8 peak, -0.7 offpeak/Sat and Sun). This correlation appears to be largely coincidental; all the fare increases in the history of the Hamilton bus network have occurred around the same time as a drop in employment in Hamilton city. This correlation could potentially be a problem, except the model building processes (see section F5) showed that (despite the undesirable mix of rising fares and dropping employment) neither of these factors had a discernible negative impact on patronage growth.

Figure F.38 Correlation between real bus fare and employment



The introduction of extra evening services in October 2006 correlate highly with growth in patronage on the Orbiter (+0.8 peak, +0.7 offpeak/Sat and Sun) and a generic dummy for jump in patronage in 2006–Q4 (+0.9). These correlations draw attention to the problem of identifying the cause of that jump in patronage.

Table F.5 Correlations between explanatory variables for peak patronage models

	r1n1PD.wk.peak.service.express.Jul08	r2n2SD.wk.peak.sevice.expess.Sep08	r3n3DDn8.wk.peak.service.express.Jul08	r9.wk.offpeak.double.frequency.Oct06	r12.wk.offpeak.double.frequency.Feb07	r26.wk.offpeak.double.frequency.Sep06	all.wk.offpeak.extra.evening.mon.to.wed.Oct06.Feb07	all.wk.offpeak.more.regular.Feb07	real.petrol.price	petrol.price.threshold.dummy.2dollar	real.bus.fare	real.retail	employment	wk.peak.pax.orbiter.growth	promotion.dummy.Oct06	period.2006Q4.to.2007Q3.dummy	HamiltonV8races.dummy.Apr08	HamiltonV8races.dummy.Apr09	Easter.dummy
r1n1PD.wk.peak.service.expess.Jul08	1.0																		
r2n2SD.wk.peak.sevice.expess.Sep08	0.0	1.0																	
r3n3DDn8.wk.peak.service.express.Jul08	0.0	0.0	1.0																
r9.wk.offpeak.double.frequency.Oct06	0.0	0.0	0.0	1.0															
r12.wk.offpeak.double.frequency.Feb07	0.0	0.0	0.0	0.0	1.0														
r26.wk.offpeak.double.frequency.Sep06	0.0	0.0	0.0	0.0	0.0	1.0													
all.wk.offpeak.extra.evening.mon.to.wed.Oct06.Feb07	-0.1	-0.1	-0.1	0.3	0.2	0.2	1.0												
all.wk.offpeak.more.regular.Feb07	0.0	0.0	0.0	0.3	0.0	0.0	0.4	1.0											
real.petrol.price	-0.1	-0.2	-0.1	-0.1	-0.1	-0.1	-0.3	-0.1	1.0										
petrol.price.threshold.dummy.2dollar	0.1	-0.1	0.1	0.0	0.0	0.0	0.0	0.0	0.5	1.0									
real.bus.fare	0.1	0.1	0.1	0.1	0.1	0.0	0.2	0.3	-0.5	0.0	1.0								
real.retail	-0.1	-0.2	-0.1	0.1	0.1	0.2	0.5	0.3	0.4	0.4	-0.1	1.0							
employment	-0.1	-0.2	-0.1	0.0	0.0	0.0	0.0	-0.1	0.4	0.2	-0.8	0.4	1.0						
wk.peak.pax.orbiter.growth	0.0	-0.1	0.0	0.2	0.2	0.2	0.8	0.4	-0.2	0.2	0.4	0.6	-0.1	1.0					
promotion.dummy.Oct06	0.0	0.0	0.0	0.1	-0.1	0.1	0.3	-0.3	-0.2	0.0	-0.3	0.2	0.2	0.2	1.0				
period.2006Q4.to.2007Q3.dummy	-0.1	-0.1	-0.1	0.3	0.2	0.3	0.9	0.4	-0.4	0.0	0.2	0.5	0.0	0.8	0.4	1.0			
HamiltonV8races.dummy.Apr08	-0.1	-0.1	-0.1	0.0	0.0	0.0	0.0	0.0	0.5	0.0	-0.2	0.2	0.2	0.2	0.0	0.0	1.0		
HamiltonV8races.dummy.Apr09	0.1	0.1	0.1	0.0	0.0	0.0	-0.1	-0.1	-0.4	0.0	0.2	-0.3	-0.3	-0.2	0.0	-0.1	-0.7	1.0	
Easter.dummy	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.2	0.0	-0.1	0.0	0.0	-0.5	0.4	1.0

Table F.6 Correlations between explanatory variables for offpeak patronage models

	r9.wk.offpeak.double.frequency.Oct06	r12.wk.offpeak.double.frequency.Feb07	r26.wk.offpeak.double.frequency.Sep06	all.wk.offpeak.extra.evening.mon.to.wed.Oct06.Feb07	all.wk.offpeak.more.regular.Feb07	all.wk.offpeak.mon.to.thur.extra.evening.Feb09	real.petrol.price	petrol.price.threshold.dummy.2dollar	real.bus.fare	real.retail	employment	wk.offpeak.pax.orbiter.growth	promotion.dummy.Oct06	period.2006Q4.to.2007Q3.dummy	HamiltonV8races.dummy.Apr08	supergoldcard.dummy.Oct08	HamiltonV8races.dummy.Apr09	Easter.dummy
r9.wk.offpeak.double.frequency.Oct06	1.0																	
r12.wk.offpeak.double.frequency.Feb07	0.0	1.0																
r26.wk.offpeak.double.frequency.Sep06	0.0	0.0	1.0															
all.wk.offpeak.extra.evening.mon.to.wed.Oct06.Feb07	0.3	0.2	0.2	1.0														
all.wk.offpeak.more.regular.Feb07	0.3	-0.1	-0.1	0.4	1.0													
all.wk.offpeak.mon.to.thur.extra.evening.Feb09	0.0	0.0	0.0	-0.1	-0.1	1.0												
real.petrol.price	-0.1	-0.1	-0.1	-0.3	-0.1	-0.3	1.0											
petrol.price.threshold.dummy.2dollar	0.0	0.0	0.0	0.0	0.0	-0.2	0.5	1.0										
real.bus.fare	0.0	0.1	0.0	0.2	0.3	0.2	-0.5	0.0	1.0									
real.retail	0.1	0.1	0.2	0.5	0.3	-0.3	0.4	0.4	-0.1	1.0								
employment	0.0	0.0	0.1	0.1	-0.1	-0.4	0.5	0.2	-0.7	0.4	1.0							
wk.offpeak.pax.orbiter.growth	0.2	0.1	0.2	0.7	0.3	0.0	-0.6	-0.1	0.3	0.3	0.1	1.0						
promotion.dummy.Oct06	0.1	-0.1	0.1	0.3	-0.3	0.0	-0.2	0.0	-0.3	0.2	0.3	0.3	1.0					
period.2006Q4.to.2007Q3.dummy	0.3	0.2	0.2	0.9	0.4	-0.1	-0.4	0.0	0.1	0.6	0.2	0.8	0.4	1.0				
HamiltonV8races.dummy.Apr08	0.0	0.0	0.0	0.0	0.0	-0.2	0.5	0.0	-0.2	0.2	0.2	-0.1	0.0	0.0	1.0			
supergoldcard.dummy.Oct08	-0.1	-0.1	-0.1	-0.3	-0.2	0.3	-0.7	-0.4	0.3	-0.7	-0.4	0.1	0.0	-0.3	-0.4	1.0		
HamiltonV8races.dummy.Apr09	0.0	0.0	0.0	-0.1	-0.1	0.3	-0.4	0.0	0.2	-0.3	-0.2	0.0	0.0	-0.1	-0.7	0.5	1.0	
Easter.dummy	0.0	0.0	0.0	0.0	0.1	0.0	0.0	0.0	0.0	0.2	0.0	-0.1	0.0	0.0	-0.6	0.0	0.4	1.0

Table F.7 Correlations between explanatory variables for Saturday and Sunday patronage models

	all.sun.services.1mnth	all.sun.services.2_4mnths	all.sun.services.5_12mnths	all.sun.services.13_22mnths	all.sat.sun.regular.services.Feb07	all.sat.sun.extra.morning.evening.Feb09	r9.wk.offpeak.double.frequency.Oct06	r12.wk.offpeak.double.frequency.Feb07	r26.wk.offpeak.double.frequency.Sep06	all.wk.offpeak.extra.evening.mon.to.wed.Oct06.Feb07	real.petrol.price	petrol.price.threshold.dummy.2dollar	real.bus.fare	real.retail	employment	sat.and.sun.pax.orbiter.growth	promotion.dummy.Oct06	period.2006Q4.to.2007Q3.dummy	HamiltonV8races.dummy.Apr08	supergoldcard.dummy.Oct08	HamiltonV8races.dummy.Apr09	Easter.dummy
all.sun.services.1mnth	1.0																					
all.sun.services.2_4mnths	0.0	1.0																				
all.sun.services.5_12mnths	-0.4	-0.1	1.0																			
all.sun.services.13_22mnths	0.0	0.0	-0.1	1.0																		
all.sat.sun.regular.services.Feb07	0.0	-0.1	-0.1	-0.1	1.0																	
all.sat.sun.extra.morning.evening.Feb09	-0.3	-0.1	0.5	0.3	-0.1	1.0																
r9.wk.offpeak.double.frequency.Oct06	0.0	0.0	0.0	0.0	0.2	0.0	1.0															
r12.wk.offpeak.double.frequency.Feb07	0.0	0.0	0.0	0.0	0.7	0.0	0.0	1.0														
r26.wk.offpeak.double.frequency.Sep06	0.0	0.0	0.0	0.0	0.2	0.0	0.0	0.0	1.0													
all.wk.offpeak.extra.evening.mon.to.wed.Oct06.Feb07	0.0	-0.1	-0.2	-0.1	0.5	-0.2	0.3	0.2	0.2	1.0												
real.petrol.price	0.4	-0.1	-0.5	0.0	-0.1	-0.3	-0.1	-0.1	-0.1	-0.3	1.0											
petrol.price.threshold.dummy.2dollar	0.8	0.0	-0.3	0.0	0.0	-0.2	0.0	0.0	0.0	0.0	0.5	1.0										
real.bus.fare	0.0	0.1	0.2	0.4	0.3	0.2	0.0	0.1	0.0	0.2	-0.5	0.0	1.0									
real.retail	0.3	-0.2	-0.5	-0.1	0.3	-0.3	0.1	0.1	0.2	0.5	0.4	0.4	-0.1	1.0								
employment	0.2	0.0	-0.3	-0.4	-0.1	-0.4	0.0	0.0	0.1	0.1	0.5	0.2	-0.7	0.4	1.0							
sat.and.sun.pax.orbiter.growth	-0.3	0.3	0.5	0.0	-0.1	0.3	0.0	0.0	0.0	0.0	-0.8	-0.4	0.4	-0.5	-0.4	1.0						
promotion.dummy.Oct06	0.0	0.0	0.0	0.0	-0.3	0.0	0.1	-0.1	0.1	0.3	-0.2	0.0	-0.3	0.2	0.3	0.2	1.0					
period.2006Q4.to.2007Q3.dummy	0.0	-0.1	-0.2	-0.1	0.4	-0.2	0.3	0.2	0.2	0.9	-0.4	0.0	0.1	0.6	0.2	0.1	0.4	1.0				
HamiltonV8races.dummy.Apr08	0.0	0.0	-0.3	0.0	0.0	-0.2	0.0	0.0	0.0	0.0	0.5	0.0	-0.2	0.2	0.2	-0.2	0.0	0.0	1.0			
supergoldcard.dummy.Oct08	-0.3	0.3	0.6	-0.1	-0.2	0.3	-0.1	-0.1	-0.1	-0.3	-0.7	-0.4	0.3	-0.7	-0.4	0.8	0.0	-0.3	-0.4	1.0		
HamiltonV8races.dummy.Apr09	0.0	0.0	0.4	-0.1	-0.1	0.3	0.0	0.0	0.0	-0.1	-0.4	0.0	0.2	-0.3	-0.2	0.3	0.0	-0.1	-0.7	0.5	1.0	
Easter.dummy	0.0	0.0	0.0	0.0	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.2	0.0	-0.1	0.0	0.0	-0.6	0.0	0.4	1.0

F4.2 Stationarity analysis

In section 2.4.2 of the main report we noted that the conventional approach in transport economics is to carry out econometric regressions with all the variables defined in levels. However, with this approach, there is a risk that the regressions can lead to spurious results if the variables are classed as nonstationary (ie they exhibit strong trends over time).

Our approach to mitigate this risk is to take seasonal differences and to look at growth rates in patronage and explanatory variables between one quarter and the preceding quarters. There is still some risk of nonstationarity and/or insufficient variation in the explanatory variables so we have proceeded with formal testing to further mitigate against the risk of spurious results.

Table F.8 shows testing for stationarity or nonstationarity of key explanatory variables. As expected, the tests are mostly inconclusive due to the short time period covered. However, the tests do suggest there are risks associated with including employment. These risks were taken into account in the model-building process by delaying the inclusion of employment until late in the process and then examining its impact on the coefficients. We found that it generally only had a minor impact on coefficients

Table F.8 Stationarity of continuous explanatory variables

		Augmented Dickey Fuller Test for stationarity[a]			KPSS test for nonstationarity[a]			
		Null hypothesis: variable is nonstationary			Null hypothesis: variable is stationary			
Variable[b]	**Period**	**Critical Value**	**p-value**	**Decision**	**Critical value**	**p-value**	**Decision**	**Conclusion**
%Δ in real petrol prices	2003-Q4 to 2010-Q1	-3.06	0.17	Do not reject null → series is nonstationary	0.123	>0.10	Do not reject null → series is stationary	Inconclusive
%Δ in real retail sales	2003-Q4 to 2010-Q1	-1.85	0.63	Do not reject null → series is nonstationary	0.333	>0.10	Do not reject null → series is stationary	Inconclusive
%Δ in employment	2003-Q4 to 2010-Q1	-3.40	0.08	Reject null → series is stationary	0.580	0.02	Reject null → series is nonstationary	Inconclusive but suspicious

[a] The ADF test incorporated 4 lags and the KPSS test employed long version of the truncation lag parameter, which had 3 lags.

[b] Service variables and real fare were excluded from the analysis because they representation 'one-off' structural changes that cannot plausibly be regarded as stationary, regardless of the results of empirical testing.

Tables A.3 to A.5 show testing for stationarity or nonstationarity of dependent variables. Again, the tests are inconclusive for most of the variables. But the tests did suggest risks associated with route 14.

Table F.9 Stationarity of dependent variable (peak patronage)

			Augmented Dickey Fuller Test for stationarity[(a)]			KPSS test for nonstationarity[(a)]			
			Null hypothesis: variable is nonstationary			Null hypothesis: variable is stationary			
Variable	**Route group**	**Period**	**t-statistic**	**p-value**	**Decision**	**t-statistic**	**p-value**	**Decision**	**Conclusion**
%Δ in peak patronage	1+1(PD)	2003-Q4 to 2010-Q2	-2.42	0.41	Do not reject null → series is nonstationary	0.11	>0.10	Do not reject null → series is stationary	Inconclusive
%Δ in peak patronage	2+2(SD)	2003-Q4 to 2010-Q2	-2.22	0.49	Do not reject null → series is nonstationary	0.19	>0.10	Do not reject null → series is stationary	Inconclusive
%Δ in peak patronage	3+3(DD)+8	2003-Q4 to 2010-Q2	-2.86	0.24	Do not reject null → series is nonstationary	0.19	>0.10	Do not reject null → series is stationary	Inconclusive
%Δ in peak patronage	4	2003-Q4 to 2010-Q2	-2.88	0.24	Do not reject null → series is nonstationary	0.17	>0.10	Do not reject null → series is stationary	Inconclusive
%Δ in peak patronage	6	2003-Q4 to 2010-Q2	-2.85	0.25	Do not reject null → series is nonstationary	0.11	>0.10	Do not reject null → series is stationary	Inconclusive
%Δ in peak patronage	7	2003-Q4 to 2010-Q2	-2.95	0.21	Do not reject null → series is nonstationary	0.14	>0.10	Do not reject null → series is stationary	Inconclusive
%Δ in peak patronage	9	2003-Q4 to 2010-Q2	-1.34	0.82	Do not reject null → series is nonstationary	0.14	>0.10	Do not reject null → series is stationary	Inconclusive
%Δ in peak patronage	10	2003-Q4 to 2010-Q2	-2.72	0.30	Do not reject null → series is nonstationary	0.12	>0.10	Do not reject null → series is stationary	Inconclusive
%Δ in peak patronage	11	2003-Q4 to 2010-Q2	-2.44	0.40	Do not reject null → series is nonstationary	0.35	>0.10	Do not reject null → series is stationary	Inconclusive
%Δ in peak patronage	12	2003-Q4 to 2010-Q2	-3.06	0.17	Do not reject null → series is nonstationary	0.17	>0.10	Do not reject null → series is stationary	Inconclusive
%Δ in peak patronage	14	2003-Q4 to 2010-Q2	-2.55	0.36	Do not reject null → series is nonstationary	0.44	0.06	Reject null → series is nonstationary	Nonstationary
%Δ in peak patronage	26	2003-Q4 to 2010-Q2	-3.12	0.14	Do not reject null → series is nonstationary	0.22	>0.10	Do not reject null → series is stationary	Inconclusive

[(a)] The ADF test incorporated 4 lags and the KPSS test employed long version of the truncation lag parameter, which had 3 lags.

Table F.10 Stationarity of dependent variable (offpeak patronage)

			Augmented Dickey Fuller Test for stationarity[a]			KPSS test for nonstationarity[a]			
			Null hypothesis: variable is nonstationary			Null hypothesis: variable is stationary			
Variable	**Route group**	**Period**	**t-statistic**	**p-value**	**Decision**	**t-statistic**	**p-value**	**Decision**	**Conclusion**
%Δ in off-peak patronage	1+1(PD)	2004-Q4 to 2010-Q2	-1.68	0.70	Do not reject null → series is nonstationary	0.24	>0.10	Do not reject null → series is stationary	Inconclusive
%Δ in off-peak patronage	2+2(SD)	2004-Q4 to 2010-Q2	-2.58	0.35	Do not reject null → series is nonstationary	0.09	>0.10	Do not reject null → series is stationary	Inconclusive
%Δ in off-peak patronage	3+3(DD)+8	2004-Q4 to 2010-Q2	-1.93	0.60	Do not reject null → series is nonstationary	0.17	>0.10	Do not reject null → series is stationary	Inconclusive
%Δ in off-peak patronage	4	2004-Q4 to 2010-Q2	-2.04	0.56	Do not reject null → series is nonstationary	0.11	>0.10	Do not reject null → series is stationary	Inconclusive
%Δ in off-peak patronage	6	2004-Q4 to 2010-Q2	-2.21	0.49	Do not reject null → series is nonstationary	0.17	>0.10	Do not reject null → series is stationary	Inconclusive
%Δ in off-peak patronage	7	2004-Q4 to 2010-Q2	-2.54	0.37	Do not reject null → series is nonstationary	0.31	>0.10	Do not reject null → series is stationary	Inconclusive
%Δ in off-peak patronage	9	2004-Q4 to 2010-Q2	-1.60	0.73	Do not reject null → series is nonstationary	0.15	>0.10	Do not reject null → series is stationary	Inconclusive
%Δ in off-peak patronage	10	2004-Q4 to 2010-Q2	-2.55	0.36	Do not reject null → series is nonstationary	0.14	>0.10	Do not reject null → series is stationary	Inconclusive
%Δ in off-peak patronage	11	2004-Q4 to 2010-Q2	-1.31	0.84	Do not reject null → series is nonstationary	0.21	>0.10	Do not reject null → series is stationary	Inconclusive
%Δ in off-peak patronage	12	2004-Q4 to 2010-Q2	-1.85	0.63	Do not reject null → series is nonstationary	0.12	>0.10	Do not reject null → series is stationary	Inconclusive
%Δ in off-peak patronage	14	2004-Q4 to 2010-Q2	-1.88	0.62	Do not reject null → series is nonstationary	0.24	>0.10	Do not reject null → series is stationary	Inconclusive
%Δ in off-peak patronage	26	2004-Q4 to 2010-Q2	-1.86	0.63	Do not reject null → series is nonstationary	0.15	>0.10	Do not reject null → series is stationary	Inconclusive

[a] The ADF test incorporated 4 lags and the KPSS test employed long version of the truncation lag parameter, which had 3 lags.

Table F.11 Stationarity of dependent variable (Saturday and Sunday patronage)

			Augmented Dickey Fuller Test for stationarity[(a)]			KPSS test for nonstationarity[(a)]			
			Null hypothesis: variable is nonstationary			Null hypothesis: variable is stationary			
Variable	**Route group**	**Period**	**t-statistic**	**p-value**	**Decision**	**t-statistic**	**p-value**	**Decision**	**Conclusion**
%Δ in sat + sun patronage	1+1(PD)	2004-Q4 to 2010-Q2	-1.82	0.64	Do not reject null → series is nonstationary	0.13	>0.10	Do not reject null → series is stationary	Inconclusive
%Δ in sat + sun patronage	2+2(SD)	2004-Q4 to 2010-Q2	-1.97	0.58	Do not reject null → series is nonstationary	0.23	>0.10	Do not reject null → series is stationary	Inconclusive
%Δ in sat + sun patronage	3+3(DD)+8	2004-Q4 to 2010-Q2	-1.79	0.65	Do not reject null → series is nonstationary	0.16	>0.10	Do not reject null → series is stationary	Inconclusive
%Δ in sat + sun patronage	4	2004-Q4 to 2010-Q2	-2.15	0.52	Do not reject null → series is nonstationary	0.12	>0.10	Do not reject null → series is stationary	Inconclusive
%Δ in sat + sun patronage	6	2004-Q4 to 2010-Q2	-2.37	0.43	Do not reject null → series is nonstationary	0.15	>0.10	Do not reject null → series is stationary	Inconclusive
%Δ in sat + sun patronage	7	2004-Q4 to 2010-Q2	-1.75	0.67	Do not reject null → series is nonstationary	0.15	>0.10	Do not reject null → series is stationary	Inconclusive
%Δ in sat + sun patronage	9	2004-Q4 to 2010-Q2	-1.77	0.66	Do not reject null → series is nonstationary	0.16	>0.10	Do not reject null → series is stationary	Inconclusive
%Δ in sat + sun patronage	10	2004-Q4 to 2010-Q2	-2.89	0.23	Do not reject null → series is nonstationary	0.09	>0.10	Do not reject null → series is stationary	Inconclusive
%Δ in sat + sun patronage	11	2004-Q4 to 2010-Q2	-2.03	0.56	Do not reject null → series is nonstationary	0.21	>0.10	Do not reject null → series is stationary	Inconclusive
%Δ in sat + sun patronage	12	2004-Q4 to 2010-Q2	-1.78	0.66	Do not reject null → series is nonstationary	0.12	>0.10	Do not reject null → series is stationary	Inconclusive
%Δ in sat + sun patronage	14	2004-Q4 to 2010-Q2	-3.02	0.18	Do not reject null → series is nonstationary	0.13	>0.10	Do not reject null → series is stationary	Inconclusive
%Δ in sat + sun patronage	26	2004-Q4 to 2010-Q2	-2.07	0.55	Do not reject null → series is nonstationary	0.20	>0.10	Do not reject null → series is stationary	Inconclusive

[(a)] The ADF test incorporated 4 lags and the KPSS test employed long version of the truncation lag parameter, which had 3 lags.

F4.3 Endogeneity issues

In section 2.4.3 we note that endogeneity or 'reverse causation' is another statistical issue that needs to be given careful consideration. In particular, the econometric models adopted in this research project assume that patronage growth is 'caused' by service improvements. However, it is conceivable that transport operators improve service levels as a means of coping with patronage demand.

In regard to analysis of the Hamilton city bus route groups, we regard the risk of endogeneity as low.

- As section 2.4.3 notes, the employment of data at the route group level minimises the risk of endogeneity because service improvements show up as 'lumpy' at a route group level and their impact on patronage generally shows up as a clear 'jump' in patronage growth. There were a variety of service changes introduced within Hamilton city. Furthermore, these service changes were usually implemented on a selection of route groups or were staggered in implementation (see table F.3); this creates a contrast between route groups that are improved and 'control' route groups and makes it easier for us to isolate the impact of the service improvement.
- The seasonal difference approach, in conjunction with the employment of data at the corridor level, also avoids the endogeneity problems associated with nonstationary data. A route group may exhibit an unusually high time trend for patronage growth and this may prompt the Waikato Regional Council to increase services for that route group; however, the subsequent patronage growth will only be attributed to the increased services if that leads to patronage growth that is higher than the time trend.

F5 Model building process

F5.1 Development of the model for peak weekday patronage

The model building process for the peak weekday patronage model began with building an initial model that encompassed a broad collection of explanatory variables and key factors. This initial model included:

- time trends for each route group
- variables relating to service improvements
- various dummy variables for events (Hamilton 2008 V8 races)
- various 'standard' explanatory variables (petrol price, Easter, real retail sales and employment).

Table F.7 shows how the initial model was revised to produce the preferred model for average peak weekday patronage.

The first step was to investigate 'network effects'; we added offpeak service variables in model 2 and then investigated whether they contributed to the overall model. These offpeak service variables produced plausible signs so they were retained. However, model 2 had a few service variables with incorrect signs so these were removed, leading to model 3.

The next step was to investigate alternative explanations for the 'jump' in patronage in 2006–Q4. Section F3.1 notes that this jump can be attributed to a range of factors. Therefore, we added the 'generic dummy for temporary growth in 2006–Q4' to reflect the temporary effect of the free ticket promotion and we added the 'generic dummy for permanent growth spurt in 2006–Q4' to reflect the permanent effects of both the free ticket promotion and the introduction of a free two-hour transfer. (A dummy variable for the 2009 V8 rRaces was also added.) The resulting model was model 4.

The estimate for the 'generic dummy for permanent growth' in model 4 had an incorrect sign so it was removed along with bus fare, leading to model 5; the implication of this is that there was no permanent 'jump' in patronage that had not been explained by other factors.

The next step was to use model 6 to explore the impact of adding employment to the model.

In the final step, we modified model 6 by omitting route 14, hence producing model 7, the preferred model. Route 14 was omitted due to the problems identified in diagnostic analysis (see section F6.1).

Table F.12 Development of the peak-time patronage model

Time trends and explanatory variables	Initial model	Model 2	Model 3	Model 4	Model 5	Model 6	Model 7 (preferred)
Time trend – route 1+PD	1%	0%	0%	-2%	-2%	-2%	-3%
Time trend – route 2+SD	4%	4%	4%*	4%'	4%	4%	3%
Time trend – routes 3+DD+8	5%	5%	6%***	4%'	3%	3%	3%'
Time trend – route 4	6%*	6%*	5%***	4%**	6%*	6%*	4%**
Time trend – route 6	4%	4%	4%**	2%	2%	2%	1%
Time trend – route 7	5%'	6%*	6%***	3%*	4%	4%	3%*
Time trend – route 9	8%*	9%**	9%***	7%***	7%*	7%*	6%***
Time trend – route 10	2%	1%	2%	1%	1%	1%	1%
Time trend – route 11	7%**	6%*	6%***	4%**	5%'	5%'	4%**
Time trend – route 12	8%**	8%**	7%***	5%*	6%'	6%'	4%*
Time trend – route 14	5%'	4%	5%**	4%**	4%	4%	Omitted
Time trend – route 26	6%*	4%	5%*	4%'	4%	4%	3%*
Intro. of Pukete Direct (Jul 08)	0.45***	0.49***	0.37***	0.38***	0.53***	0.53***	0.43***
Intro. of Silverdale Direct (Sep 08)	0.46**	0.46**	0.38**	0.35**	0.44**	0.45**	0.40**
Intro. of Dinsdale Direct (Jul 08)	-0.07	0.00	Zero coefficient				
Extra peak morning services (Oct 06, Feb 09)	0.78 '	-0.16	Implausible sign				
Doubling of frequency on route 9 (Oct 06)		0.19	0.08	0.04	0.13	0.13	0.03
Doubling of frequency on route 12 (Feb 07)		0.00	0.02	0.12	0.16	0.16	0.13
Doubling of frequency on route 26 (Sep 06)		0.37'	0.40**	0.43**	0.32*	0.32*	0.40**
Extension of evening hours on Wed (Oct 06, Feb 07)		0.62'	0.48	0.40	0.09	0.08	-0.03
More regular hours lunchtime and evening (Feb 07)		0.08	0.30	0.83*	0.78*	0.78*	0.83*
Real bus fare elasticity	-0.08	-0.02	-0.08	0.05	Implausible sign		
Real petrol price cross-elasticity	-0.06	0.10	0.08	0.14	0.21*	0.21'	0.20'
$2.00 petrol price threshold dummy (2008 Q3)	14%***	11%***	11%***	7%*	7%*	7%*	6%'
Real retail sales	0.18	-0.14	-0.17	0.11	-0.04	-0.04	0.03
2008 HamiltonV8 races dummy (Apr	14%***	12%***	11%***	9%**	9%**	9%**	8%*

Time trends and explanatory variables	Initial model	Model 2	Model 3	Model 4	Model 5	Model 6	Model 7 (preferred)
08)							
Easter dummy	-3%**	-3%**	-3%**	-4%***	-4%***	-4***	-4%***
Generic dummy for temporary growth in 2006 Q4				10%**	9%***	9%***	9%***
Generic dummy for permanent growth spurt in 2006 Q4				-6%	Implausible sign		
Hamilton 2009 V8 races				1%	2%	2%	2%
Employment						0.02	0.17

Note for symbols of statistical significance: *** → 0.1%, ** → 1%, * → 5%, ‘ →10%

F5.2 Development of the model for offpeak weekday patronage

The model building process for the offpeak weekday patronage model was similar to that presented in section F5.1. We began with building an initial model that encompassed a broad collection of explanatory variables and key factors.

Table F.8 shows how the preferred model for offpeak weekday patronage was identified. An examination of the general model showed that the further extension of evening hours, real petrol prices and SuperGold[61] all had incorrect signs. These variables were removed producing model 2. In the next iteration, real bus fare was removed, producing model 3.

The next stage of the analysis replicated attempts in section F5.1 to explain the ‘jump’ in patronage in 2006–Q4. We added the ‘generic dummy for temporary growth in 2006–Q4’ to reflect the temporary effect of the free ticket promotion and we added the ‘generic dummy for permanent growth spurt in 2006–Q4’ to reflect the permanent effects of both the free ticket promotion and the introduction of a free two-hour transfer. (Again, a dummy variable for the 2009 V8 races was also added.) These additions produced model 4.

We found that the free ticket promotion had no discernible temporary effect. However, there is evidence that the free two-hour transfer (and perhaps the free ticket promotion) may have had a permanent impact on offpeak patronage, increasing total offpeak patronage by about 6%.

During the next stage of analysis, we tested the impact of employment using model 5. However, diagnostic analysis showed problems with route 4 and route 6 so these were removed from model 5, leading to model 6, the preferred model.

[61] Based on our examination of the data provided, we concluded that the route-level patronage data excluded SuperGold patronage. Therefore, one would expect that the introduction of the SuperGold Card should have a *negative* impact on route-level patronage, not a positive impact.

Table F.13 Development of the offpeak patronage model

Time trends and explanatory variables	Initial model	Model 2	Model 3	Model 4	Model 5	Model 6 (preferred)
Time trend – route 1+PD	4%*	3%‘	3%*	3%‘	3%‘	3%‘
Time trend – route 2+SD	6%**	7%***	8%***	7%***	7%***	6%***
Time trend – routes 3+DD+8	11%***	9%***	9%***	8%***	8%***	8%***
Time trend – route 4	6%**	7%***	8%***	7%***	8%***	Omitted
Time trend – route 6	11%***	12%***	12%***	12%***	12%***	Omitted
Time trend – route 7	10%***	9%***	9%***	9%***	9%***	9%***
Time trend – route 9	19%***	16%***	17%***	16%***	16%***	17%***
Time trend – route 10	5%*	6%***	6%***	6%***	6%***	5%***
Time trend – route 11	8%***	9%***	9%***	9%***	9%***	9%***
Time trend – route 12	5%**	7%***	8%***	7%***	7%***	7%***
Time trend – route 14	7%***	8%***	9%***	8%***	9%***	7%***
Time trend – route 26	8%***	10%***	10%***	10%***	10%***	10%***
Doubling of frequency on route 9 (Oct 06)	0.17	0.26*	0.25*	0.24*	0.24*	0.22‘
Doubling of frequency on route 12 (Feb 07)	0.65***	0.63***	0.64***	0.66***	0.67***	0.60***
Doubling of frequency on route 26 (Sep 06)	0.87***	0.85***	0.84***	0.82***	0.82***	0.76***
Extension of evening hours Mon–Wed (Oct 06, Feb 07)	1.26***	1.41***	1.40***	0.83*	0.81‘	0.82‘
More regular hours lunchtime and evening (Feb 07)	0.59*	0.84**	0.86***	0.89**	0.90**	0.60‘
Further extension of evening hours Mon–Thur (Feb 09)	-1.03***	Implausible sign				
Real bus fare elasticity	-0.22*	0.03	Implausible sign			
Real petrol price cross-elasticity	-0.26*	Implausible sign				
$2.00 petrol price threshold dummy (2008–Q3)	17%***	8%***	8%***	7%***	7%***	8%***
Real retail sales	-0.37‘	-0.81***	-0.83***	-0.83***	-0.86***	-0.86***
2008 HamiltonV8 races dummy (Apr 08)	20%***	14%***	14%***	14%***	14%***	15%***
Introduction of SuperGold Card (Oct 08)	9%**	Implausible sign				
Easter dummy	-1%	-1%	-1%	-1%	-1%	-1%
Generic dummy for temporary growth in 2006 Q4				0%	0%	-4%
Generic dummy for permanent growth spurt in 2006 Q4				6%	6%	9%*
Hamilton 2009 V8 races				2%	2%	1%
Employment					0.11	0.24

Note for symbols of statistical significance: *** → 0.1%, ** → 1%, * → 5%, ‘ →10%

F5.3 Development of the model for weekend patronage

The model building process for the weekend patronage model was similar to that presented in section F5.1. We began with building a general model that encompassed a broad collection of explanatory variables and key factors.

Table F.9 shows how the preferred model for weekend patronage was identified. The general model was fitted first and produced generally plausible estimates.

The next stage of the analysis replicated attempts in section F5.1 to explain the 'jump' in patronage in 2006–Q4. We added the 'generic dummy for temporary growth in 2006–Q4' to reflect the temporary effect of the free ticket promotion and we added the 'generic dummy for permanent growth spurt in 2006–Q4' to reflect the permanent effects of both the free ticket promotion and the introduction of a free two-hour transfer. (Again, a dummy variable for the 2009 V8rRaces was also added.) These additions produced model 4.

The generic dummy for temporary growth in 2006–Q4 in model 4 had an incorrect sign so it was dropped, hence producing model 5. A few routes with statistical problems were then removed from model 5, hence producing the preferred model.

In model 6 we added employment to the model. However, diagnostic analysis (see section F6.3) indicated that routes 4 and 12 had problems relating to the residuals so those routes were removed, leading to model 7, the preferred model.

Table F.14 Development of the weekend patronage model

Time trends and explanatory variables	Initial model	Model 2	Model 3	Model 4	Model 5	Model 6	Model 7 (preferred)
Time trend – route 1	2%	-2%	-3%	-5%‘	-6%*	-7%*	-8%*
Time trend – route 2	5%	0%	0%	-2%	-2%	-3%	-4%
Time trend – routes 3 and 8	12%**	9%*	8%**	5%	4%	3%	2%
Time trend – route 4	5%	0%	0%	-2%	-2%	-3%	Omitted
Time trend – route 6	21%***	15%***	15%***	14%***	13%***	12%***	12%***
Time trend – route 7	13%***	9%*	8%**	7%*	5%*	4%	4%
Time trend – route 9	21%***	15%***	14%***	12%***	11%***	10%**	9%*
Time trend – route 10	12%***	6%‘	6%**	4%*	4%‘	3%	3%
Time trend – route 11	7%*	3%	4%	2%	1%	0%	-1%
Time trend – route 12	14%***	9%*	9%**	8%*	6%*	5%‘	Omitted
Time trend – route 14	18%***	12%***	13%***	11%***	11%***	10%***	9%**
Time trend – route 26	15%***	5%	5%‘	4%‘	3%	3%	2%
Provision of more regular lunch hours on Saturday (Sat, Feb 07)	2.40***	1.87***	1.93***	1.73**	2.22***	2.23***	2.18***
Introduction of Sunday services (Sep 08)							
– impact during first month	0.71**	0.64**	0.67**	0.73**	0.72**	0.73**	0.81**
– impact after 2-4 months	0.81***	0.76***	0.78***	0.92***	0.93***	0.94***	0.97***
– impact after 5-12 months	1.05***	1.00***	0.99***	0.94***	0.93***	0.95***	0.95***
– impact after subsequent year	0.29***	0.27***	0.23***	0.32***	0.30***	0.31***	0.30***
Extension of hours (Sat, Sun, Feb 09)	-0.46	-0.39	Implausible sign				
Doubling of offpeak weekday frequency on route 9 (weekday, Oct 06)		0.19	0.23	0.25	0.20	0.21	0.20
Doubling of offpeak weekday frequency on route 12 (weekday, Feb 07)		0.11	0.09	0.15	0.07	0.06	

Time trends and explanatory variables	Initial model	Model 2	Model 3	Model 4	Model 5	Model 6	Model 7 (preferred)
Doubling of offpeak weekday frequency on route 26 (weekday, Sep 06)		0.46**	0.45**	0.39*	0.36*	0.34*	0.34‘
Extension of evening hours Mon–Wed (Oct 06, Feb 07)		1.49*	1.56***	-0.41	Implausible sign		
Real bus fare elasticity	-1.52***	-1.32***	-1.22***	-1.44***	-1.34***	-1.15***	-1.20***
Real petrol price cross-elasticity	-0.58***	-0.09	Implausible sign				
$2.00 petrol price threshold dummy (2008-Q3)	13%*	12%*	9%‘	4%	3%	2%	2%
Real retail sales	1.34***	0.75‘	0.61	0.49	0.70‘	0.64‘	0.80‘
Introduction of SuperGold Card (Oct 08)	-9%‘	2%	Implausible sign				
2008 HamiltonV8 races dummy (Apr 08)	57%***	55%***	53%***	65%***	64%***	63%***	65%***
Easter dummy	-5%*	-5%*	-5%*	-5%*	-5%*	-5%**	-5%*
Generic dummy for temporary growth in 2006–Q4				-8%‘	Implausible sign		
Generic dummy for permanent growth spurt in 2006–Q4				25%***	16% **	16%***	16%***
Hamilton 2009 V8 races				27%***	26%***	25%***	28%***
Employment – Hamilton city						0.53	0.36

Note for symbols of statistical significance: *** → 0.1%, ** → 1%, * → 5%, ‘ →10%

F6 Diagnostic analysis

F6.1 Diagnostic analysis for the peak-time patronage model

The figures below show diagnostic plots for the residuals from model 6 in table F.12.

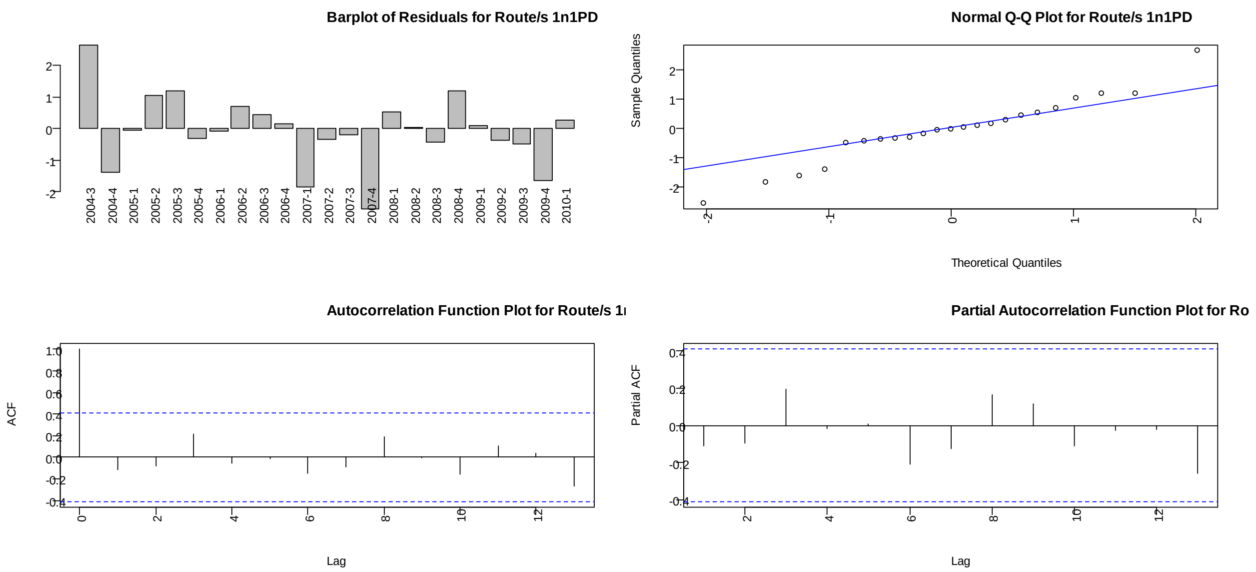
The diagnostic plots show that the residuals for most route groups are consistent with the key assumption of normality.

Autocorrelation is generally mild on most of the routes observed. The two most problematic routes are routes 14 and 26:

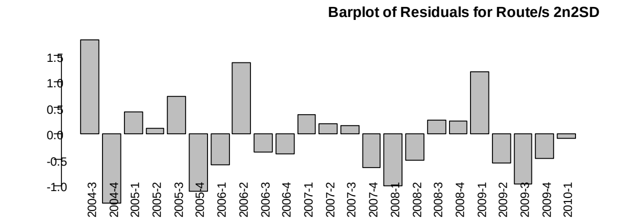
- Route 14 showed evidence of a ‘structural break’ around 2007-Q1. Prior to this date, most of the residuals were negative but from this point onwards they were mostly positive. This suggests that the model omitted some factor that contributed to higher expected peak-time growth on this route.
- Route 26 showed evidence of clustering behaviour. There was a cluster of positive residuals in 2005 to 2006 and a cluster of negative residuals from 2009 onwards. This suggests that the model omitted some important factors on this route.

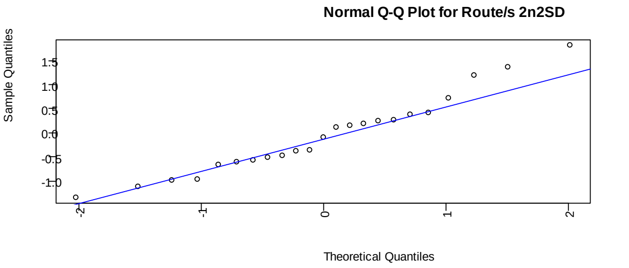
We decided in favour of removing route 14 from the preferred model due to the seriousness of the ‘structural break’.[62]

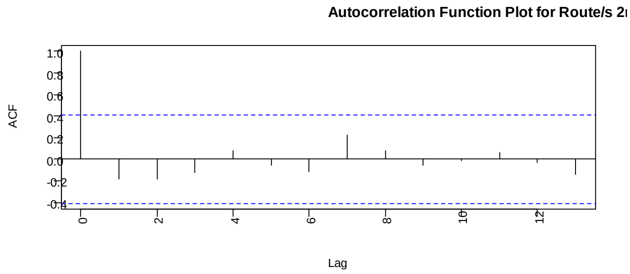
We also contemplated removal of route 26 but decided against it because we wanted to investigate the ‘network effects’ associated with improvements to the route 26 timetable.

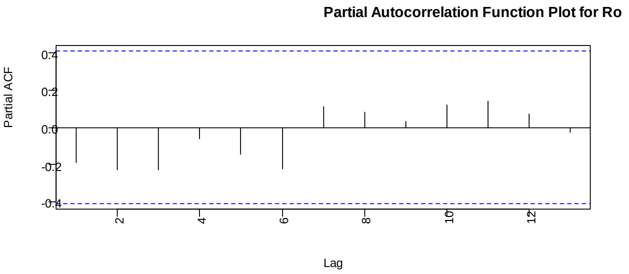


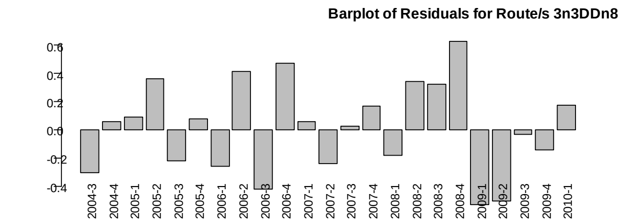
[62] We note that our concern with route 14 was exacerbated by the analysis in section F4.2 that concluded there was evidence of nonstationarity in route 14 peak patronage.

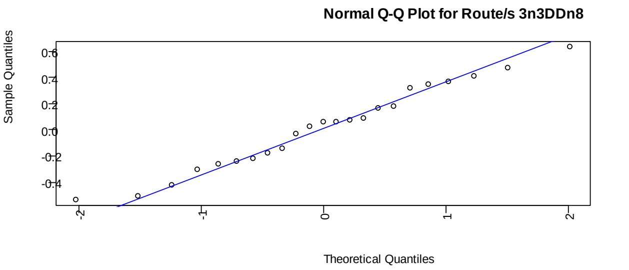

Barplot of Residuals for Route/s 2n2SD

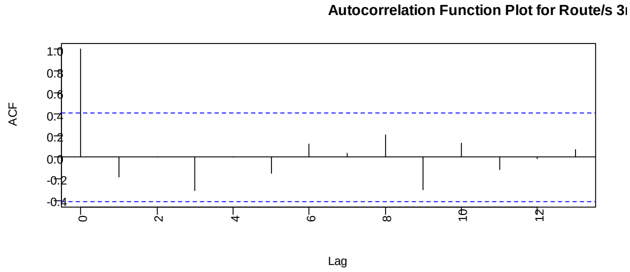

Normal Q-Q Plot for Route/s 2n2SD
Sample Quantiles
Theoretical Quantiles

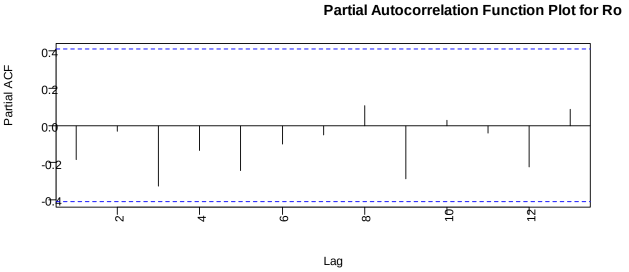

Autocorrelation Function Plot for Route/s 2
ACF
Lag

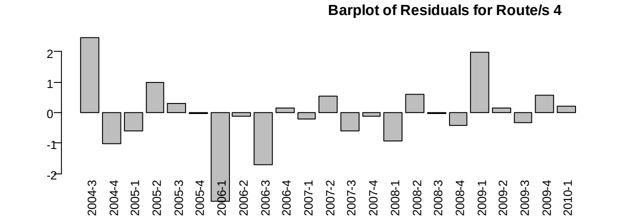

Partial Autocorrelation Function Plot for Ro
Partial ACF
Lag

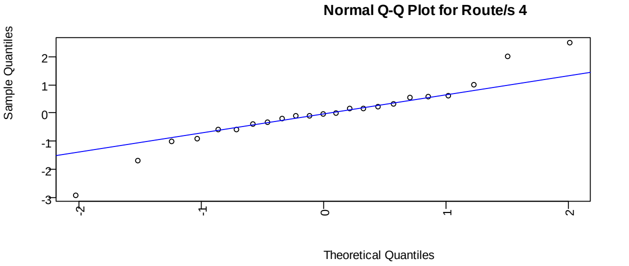

Barplot of Residuals for Route/s 3n3DDn8

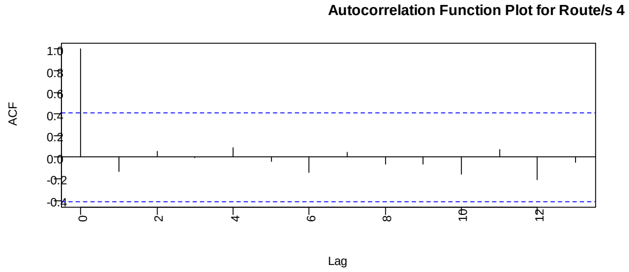

Normal Q-Q Plot for Route/s 3n3DDn8
Sample Quantiles
Theoretical Quantiles

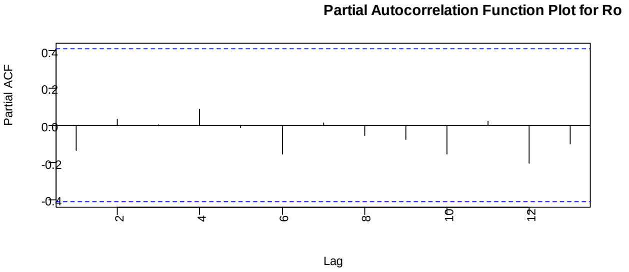

Autocorrelation Function Plot for Route/s 3
ACF
Lag


Partial Autocorrelation Function Plot for Ro
Partial ACF
Lag

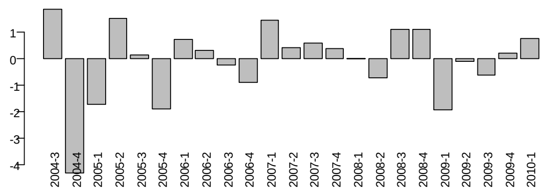

Barplot of Residuals for Route/s 4


Normal Q-Q Plot for Route/s 4
Sample Quantiles
Theoretical Quantiles

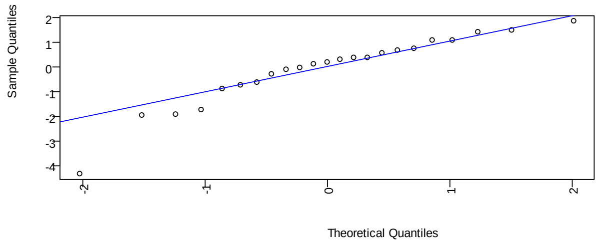

Autocorrelation Function Plot for Route/s 4
ACF
Lag


Partial Autocorrelation Function Plot for Ro
Partial ACF
Lag

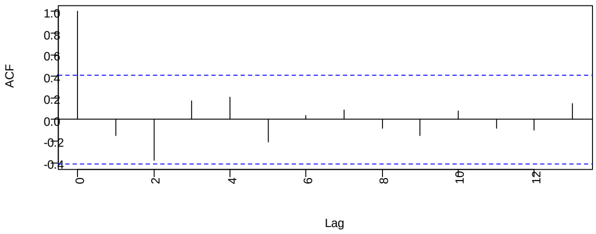
Barplot of Residuals for Route/s 6



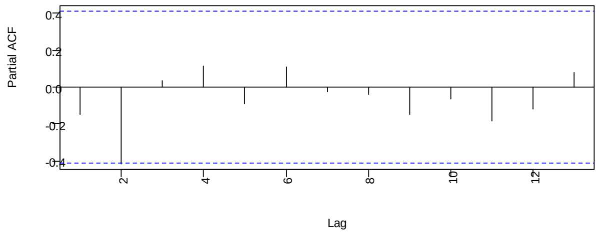
Normal Q-Q Plot for Route/s 6



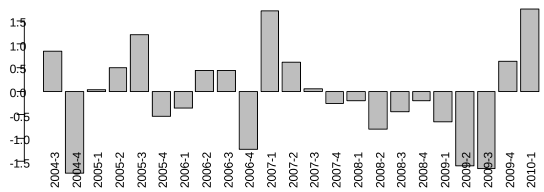
Autocorrelation Function Plot for Route/s 6



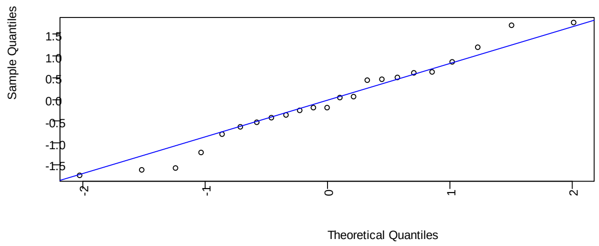
Partial Autocorrelation Function Plot for Ro



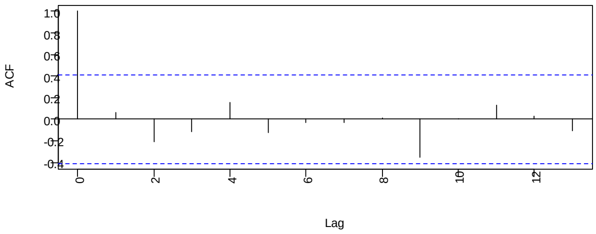
Barplot of Residuals for Route/s 7



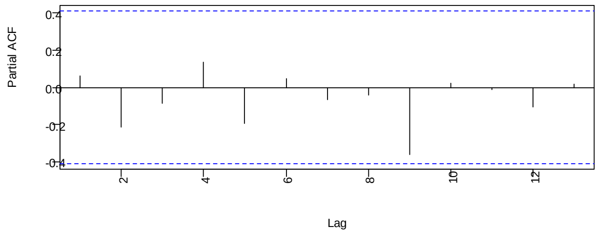
Normal Q-Q Plot for Route/s 7



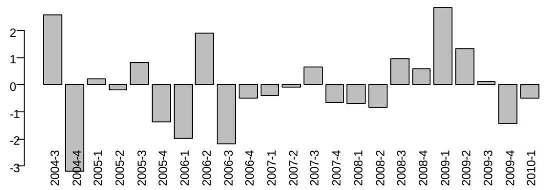
Autocorrelation Function Plot for Route/s 7



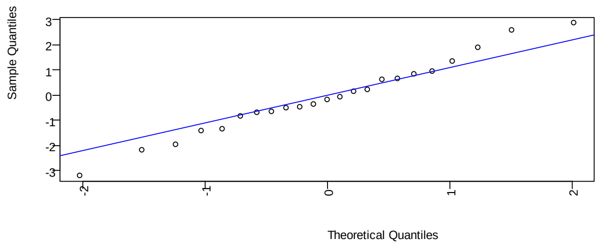
Partial Autocorrelation Function Plot for Ro



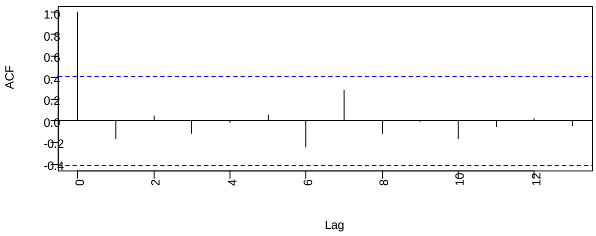
Barplot of Residuals for Route/s 9



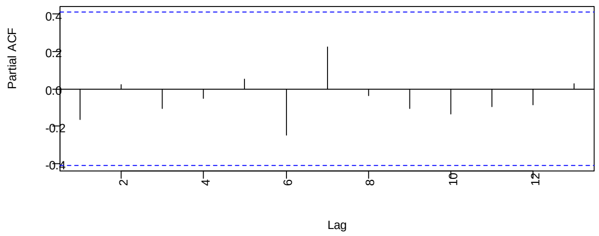
Normal Q-Q Plot for Route/s 9

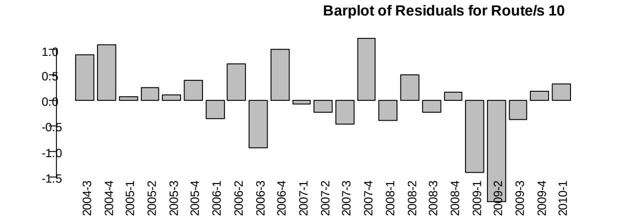


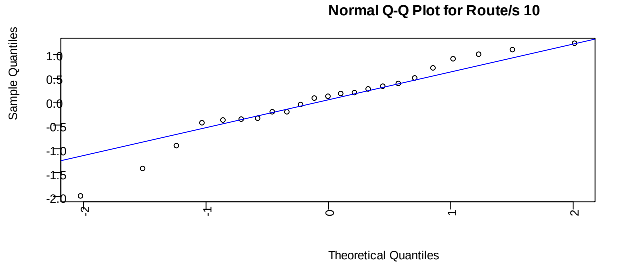
Autocorrelation Function Plot for Route/s 9

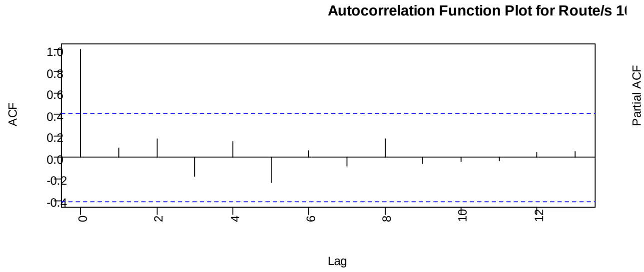


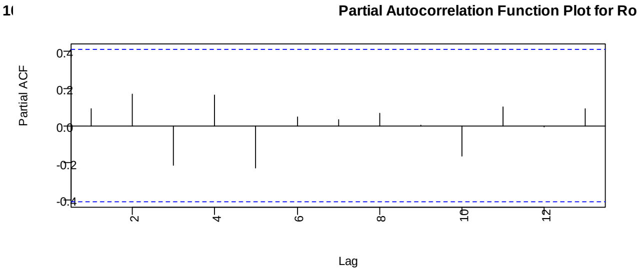
Partial Autocorrelation Function Plot for Ro

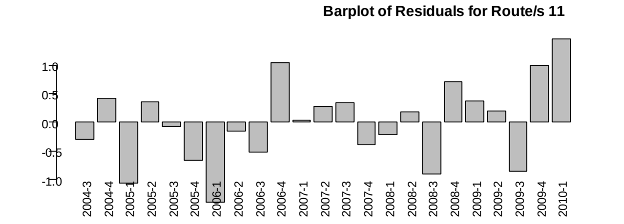


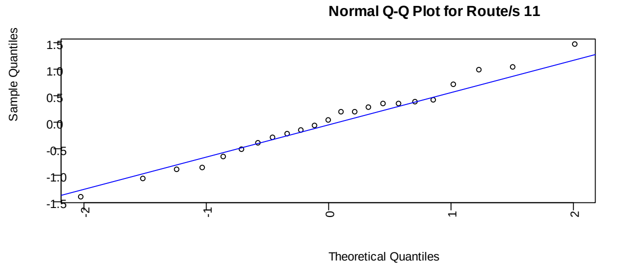

Barplot of Residuals for Route/s 10

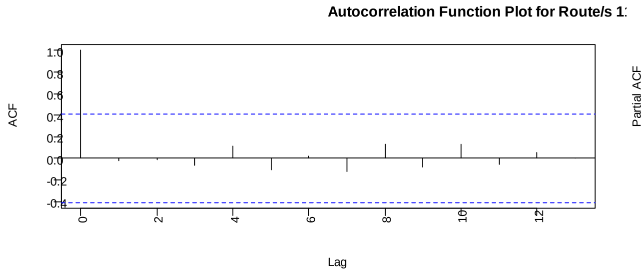

Normal Q-Q Plot for Route/s 10
Sample Quantiles
Theoretical Quantiles

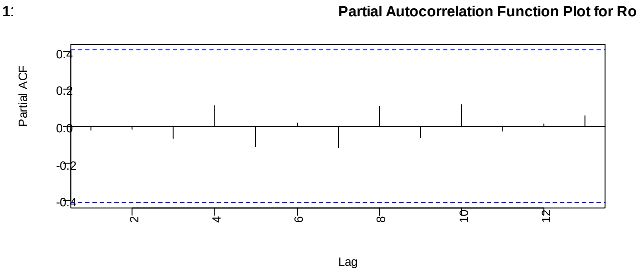

Autocorrelation Function Plot for Route/s 1(
ACF
Lag

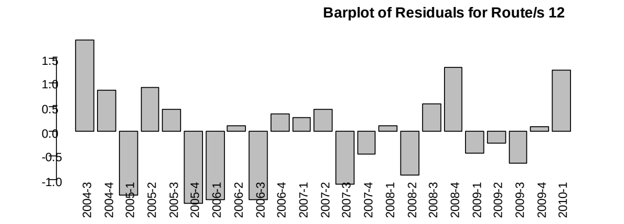

Partial Autocorrelation Function Plot for Ro
Partial ACF
Lag

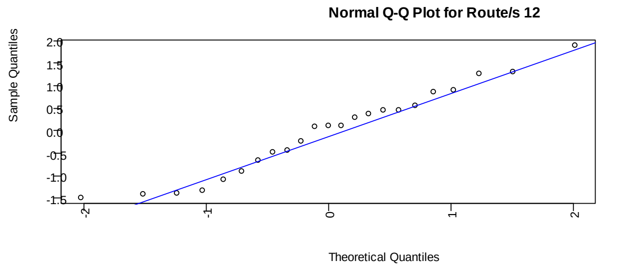

Barplot of Residuals for Route/s 11

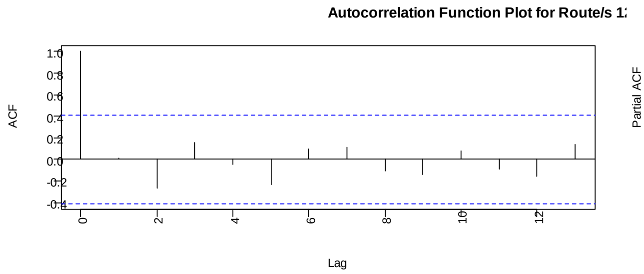

Normal Q-Q Plot for Route/s 11
Sample Quantiles
Theoretical Quantiles

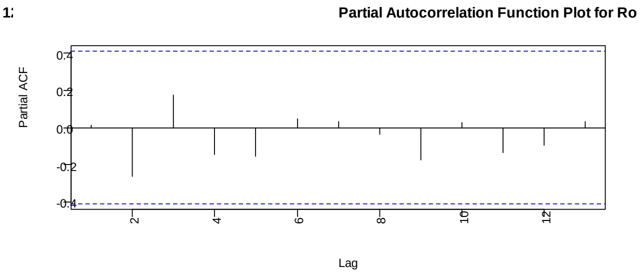

Autocorrelation Function Plot for Route/s 1:
ACF
Lag

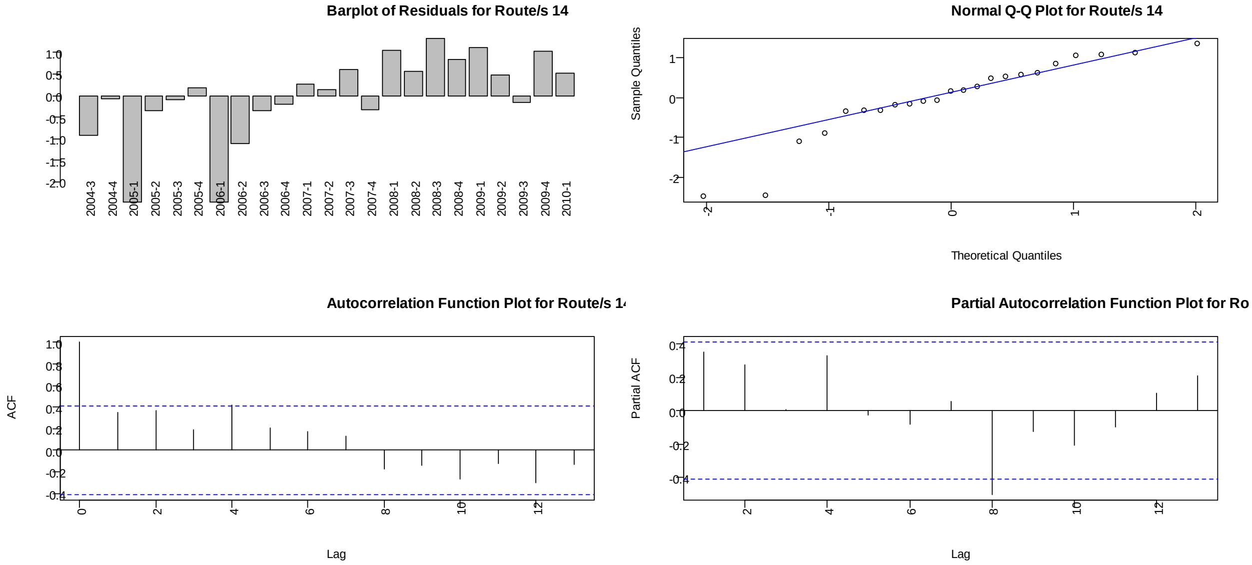

Partial Autocorrelation Function Plot for Ro
Partial ACF
Lag


Barplot of Residuals for Route/s 12


Normal Q-Q Plot for Route/s 12
Sample Quantiles
Theoretical Quantiles


Autocorrelation Function Plot for Route/s 1:
ACF
Lag


Partial Autocorrelation Function Plot for Ro
Partial ACF
Lag

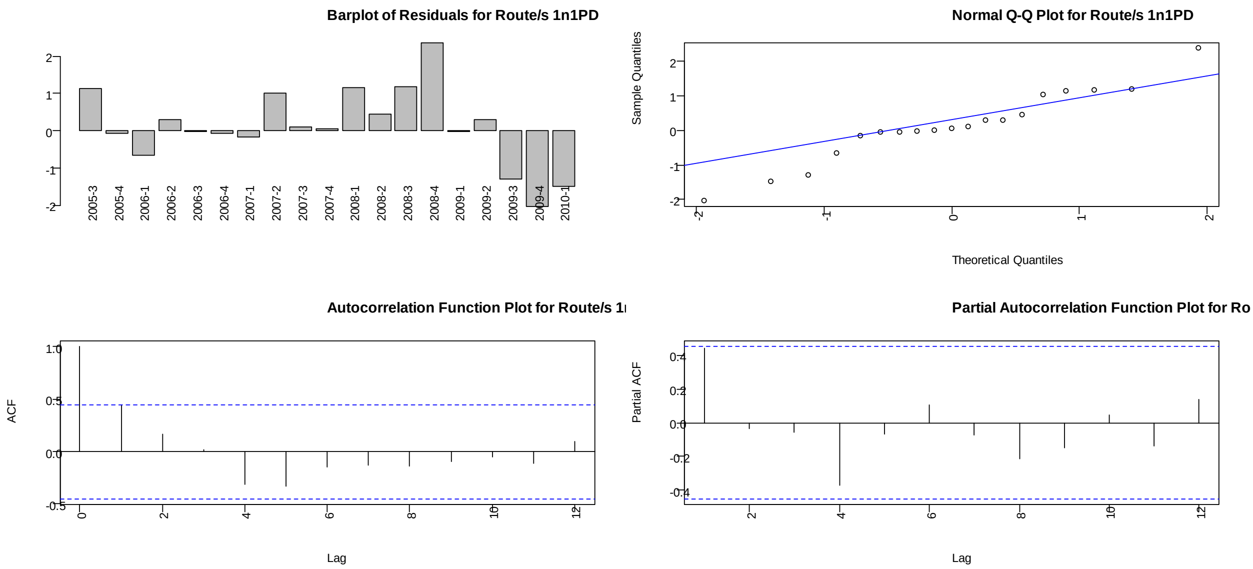


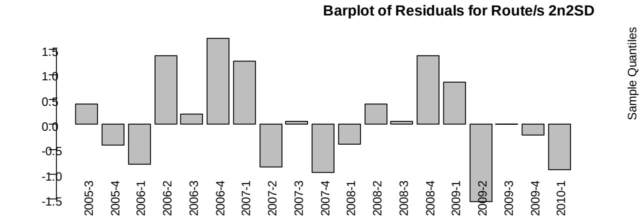
F6.2 Diagnostic analysis for the offpeak patronage model

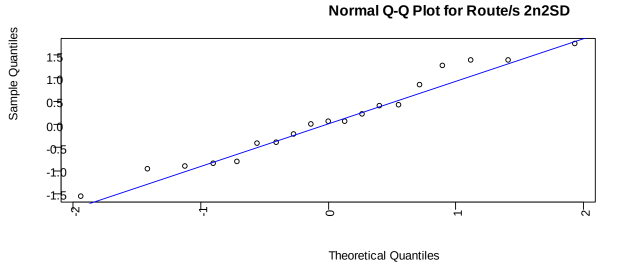
The figures below show diagnostic plots for the residuals from model 5 in table F.8.

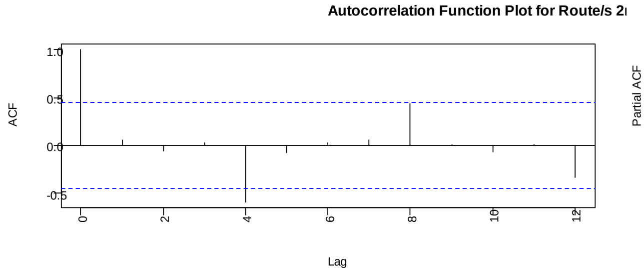
The diagnostic plots show that the residuals for most route groups are generally consistent with key assumptions of normality.

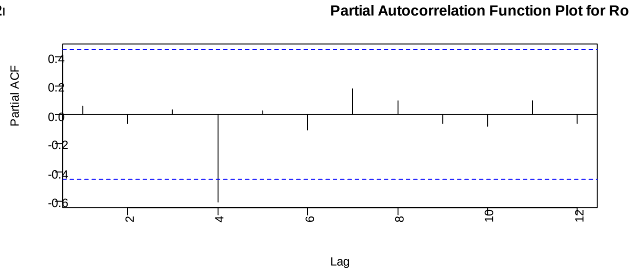
There are instances of 'clustering' of residuals for a number of the routes, including routes 4, 6, 7, 11 and 12. The most concerning cases relate to routes 4 and 6 because they show large 'clusters' of positive and negative residuals. Routes 4 and 5 were therefore removed from the preferred model.

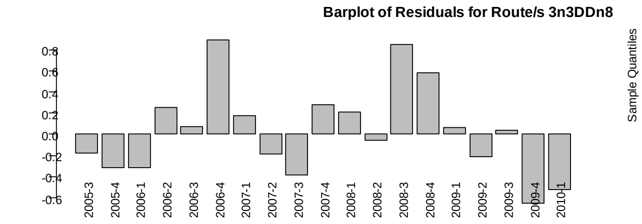


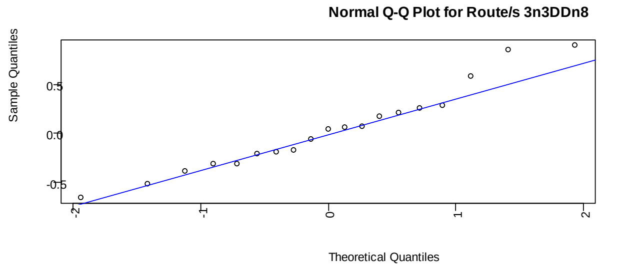

Barplot of Residuals for Route/s 2n2SD

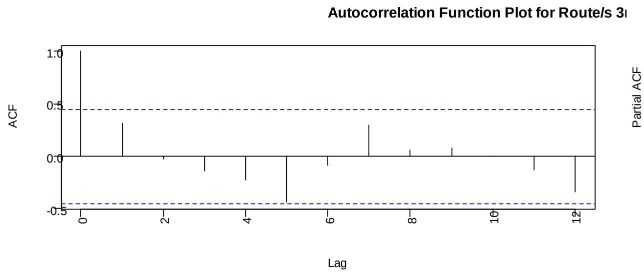

Normal Q-Q Plot for Route/s 2n2SD
Sample Quantiles
Theoretical Quantiles

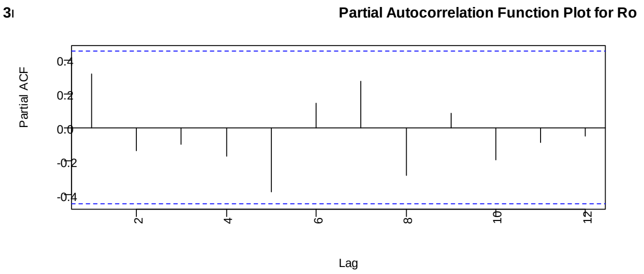

Autocorrelation Function Plot for Route/s 2
ACF
Lag

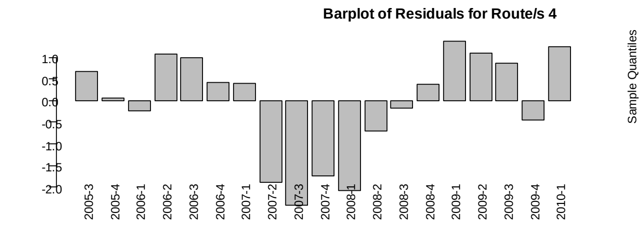

Partial Autocorrelation Function Plot for Ro
Partial ACF
Lag

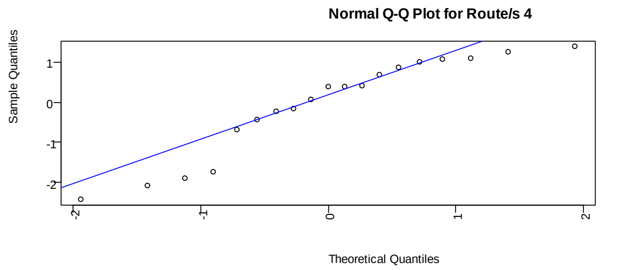

Barplot of Residuals for Route/s 3n3DDn8

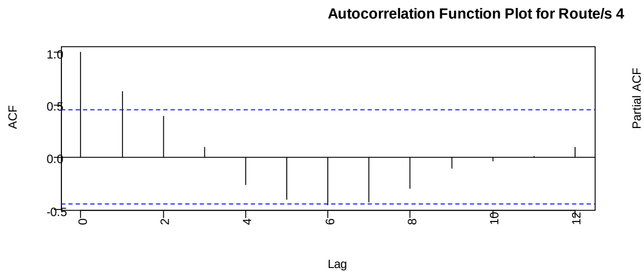

Normal Q-Q Plot for Route/s 3n3DDn8
Sample Quantiles
Theoretical Quantiles

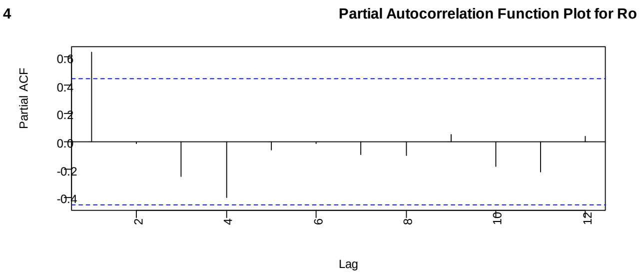

Autocorrelation Function Plot for Route/s 3
ACF
Lag

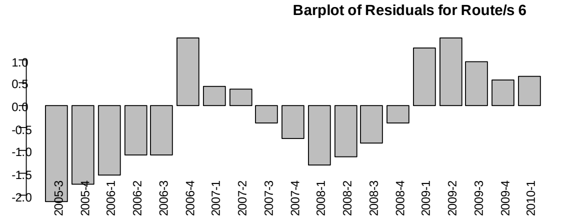

Partial Autocorrelation Function Plot for Ro
Partial ACF
Lag

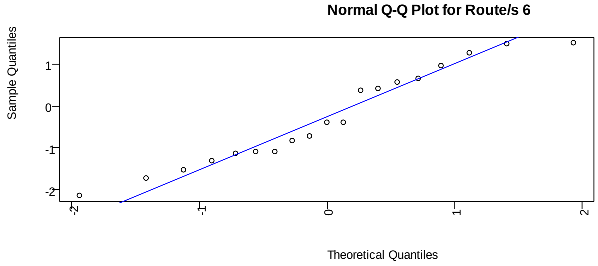

Barplot of Residuals for Route/s 4

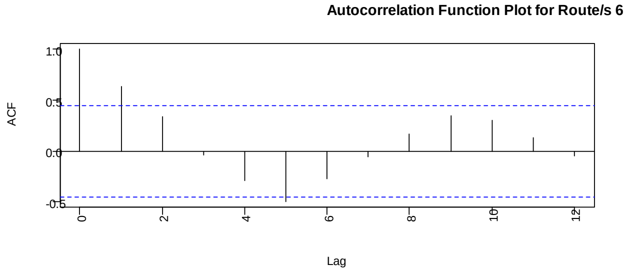

Normal Q-Q Plot for Route/s 4
Sample Quantiles
Theoretical Quantiles

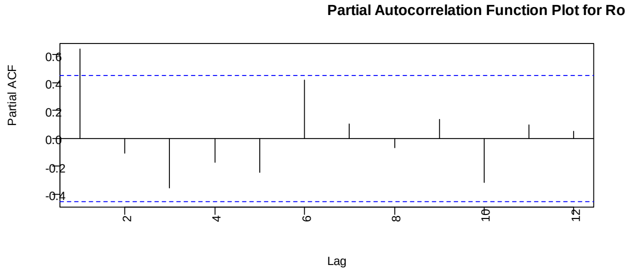

Autocorrelation Function Plot for Route/s 4
ACF
Lag

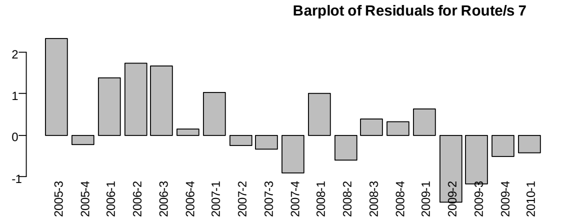

Partial Autocorrelation Function Plot for Ro
Partial ACF
Lag

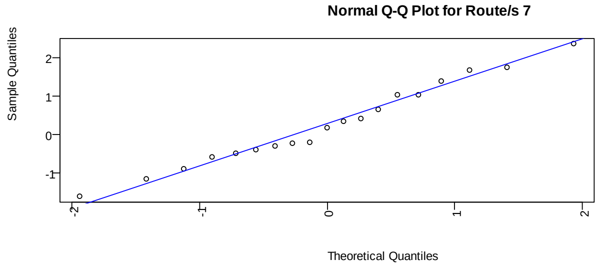

Barplot of Residuals for Route/s 6

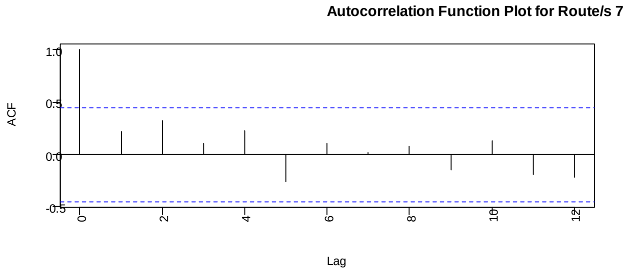

Normal Q-Q Plot for Route/s 6
Sample Quantiles
Theoretical Quantiles

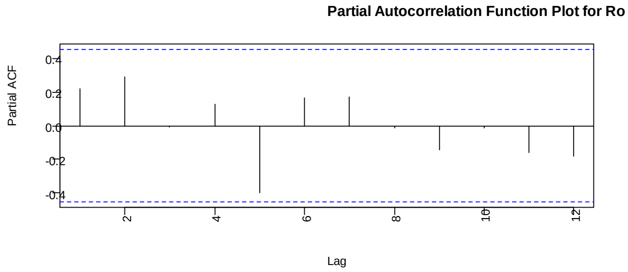

Autocorrelation Function Plot for Route/s 6
ACF
Lag

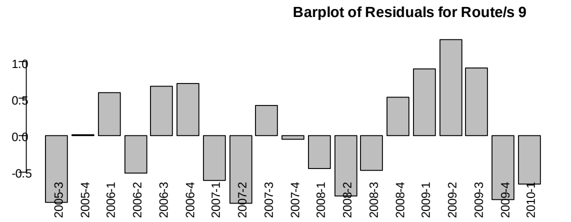

Partial Autocorrelation Function Plot for Ro
Partial ACF
Lag

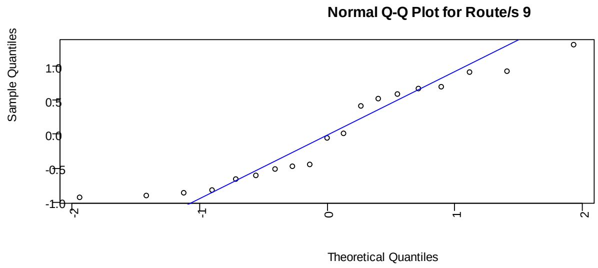

Barplot of Residuals for Route/s 7

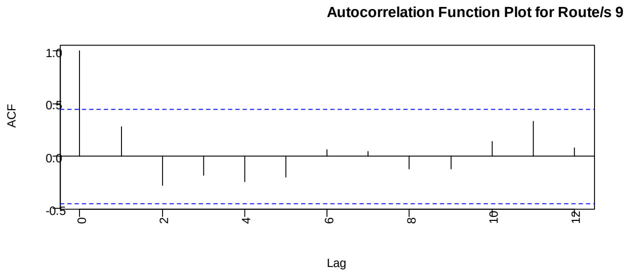

Normal Q-Q Plot for Route/s 7
Sample Quantiles
Theoretical Quantiles

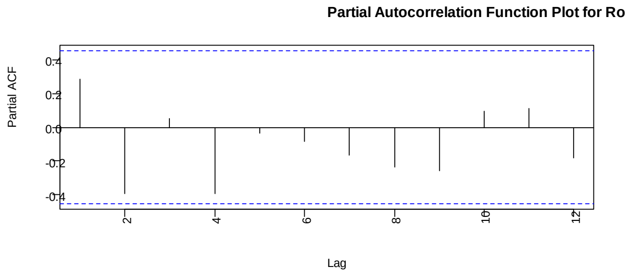

Autocorrelation Function Plot for Route/s 7
ACF
Lag

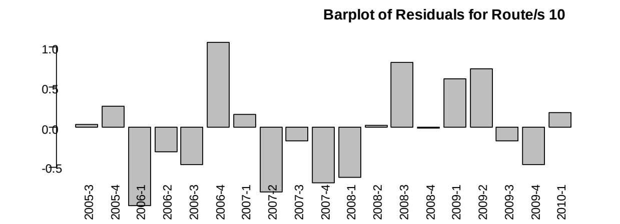

Partial Autocorrelation Function Plot for Ro
Partial ACF
Lag

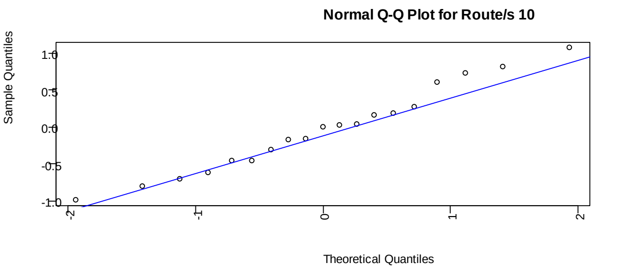

Barplot of Residuals for Route/s 9

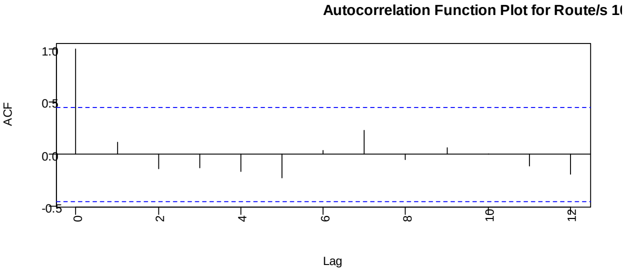

Normal Q-Q Plot for Route/s 9
Sample Quantiles
Theoretical Quantiles

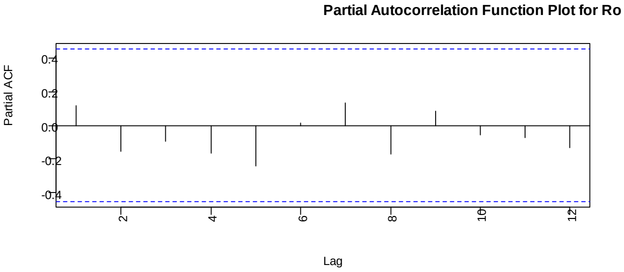

Autocorrelation Function Plot for Route/s 9
ACF
Lag

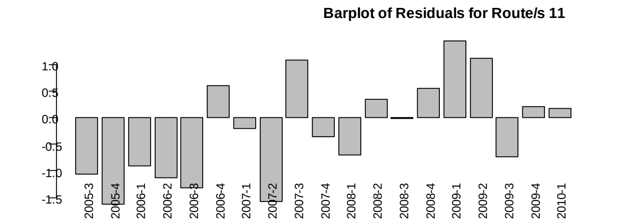

Partial Autocorrelation Function Plot for Ro
Partial ACF
Lag

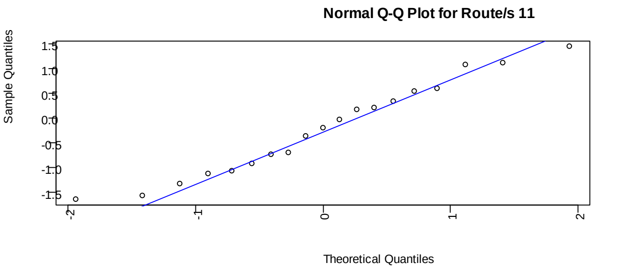

Barplot of Residuals for Route/s 10

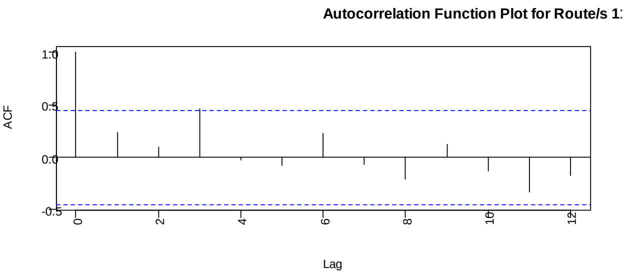

Normal Q-Q Plot for Route/s 10
Sample Quantiles
Theoretical Quantiles

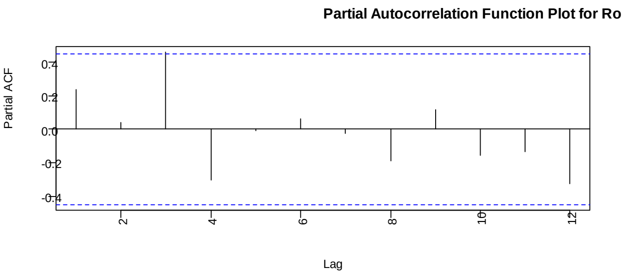

Autocorrelation Function Plot for Route/s 1(
ACF
Lag

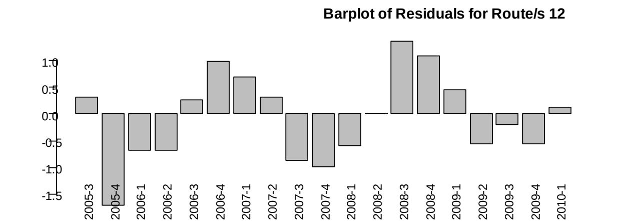

Partial Autocorrelation Function Plot for Ro
Partial ACF
Lag

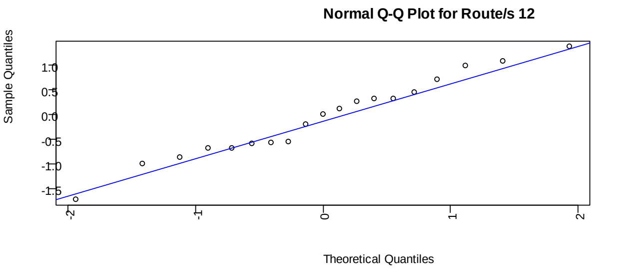

Barplot of Residuals for Route/s 11

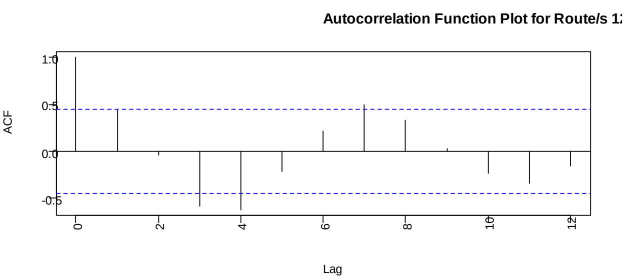

Normal Q-Q Plot for Route/s 11
Sample Quantiles
Theoretical Quantiles

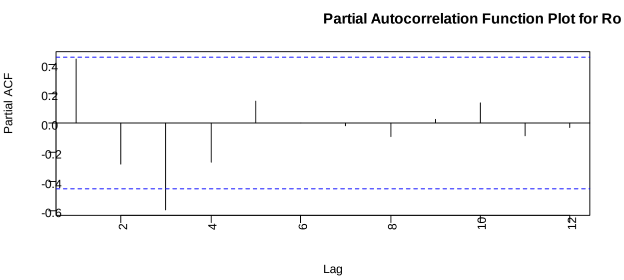

Autocorrelation Function Plot for Route/s 1:
ACF
Lag

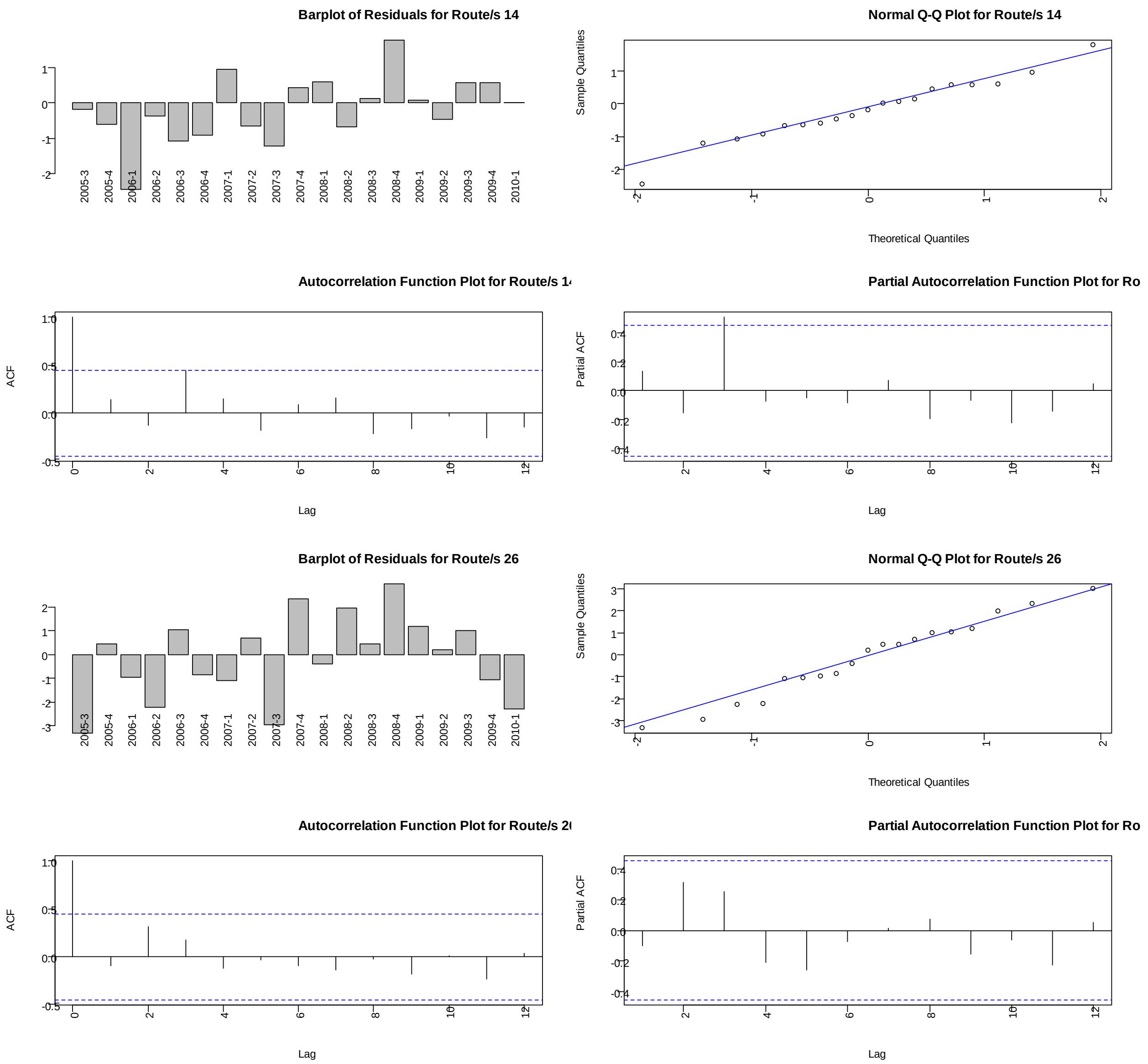

Partial Autocorrelation Function Plot for Ro
Partial ACF
Lag


Barplot of Residuals for Route/s 12


Normal Q-Q Plot for Route/s 12
Sample Quantiles
Theoretical Quantiles


Autocorrelation Function Plot for Route/s 1:
ACF
Lag

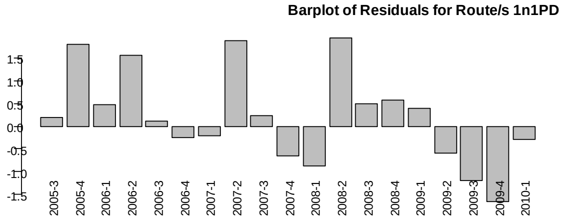

Partial Autocorrelation Function Plot for Ro
Partial ACF
Lag

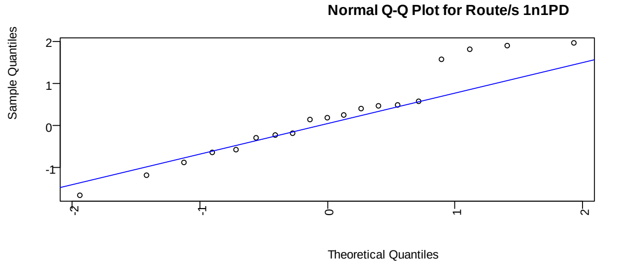


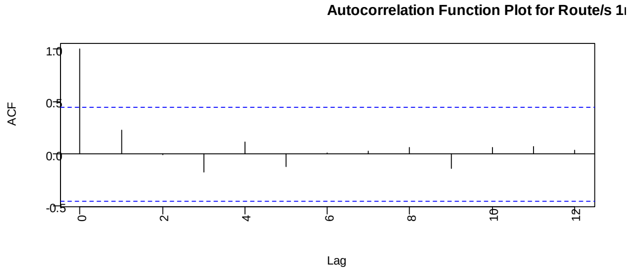
F6.3 Diagnostic analysis for the weekend patronage model

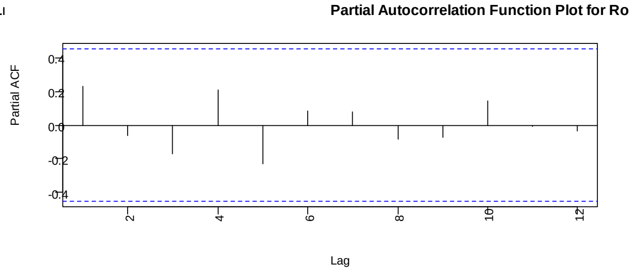
The following figures show diagnostic plots for the residuals from model 6 in table F.14. The Q-Q plots show that the residuals are generally normally distributed, but there are exceptions on a few routes due to the presence of outliers. These outliers are most prominent on routes 1, 2 and 6.

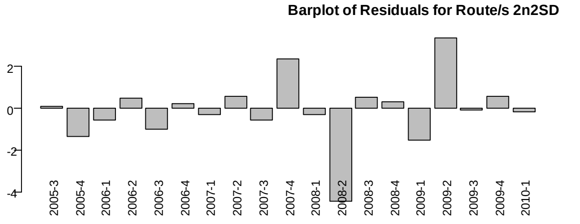
The barplots of residuals show evidence of mild autocorrelation via small ‘clusters’ or positive or negative residuals. Routes 4, 7 and 12 are the best examples of this. Route 4, in particular, shows evidence of a ‘structural break’ around 2007-Q3 when residuals went from generally positive to generally negative. The problems with routes 4 and 12 were regarded as serious enough for them to be omitted from the preferred model.

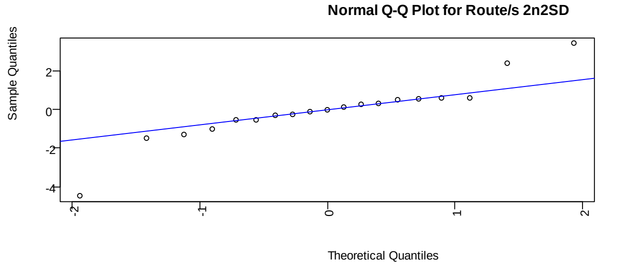

Barplot of Residuals for Route/s 1n1PD

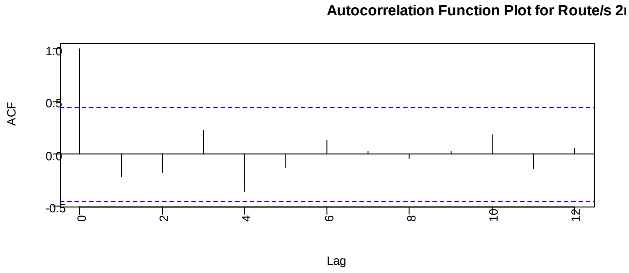

Normal Q-Q Plot for Route/s 1n1PD
Sample Quantiles
Theoretical Quantiles

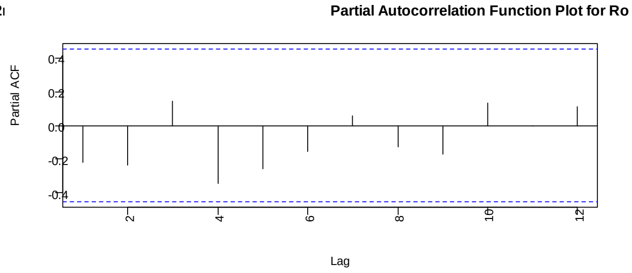

Autocorrelation Function Plot for Route/s 1
ACF
Lag

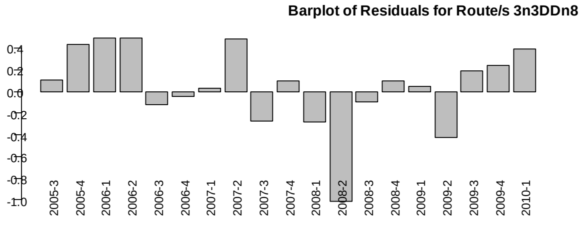

Partial Autocorrelation Function Plot for Ro
Partial ACF
Lag

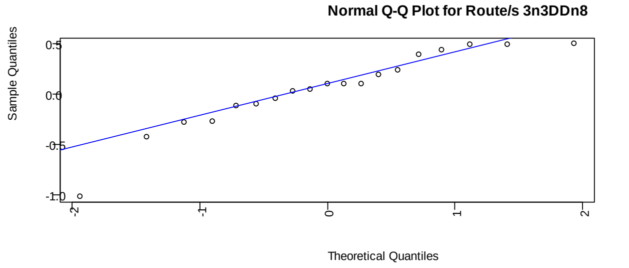

Barplot of Residuals for Route/s 2n2SD

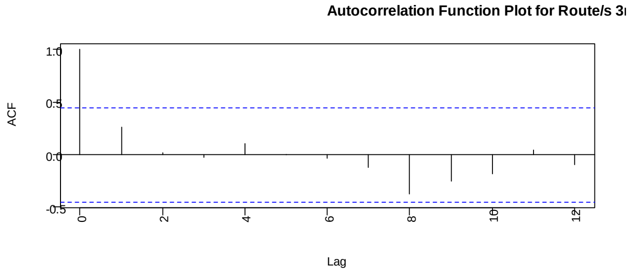

Normal Q-Q Plot for Route/s 2n2SD
Sample Quantiles
Theoretical Quantiles

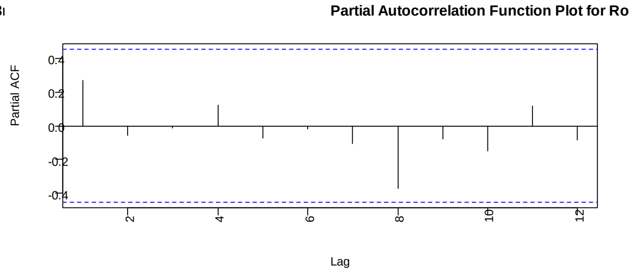

Autocorrelation Function Plot for Route/s 2
ACF
Lag

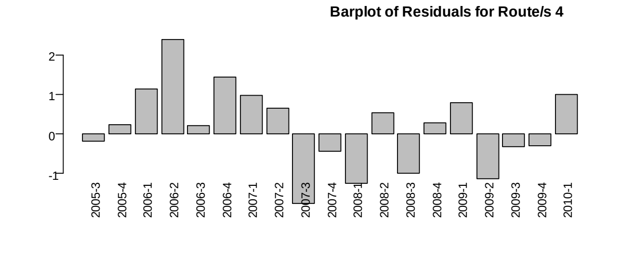

Partial Autocorrelation Function Plot for Ro
Partial ACF
Lag

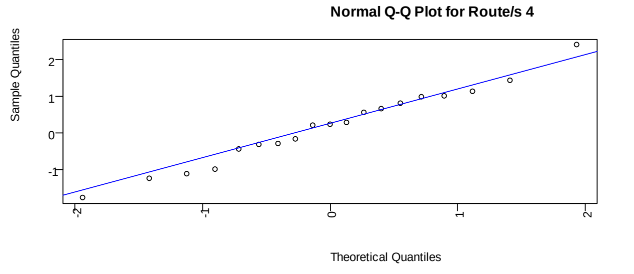

Barplot of Residuals for Route/s 3n3DDn8

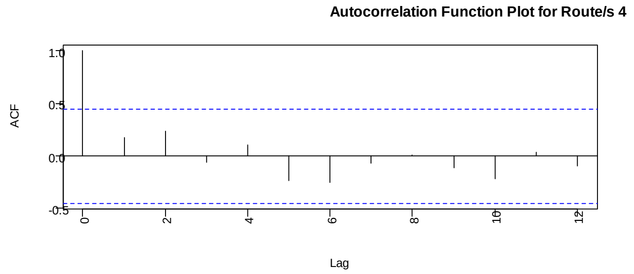

Normal Q-Q Plot for Route/s 3n3DDn8
Sample Quantiles
Theoretical Quantiles

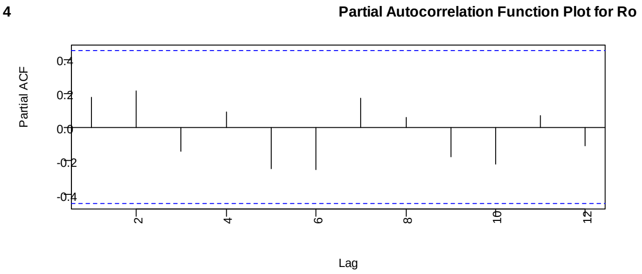

Autocorrelation Function Plot for Route/s 3
ACF
Lag

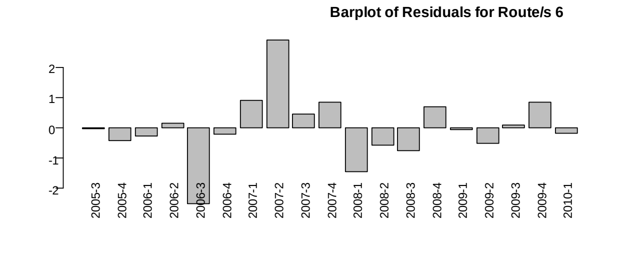

Partial Autocorrelation Function Plot for Ro
Partial ACF
Lag

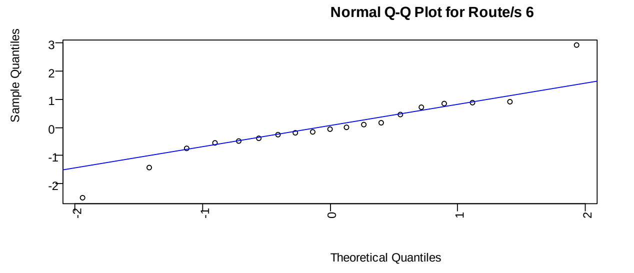

Barplot of Residuals for Route/s 4

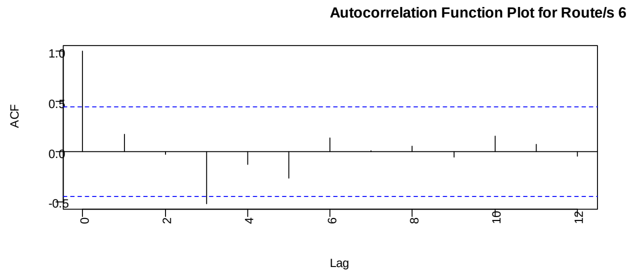

Normal Q-Q Plot for Route/s 4
Sample Quantiles
Theoretical Quantiles

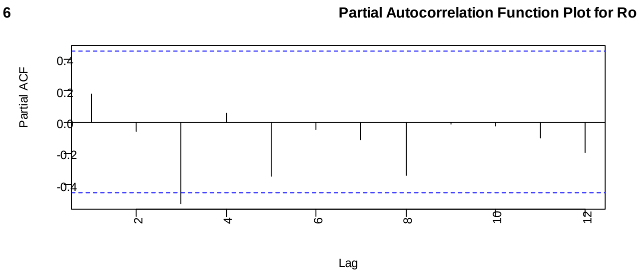

Autocorrelation Function Plot for Route/s 4
ACF
Lag

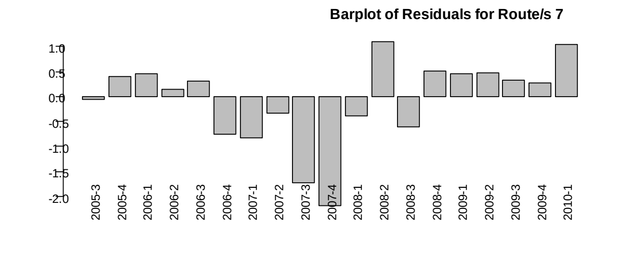

Partial Autocorrelation Function Plot for Ro
Partial ACF
Lag

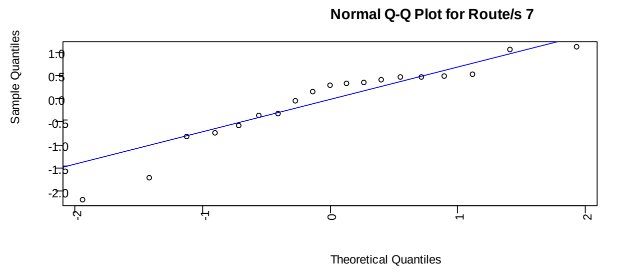

Barplot of Residuals for Route/s 6

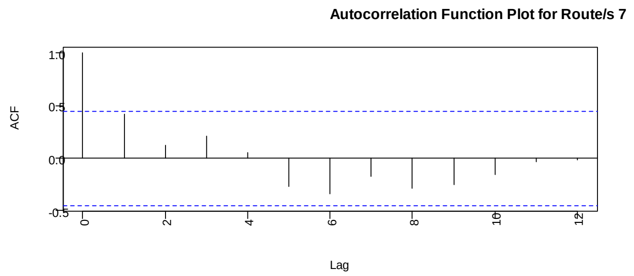

Normal Q-Q Plot for Route/s 6
Sample Quantiles
Theoretical Quantiles

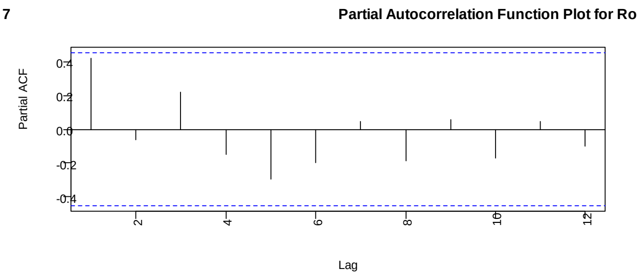

Autocorrelation Function Plot for Route/s 6
ACF
Lag

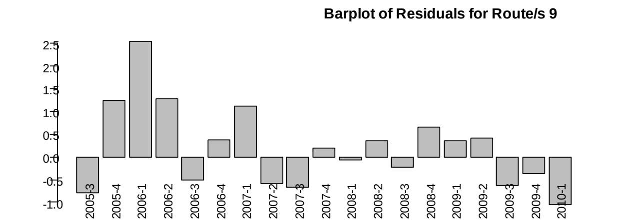

Partial Autocorrelation Function Plot for Ro
Partial ACF
Lag

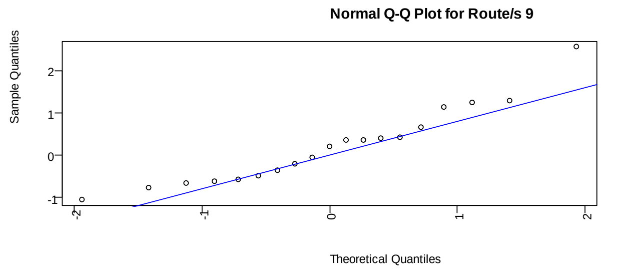

Barplot of Residuals for Route/s 7

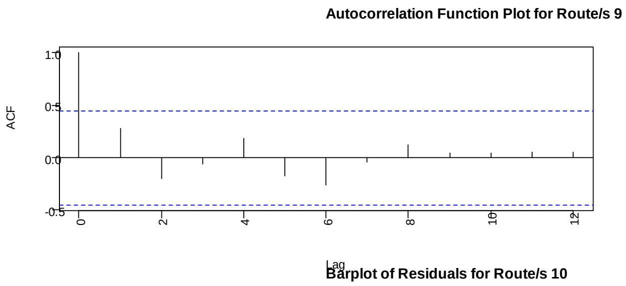

Normal Q-Q Plot for Route/s 7
Sample Quantiles
Theoretical Quantiles

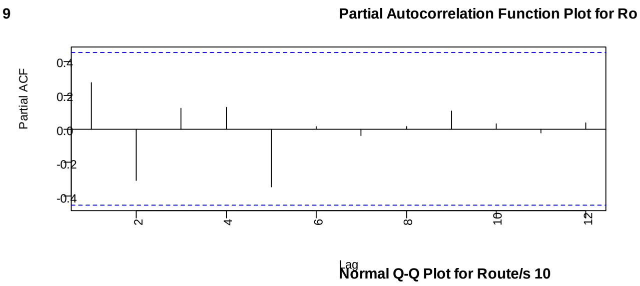

Autocorrelation Function Plot for Route/s 7
ACF
Lag

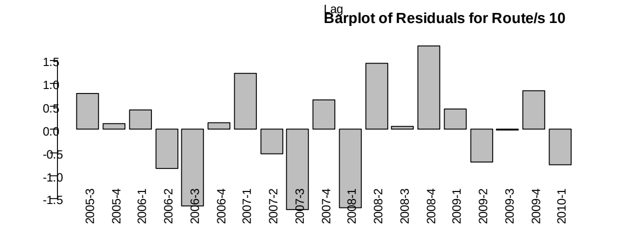

Partial Autocorrelation Function Plot for Ro
Partial ACF
Lag

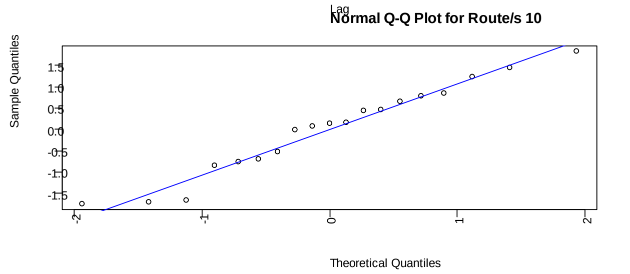

Barplot of Residuals for Route/s 9

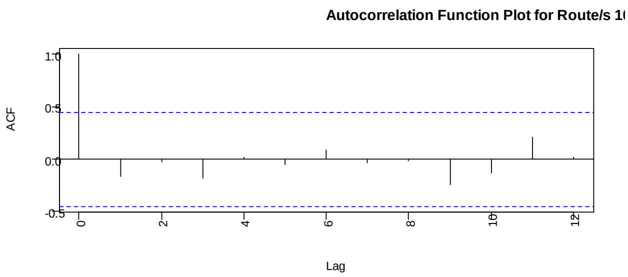

Normal Q-Q Plot for Route/s 9
Sample Quantiles
Theoretical Quantiles

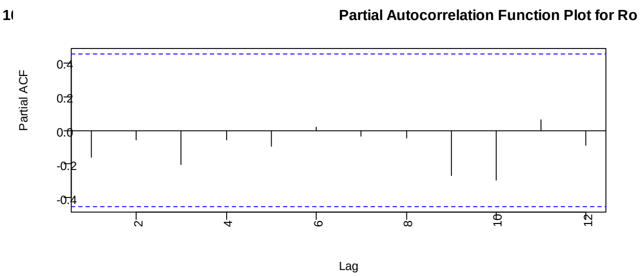

Autocorrelation Function Plot for Route/s 9
ACF
Lag

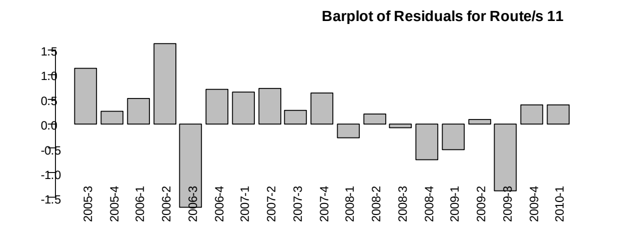

Partial Autocorrelation Function Plot for Ro
Partial ACF
Lag

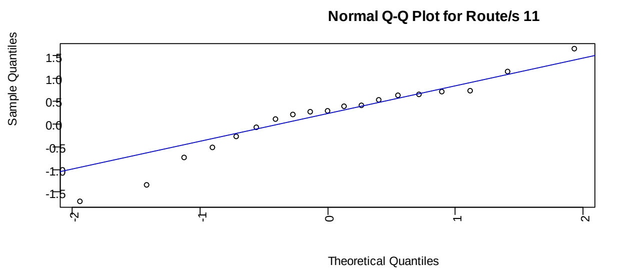

Barplot of Residuals for Route/s 10

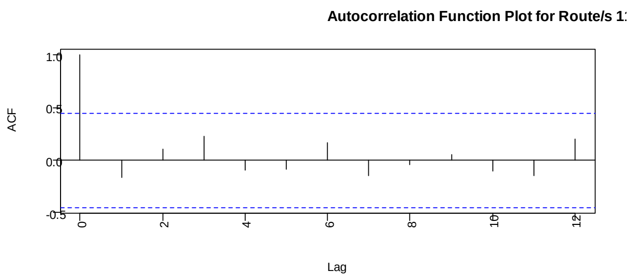

Normal Q-Q Plot for Route/s 10
Sample Quantiles
Theoretical Quantiles


Autocorrelation Function Plot for Route/s 1
ACF
Lag


Partial Autocorrelation Function Plot for Ro
Partial ACF
Lag


Barplot of Residuals for Route/s 11


Normal Q-Q Plot for Route/s 11
Sample Quantiles
Theoretical Quantiles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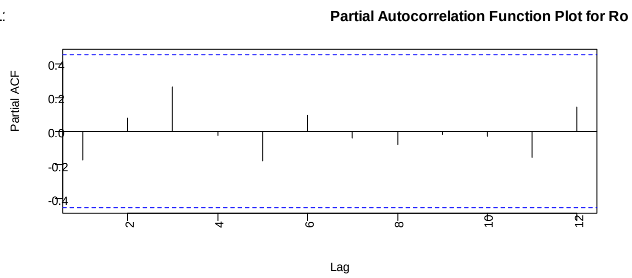
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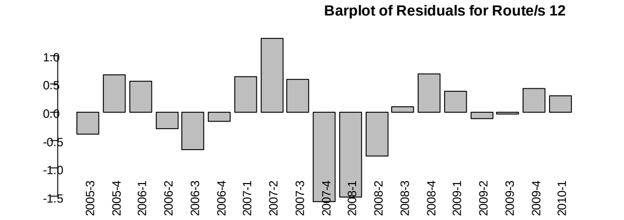
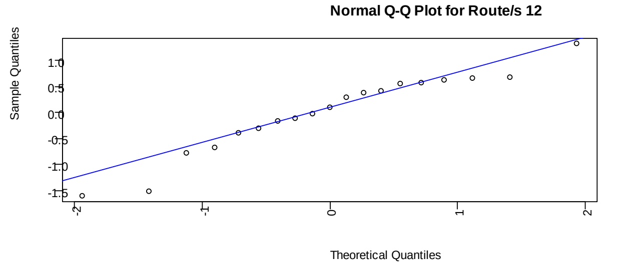
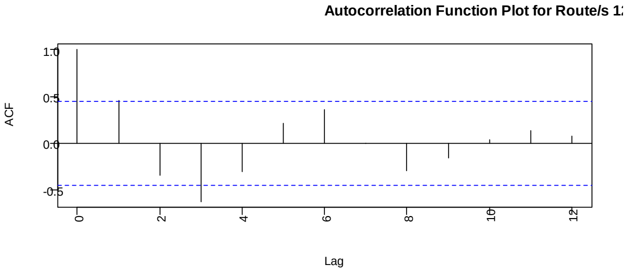
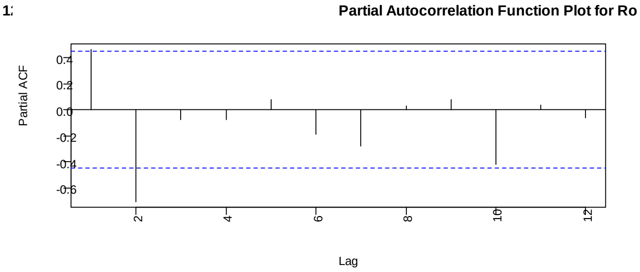
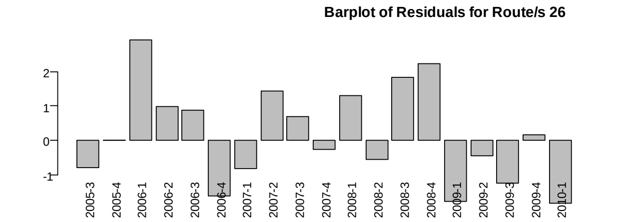
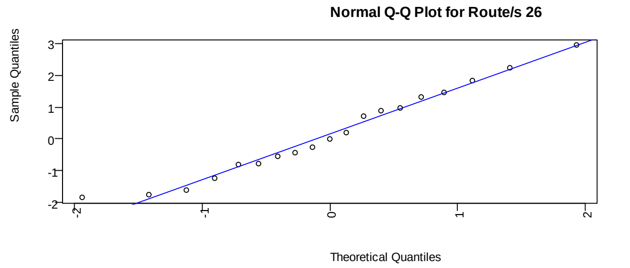


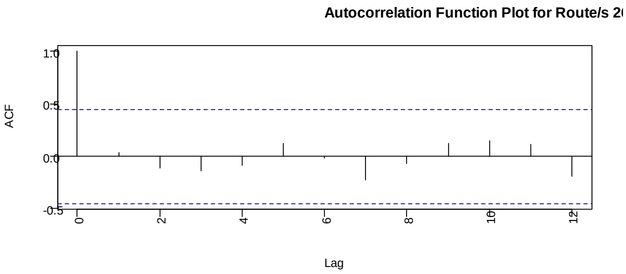


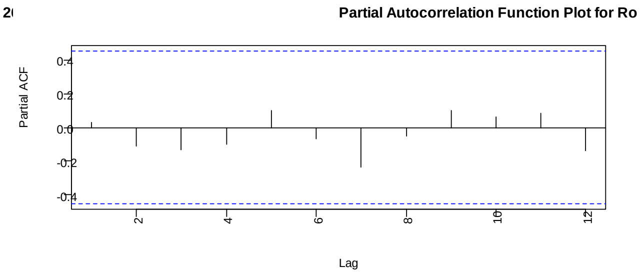












F7 Final model estimates

This section presents the coefficients estimated using our econometric panel data model.

Table F.15 shows our estimates for the impact of economic variables.

Table F.15 Estimates for economic variables

Economic variables	Weekday		Weekend
	Peak	Offpeak	
Real bus fare elasticity	Removed due to implausible sign	Removed due to implausible sign	-1.20*** (-1.77,-0.64)
Real petrol price cross-elasticity	0.20‘ (-0.03,0.44)	Removed due to implausible sign	Removed due to implausible sign
$2.00 petrol price threshold dummy (2008–Q3)	6%‘ (0%,12%)	8%*** (4%,12%)	2% (-8%,12%)
Real retail sales	0.03 (-0.44,0.49)	-0.86*** (-1.32,-0.40)	0.80‘ (-0.03,1.64)
Employment	0.17 (-0.31,0.66)	0.24 (-19%,66%)	0.36 (-0.86,1.58)

Note for symbols of statistical significance: *** → 0.1%, ** → 1%, * → 5%, ‘ →10%

Key findings from table F.15 include the following:

- There were a number of fare increases during the time period observed, and yet these did not have a discernible impact on offpeak weekday patronage. However, weekend patronage did seem quite responsive to fare increases with an estimated elasticity of -1.2.
- Real petrol price elasticities were +0.2 during the weekday peak and the $2.00 petrol price thresholds had a discernible impact on weekday patronage (both peak and offpeak).
- Real retail sales seemed to have a negative association with offpeak patronage but a positive relationship with weekend patronage.
- The relationship between employment and patronage was positive across all time periods, but modest and not statistically significant.

Table F.16 shows our estimates for service elasticities. Direct impacts are shown in table 8.2 in orange shading. Indirect impacts are shown unshaded and in *italics*.

Key findings from table F.16 include the following:

- The introduction of the direct services had service elasticities of around +0.4 in two instances and zero impact in the other instance.
- The doubling of offpeak frequency on a selection of routes had service elasticities ranging from +0.2 through to +0.8. However, there was evidence of considerable ‘network effects’ because these offpeak weekday timetable improvements seemed to have a positive impact on both peak weekday patronage and weekend patronage.
- The extension of hours for weekday services from about 6pm to 7.30pm had a positive impact on patronage. But there was also evidence of diminishing returns: the further extension of hours from 7.30pm to about 10pm did not have the same effect.
- The refinement of timetables to make them more regular was well received and was associated with high service elasticities both during the weekday and on weekends.
- The Sunday service elasticities imply that the introduction of the Sunday services (ie a 100% increase in weekend service trips) was associated with a 95% increase in weekend patronage within a year and

another 30% increase in patronage within the subsequent year. This meant that, overall, weekend patronage increased by about 125% upon introduction of Sunday services.

Table F.16 Service elasticity estimates

Service trip elasticities		Weekday		Weekend
		Peak	Offpeak	
Peak weekday service improvements	Intro. of Pukete Direct (Jul 08)	0.43*** (0.22,0.63)		
	Intro. of Silverdale Direct (Sep 08)	0.40** (0.16,0.65)		
	Intro. of Dinsdale Direct (Jul 08)	Removed due to implausible sign		
	Extra peak morning services (Oct 06, Feb 09)	Removed due to implausible sign		
Offpeak weekday service improvements	Doubling of frequency on route 9 (Oct 06)	0.03 (-0.22,0.28)	0.22‘ (0.00,0.45)	0.20 (-0.15,0.55)
	Doubling of frequency on route 12 (Feb 07)	0.13 (-0.08,0.34)	0.60*** (0.41,0.79)	Omitted
	Doubling of frequency on route 26 (Sep -06)	0.40** (0.16,0.65)	0.76*** (0.54,0.98)	0.34‘ (-0.01,0.69)
	Extension of evening hours on mon-wed from (about) 6pm to 7.30pm (Oct 06, Feb 07)	Removed due to implausible sign	0.82‘ (-0.04,1.67)	
	More regular hours lunchtime and evening (Feb 07)	0.83* (0.20,1.46)	0.60‘ (-0.04,1.23)	
	Further extension of evening hours on mon-thur from (about) 7.30pm to 10pm (Feb 09)		Removed due to implausible sign	
Weekend service improvements	Provision of more regular lunch hours on Saturday (Sat, Feb 07)			2.18*** (1.08,3.27)
	Introduction of Sunday services (Sep 08)			
	- impact during first month			0.81** (0.30,1.32)
	- impact after 2-4 months			0.97*** (0.82,1.12)
	- impact after 5-12 months			0.95*** (0.79,1.10)
	- impact after subsequent year			0.30*** (0.15,0.45)
	Extension of hours (Sat, Sun, Feb 09)			Removed due to implausible sign

Note for symbols of statistical significance: *** → 0.1%, ** → 1%, * → 5%, ‘ →10%

Table F.17 shows our estimates for the impact of various miscellaneous events.

Table F.17 Dummy variables for miscellaneous events

Dummy variables for miscellaneous events	Weekday		Weekend
	Peak	Offpeak	
Generic dummy for temporary growth spurt in 2006–Q4 (ie free ticket promotion)	9%*** (4%,14%)	-4% (-9%,2%)	Removed due to implausible sign
Generic dummy for permanent growth spurt in 2006–Q4 (ie two-hour free transfer, free ticket promotion)	Removed due to implausible sign	9%* (1%,18%)	16%*** (8%,24%)
2008 HamiltonV8 races dummy (Apr 08)	8%* (2%,13%)	15%*** (11%,20%)	65%*** (56%,73%)
2009 HamiltonV8rRaces dummy (Apr 09)	2% (-4%,7%)	1% (-3%,6%)	28%*** (20%,36%)
Introduction of SuperGold Card (Oct 08)	Not applicable to peak	Removed due to implausible sign	Removed due to implausible sign
Easter dummy	-4%*** (-7%,-2%)	-1% (-3%,1%)	-5%* (-10%,0%)

Note for symbols of statistical significance: *** → 0.1%, ** → 1%, * → 5%, ‘ →10%

The key findings from table F.17 are as follows:

- Even after controlling for all other events, there was still a 9% jump in offpeak weekday patronage and a 16% jump in weekend patronage that remained unexplained. We consider that this can most likely be attributed to the impact of a two-hour free transfer, which we understand from general conversation with the Waikato Regional Council was introduced in October 2007.
- The free ticket promotion (also in October 2007) may have also played a role, but most likely mainly in regard to the temporary impact on patronage.
- The 2008 V8 races had a discernible impact on weekend patronage but the impact the next year, although still considerable, was less.

Appendix G: Econometric analysis of patronage growth on the Tauranga city bus system

G1 Introduction

In section 9.4 of the main report we presented our conclusions regarding the contribution of explanatory variables to Tauranga city bus patronage growth over the four-year period from 2005–Q3 to 2009–Q2. Then in section 9.5 we presented our findings in regard to estimates for those explanatory variables.

Those conclusions and findings are based on a thorough econometric methodology[63] that helps us to understand as much as we can about what is driving patronage growth at a corridor level. We then bundled data from the bus corridors together and used an econometric tool (called a panel data model) to estimate what is driving bus patronage across the Tauranga city bus system.

The following sections show how the econometric methodology was applied to analysis of Tauranga city bus patronage, and describe the analyses underlying our conclusions and findings.

- *G2 Data collection and data manipulation* – the analytical process begins with data collection. The data then has to be checked and manipulated into a form suitable for econometric analysis.
- *G3 Graphical analysis* – we believe it is important to look at the data and make sense of it intuitively before proceeding onto econometric analysis. In section G3 we look at patronage growth along each of the main train lines and seek to explain and understand any trends or anomalies in the data. The observations here feed into the models tested in sections G4 to G7.
- *G4 Data analysis* – there are a number of statistical problems that can potentially undermine the validity of the econometric analysis. (These problems are technically referred to as multicollinearity and spurious regression and endogeneity.) In section G4 we show that we have examined the data for presence of these problems and have responded accordingly where there is evidence of a problem.
- *G5 Model building process* – the process of building models for patronage growth involves looking at the data and fitting a general model that explains the patterns in the data as well as possible. We then investigate the contribution of the explanatory variables in the general model, removing those that look suspect or indeterminate, and whittling the model down to its core components. Section G5 describes the process by which each of the initial models was whittled down into preferred models.
- *G6 Diagnostic analysis* – the preferred model will still not be statistically valid unless the residuals of the model meet certain criteria. In section G6 we show our examination of the residuals of each individual line, in which we look for evidence of autocorrelation, non-normality or omitted variables
- *G7 Final model findings* – in section G7 we show the estimates produced using the preferred models.
- *G8 Model for 'net patronage' from the Lakes (12) service* – in section G8 we extend the model-building process and demonstrate that a panel data model can assist in estimating the net impact of a new route on city-wide patronage.

[63] See chapter 2 of the main report for presentation and explanation of the econometric methodology.

G2 Data collection and data manipulation

G2.1 Patronage data

The Bay of Plenty Regional Council (BOPRC) provided us with monthly patronage data, broken down by route, from to 2005–Q3 to 2009–Q2. This patronage data was broken down into:

- weekday patronage
- Saturday patronage.

The data ends in 2009–Q2 because there were quite dramatic changes to the Tauranga bus network in July 2009. Most notably, the routes on the network were changed substantially hence making a comparison of these routes before and afterwards impractical.

We also note there was no Sunday patronage from 2003–Q3 to 2009–Q2 because Sunday services were not introduced until July 2009.The BOPRC provided us with data on average patronage per quarter. From our examination of the data, we concluded the following:

- Average weekday patronage was calculated as total weekday patronage divided by the number of weekdays on which weekday services ran (ie weekdays with a public holiday were excluded).
- Average 'Saturday' patronage was calculated as total Saturday and public holiday patronage divided by the number of actual Saturdays (rather than the number of days on which a Saturday timetable ran).

The definition of 'Saturday' patronage is problematic because it does not make an adjustment for Saturdays on which no services were provided or public holidays that fell on a weekday but operated a 'Saturday' service.[64] This created a distortion when public holiday services were introduced in October 2006 (see table G.4) because 'Saturday' patronage went up but the number of actual Saturdays remained the same.[65] We controlled for this distortion in the econometric modelling using dummy variables.

We observed that some of the routes had very close interrelationships and therefore needed to be combined and treated as a single route group. Table G.1 shows how these routes were grouped together.

Table G.1 Route groupings

Route group	Route number	Route name	Notes
1&2	1	Mount-Bayfair	Routes 1 and 2 both ran on a circular route from the Mount to Bayfair. However, one route ran in a clockwise direction and the other ran in an anti-clockwise direction.
	2	Bayfair-Mount	
3	3	Belvedere Brookfield	
4&5	4	Matua Brookfield	Routes 1 and 2 both ran on a circular route from the Matua to Brookfield. However, one route ran in a clockwise direction and the other ran in an anti-clockwise direction.
	5	Brookfield Matua	
6	6	Papamoa (via Maungatapu)	
	6D	Papamoa Direct (via Harbour Bridge)	

[64] This appears to be an error in the spreadsheets provided to ENVBOP by their data provider.

[65] Obviously, we would like to control for this by dividing Saturday and public holiday patronage by the number of Saturdays and public holidays on which a service was provided in each year of operation. Unfortunately, we cannot do this because we do not have data on the later.

Route group	Route number	Route name	Notes
7	7	Greerton (via Merivale)	Route 7 previously operated on a standard service with ‘Greerton via Merivale’ and ‘Greeton Direct’ services. But in it was converted into ‘orbiter’-type services that go in both clockwise and anticlockwise directions.
	7D	Greerton Direct	
8	8	Windermere Ohauiti (via Greerton)	
9	9	Welcome Bay	
10	10	Bethlehem Brookfield	
11	11	Pyes Pa (via Sunvale)	
12	12	The Lakes	Route 12 was introduced in May 2008.

G2.2 Service data

The Tauranga bus system is a very interesting case study because there were a number of quite dramatic changes to the bus network and service timetables during the period covered. The key changes affecting weekday services[66] are shown in table G.2.

Table G.2 Timetable/service changes for weekday services

Route group	Route group name	Date	Details	% change in service trips	Notes
1&2	Mount-Bayfair/ Bayfair-Mount	Oct 07	Extension of hours on route 1 and doubling of frequency from hourly to 30 min on route 2	48%	Additional departures on route 1 at 8.30am and 7.15pm
3	Belvedere/ Brookfield	May 08	The Belvedere/Brookfield (3) route was changed so that it passed close to the Pillans Rd retirement village		
4&5	Matua-Brookfield/ Brookfield Matura	Dec 06	Doubling of frequency on route 4	50%	
		Oct 07	Extension of hrs on route 4 and doubling of frequency to 30 min on route 5.	36%	Additional departure on route 4 at 7.15pm
6	Papamoa	Dec 06	Doubling of frequency from hourly to 30 min (via express routes)	117%	All additional routes were introduced as direct routes via Harbour Bridge, whereas the previous routes were via Maungatapu

[66] We note that the ENVBOP, like most regional councils in New Zealand, did not document historic service changes in a systematic manner. Therefore the the key changes presented in tables F.2 and F.3 had to be drawn from a number of sources (including service trip data, service variation letters, promotional materials and historical timetables). These sources were often inconsistent so we had to use judgement in assessing and weighing their accuracy; tables F.2 and F.3 therefore represent ‘educated guesses’ based on a thorough investigation of the data.

Route group	Route group name	Date	Details	% change in service trips	Notes
7	Greerton	Oct 07	Additional services introduced in the transition to an 'orbiter' service	17%	Route 7 previously operated on a standard service with 'Greerton via Merivale' and 'Greeton Direct' services. But it was converted into 'orbiter'-type services that go in both clockwise and anticlockwise directions. This conversion was accompanied by a 17% increase in overall service trips
8	Windermere	Dec 06	Doubling of frequency from hourly to 30 min	108%	
9	Welcome Bay	Dec 06	Doubling of frequency from hourly to 30 min	92%	
		Oct 07	Extension of hours	9%	Additional depatures on route 9 at 6.05am, 6.40am and 7.15pm
10	Bethlehem Brookfield	Oct 07	Doubling of frequency from hourly to 30 min	83%	
12	The Lakes	May 08	New route was introduced		Route 12 was introduced in May 2008. We note that it covers a similar catchment to routes 7 and 11 and could potentially have stolen patronage from those routes

The key changes affecting Saturday services are shown in table G.3.

Table G.3 Timetable/service changes for Saturday services

Route group	Route group name	Date	Details	% change in service trips	Notes
4&5	Matua-Brookfield/ Brookfield Matura	Dec 06	Extension of hours on route 4	12%	Additional departures on route 4 before 8.00am and after 5.15pm
7	Greerton	Oct 07	Additional services introduced in the transition to an 'orbiter' service	125%	Route 7 previously operated on a standard service with 'Greerton via Merivale' and 'Greeton Direct' services. But it was converted into 'orbiter'-type services that go in both clockwise and anticlockwise directions. We estimate from investigation of timetables and service trip data that this was accompanied by an increase in service headway from 45 min to 20 min, hence there was a 125% increase in overall service trips
8	Windermere	Dec 06	Extension of hours on route 8	19%	Additional departures on route 8 before 8.00am and after 5.15pm
9	Welcome Bay	Dec 06	Extension of hours on route 9	16%	Additional departures on route 9 before 8.00am and after 5.15pm

G2.3 Other data

We collected and incorporated data on a number of explanatory variables: fares, petrol prices, retail sales and employment. Where applicable, these variables were then adjusted for inflation and hence the rest of the report refers to them as real fares, real petrol prices and real retail sales.

The retail sales and employment data reflect economic activity within the ‘Tauranga city’ territorial authority, which seems appropriate since we are only focusing on Tauranga city bus routes.

We also collected data on cars licensed by the territorial authority but, after examination we found evidence of substantial corruption in the data so it was discarded.

In section 2.2.2 of the main report, we explain why we decided against incorporating population statistics into the econometric analyses. In general, we have doubts about the statistical robustness of findings produced using population statistics because they are low frequency (ie data is only annual) low accuracy (ie data is only an estimate), exhibit low variance (ie populations exhibit steady growth rates over time) and could only be obtained for broad geographical regions (ie territorial authorities).

Ideally, econometric modelling should control for the impact of key historical events. Table G.4 shows key events that we have identified.

Table G.4 Miscellaneous events

Event	Months affected	Quarters affected	Notes relating to event
Public holiday services introduced	Oct 06 onwards	2006–Q3 onwards	Public holiday services were introduced on holidays that fell on a weekday or Saturday (except Christmas Day, Good Friday and Anzac Day. Prior to this, services did not operate on a public holiday.
Bus lanes began operation	Oct 07	2007–Q4	Bus lanes were painted on Hewletts Rd and began operation. Brochures on bus lanes were sent out. Only certain bus routes operate on Hewletts Rd (1&2 – Mount-Bayfair, 6 – Papamoa)
Crossing of the $2.00 nominal petrol price threshold	May 08 through Aug 08	2008–Q2, 2008–Q3	During the period from 22 May 08 to 13 August 08 the nominal price of regular petrol crossed the $2.00 threshold. There is reason to believe that the crossing of this threshold may have been a key trigger for behavioural change. (However, is important to note that the impact of thresholds like the $2.00 mark is not concrete – it may reflect a number of other issues around the same time (eg media attention on ‘peak oil’) and may very well have changed as people have become accustomed to higher petrol prices.)
Introduction of SuperGold Card	Oct 08	2008–Q3	The SuperGold Card was introduced in October 2008, providing free off-peak and weekend travel for persons over 65.
Larger buses introduced	Oct 08	2008–Q3	On routes 4, 5 and 10, 22-seat Hino buses were replaced with 29-seat MAN 10.160 buses, hence increasing capability. On route 6, four 29 MAN 10.160 buses were replaced with four 43-seat Volvo 5 buses
Easter holidays	March or April depending on calendar	Q1 or Q2 depending on calendar	The Easter holidays occur sometimes in March and sometimes in April, depending on the calendar at the time. This can affect patronage because the timetables are more limited and because patrons are on holiday and hence less likely to use the buses for transportation.
Tauranga Jazz Festival	March or April depending on calendar	Q1 or Q2 depending on calendar	Tauranga has a jazz festival that runs on weekends coinciding with the Easter holiday period mentioned above.

Based on the advice of a peer reviewer, we inquired when electronic ticketing was introduced. The BOPRC informed us that electronic ticketing was introduced in 2003, which pre-dates the dataset used for this research project (2005-Q3 to 2009-Q2) by some time.

We took into account the introduction of public holiday services in October 2006 in our econometric modelling. The introduction of public holiday services increased total 'Saturday' patronage. However, this created a 'jump' in the data because average Saturday patronage was calculated based on the number of Saturdays in a calendar, not the number of days in which a Saturday timetable operated. We adjusted for these 'jumps' in the data by using dummy variables.

During our econometric analysis (see section G.5 we used dummy variables to control for the impact of the $2.00 nominal petrol price threshold, the introduction of SuperGold Card and the Easter holidays/jazz festival. However, since the Easter holidays and the jazz festival occur at the same time each year they could not be distinguished; they were therefore integrated into the same variable.

G3 Graphical analysis

G3.1 Key themes from graphical analysis

Figures G.1 and G.2 show patronage growth across all routes, along with growth in explanatory variables. Each of these routes has been graphically analysed in turn (see sections G3.2 to G3.10). The overall themes and patterns arising from graphical analysis of these routes are:

- Improvements to weekday service timetables had a noticeable impact on weekday patronage.
- There is also evidence that improvements to weekday service timetables may have had a 'network effect' on weekend patronage by making public transport a more feasible transport option.
- Saturday patronage showed a dramatic jump in 2006-Q4 and 2007-Q1, attributable to the introduction of the public holiday services, as discussed in section G2.3.
- Saturday patronage also showed a drop in patronage in 2009-Q2, with patronage growth generally shifting from positive in 2009-Q1 to sharply negative in 2009-Q2. Investigation of the data at a monthly level shows that patronage fell for the months from March 2009 through to June 2009. The BOPRC suggested this could be due to a loss of data in the transition to the new ticketing system in July 2003.

Figure G.1 All Tauranga bus routes – analysis of weekday patronage growth

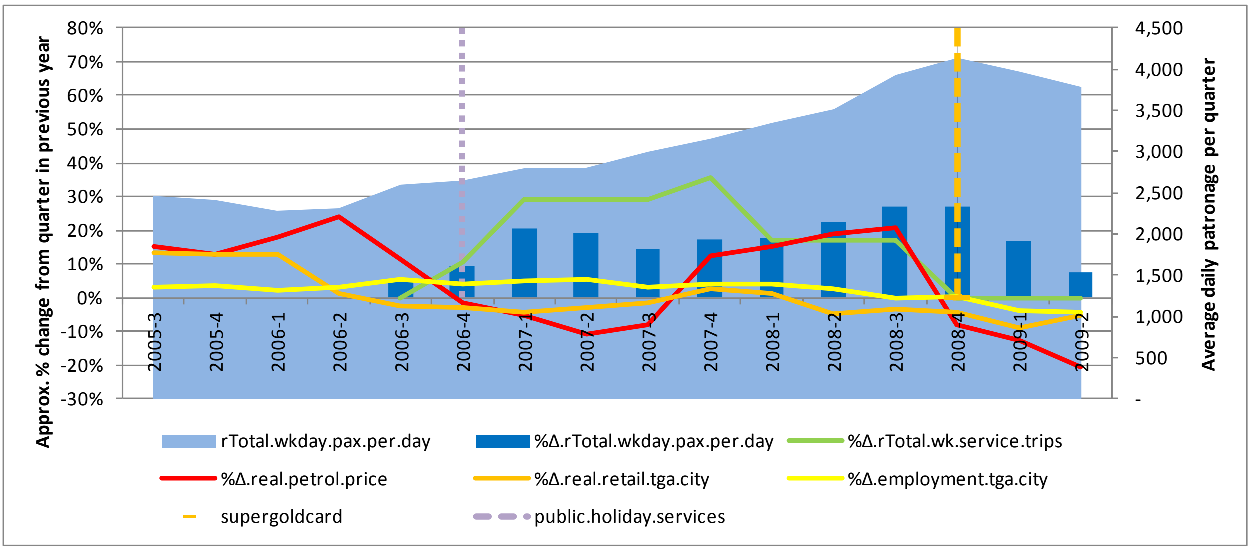
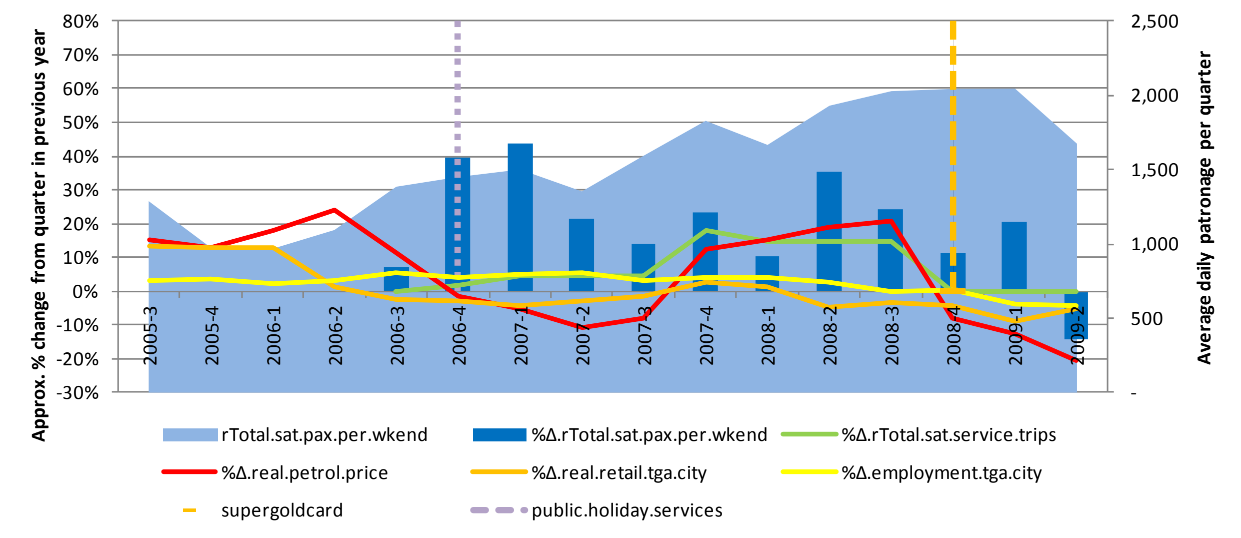


Figure G.2 All Tauranga bus routes – analysis of Saturday patronage growth



G3.2 Graphical analysis of Mount-Bayfair (1) and Bayfair-Mount (2) routes

This section shows graphical analysis of ticket sales for routes 1 and 2. Both of these routes follow the same circular path, except that one service goes in a clockwise direction while the other goes in an anti-clockwise direction. Figures G.3 and G.4, respectively, show growth in weekday and Saturday patronage.

The overall patterns from graphical analysis of routes 1 and 2 are:

- The improvements to service frequency in October 2007 have had a noticeable impact on weekday patronage growth; there may have been a further boost to weekday patronage when the SuperGold Card was introduced in October 2008.
- In theory, the introduction of a bus lane on Hewletts Rd in October 2007 (see section G2.3) could have had an impact on weekday patronage, but it is difficult to discern its impact from the improvements to service frequency around the same time.
- Saturday patronage showed a dramatic jump in 2006-Q4 and 2007-Q1, attributable to the introduction of the public holiday services, as discussed in section G2.3. That said, there was still strong growth in demand for weekend services throughout the period from 2006 to 2009.
- Saturday patronage showed sharp change from positive growth rate in 2009-Q1 to a negative growth rate in 2009-Q2.

Figure G.3 Mount-Bayfair (1) and Bayfair-Mount (2) – analysis of weekday patronage growth

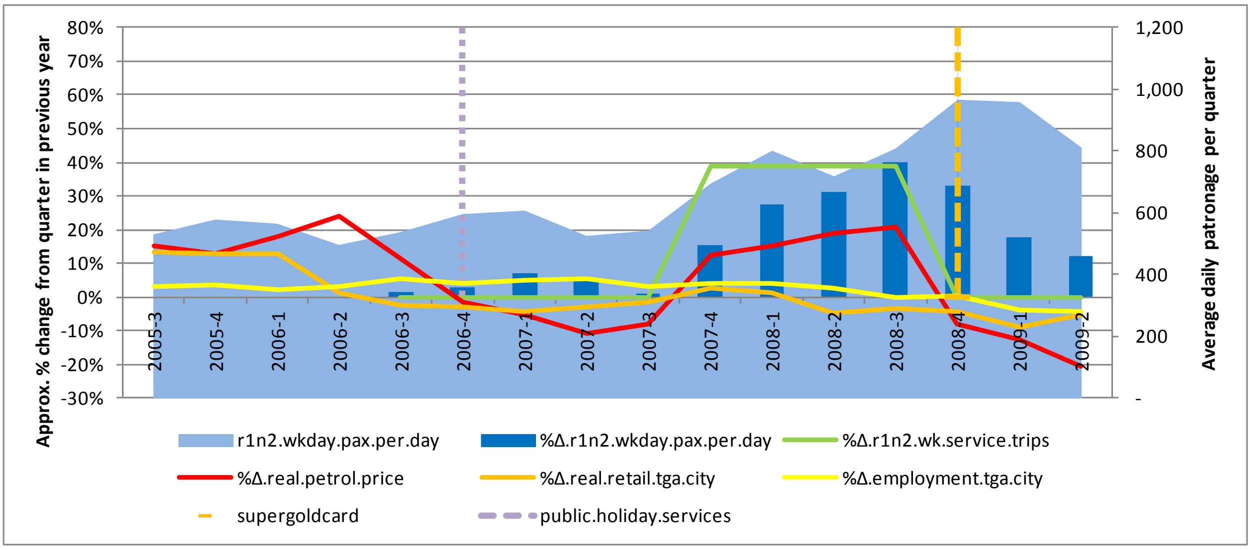
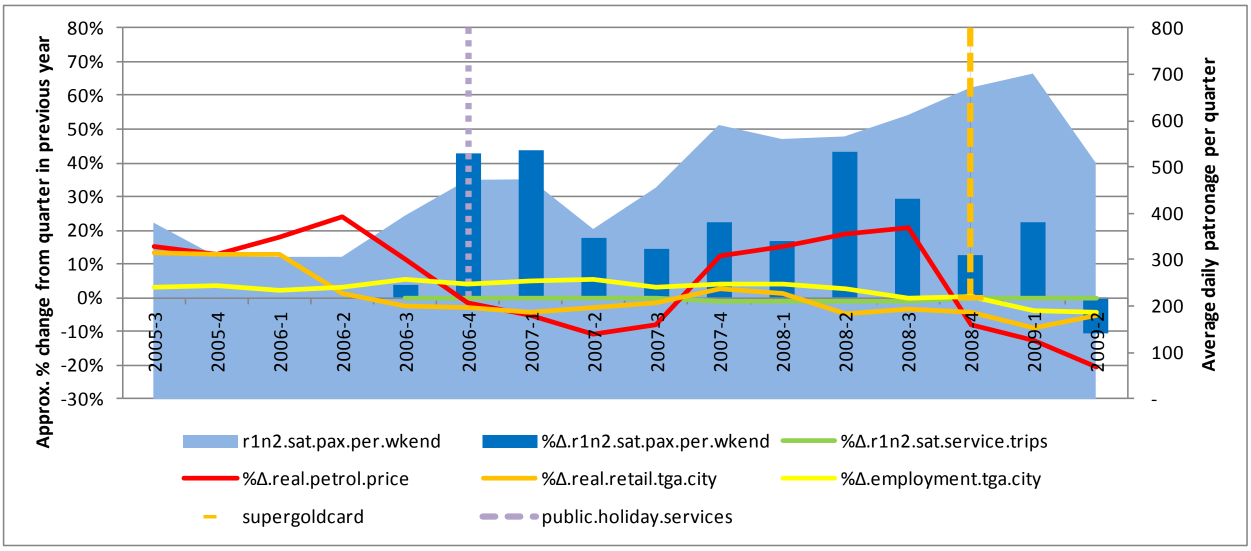


Figure G.4 – Mount-Bayfair (1) and Bayfair-Mount (2) – analysis of Saturday patronage growth



G3.3 Graphical analysis of Belvedere-Brookfield (3) route

This section shows graphical analysis of ticket sales for route 3. Figures G.5 and G.6, respectively, show growth in weekday and Saturday patronage.

The overall patterns from graphical analysis of route 3 are:

- Weekday patronage was reasonably flat during the period covered, but this is plausible given that there were no service improvements on this route.
- Saturday patronage showed a dramatic jump in 2006-Q4 and 2007-Q1, attributable to the introduction of public holiday services, as discussed in section G2.3.
- Saturday patronage showed sharp change from positive growth rate in 2009-Q1 to a negative growth rate in 2009-Q2.

Figure G.5 Belvedere-Brookfield (3) – analysis of weekday patronage growth

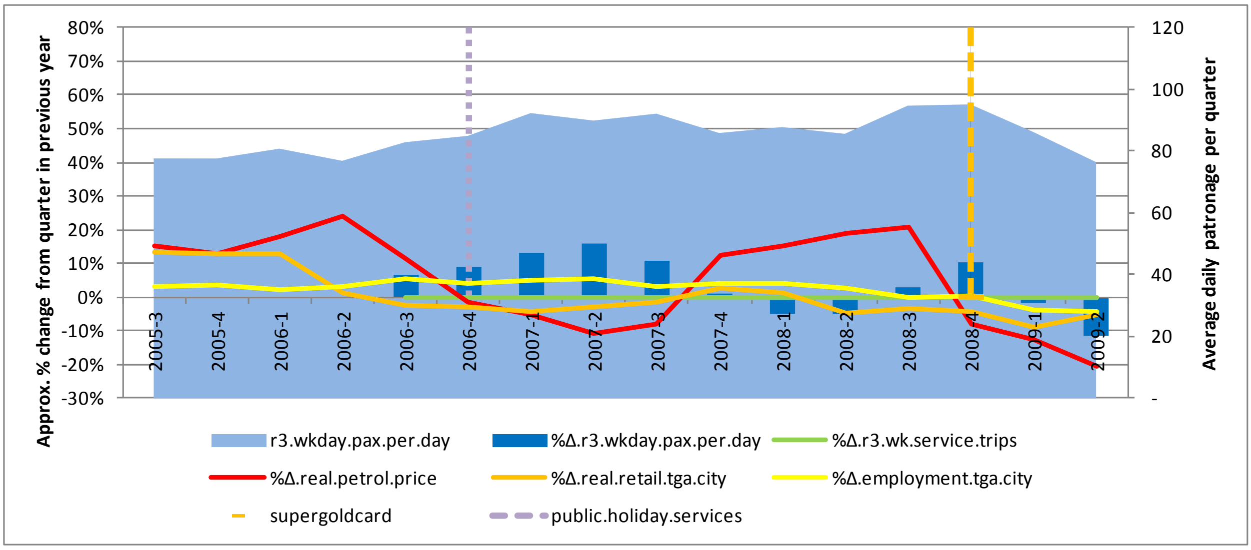
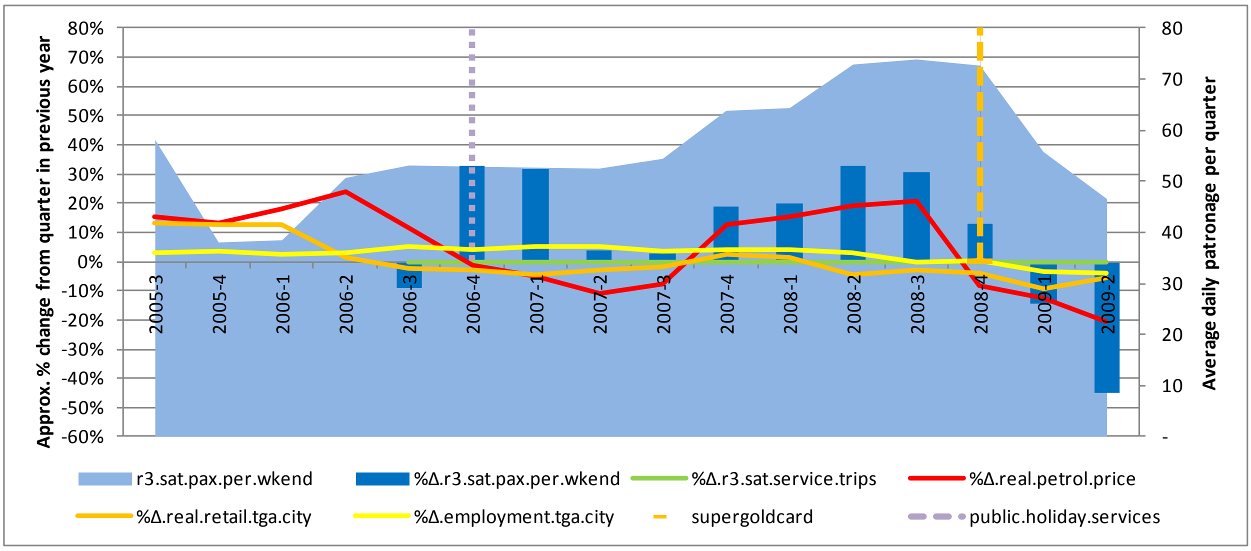


Figure G.6 Belvedere-Brookfield (3) – analysis of Saturday patronage growth



G3.4 Graphical analysis of Matua-Brookfield (4) and Brookfield-Matua (5) routes

This section shows graphical analysis of ticket sales for routes 4 and 5. Both of these routes follow the same circular path, except that one service goes in a clockwise direction while the other goes in an anti-clockwise direction. Figures G.7 and G.8, respectively, show growth in weekday and Saturday patronage.

The overall patterns from graphical analysis of routes 4 and 5 are:

- The improvements to service frequency in December 2006 and again in October 2007 have had a noticeable impact on weekday patronage growth; there may have been a further boost to weekday patronage when the SuperGold Card was introduced in October 2008.
- Saturday patronage showed a dramatic jump in 2006–Q4 and 2007–Q1, attributable to the introduction of the public holiday services, as discussed in section G2.3.

- Saturday patronage showed sharp change from positive growth rate in 2009–Q1 to a negative growth rate in 2009–Q2.

Figure G.7 Matua-Brookfield (4) and Brookfield-Matua (5) – analysis of weekday patronage growth

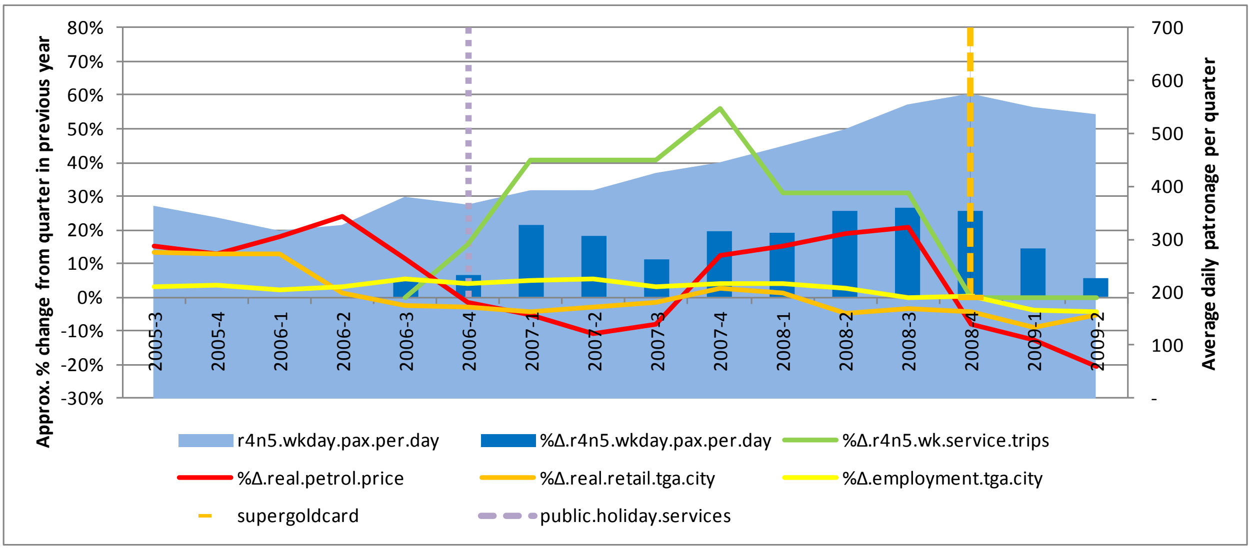
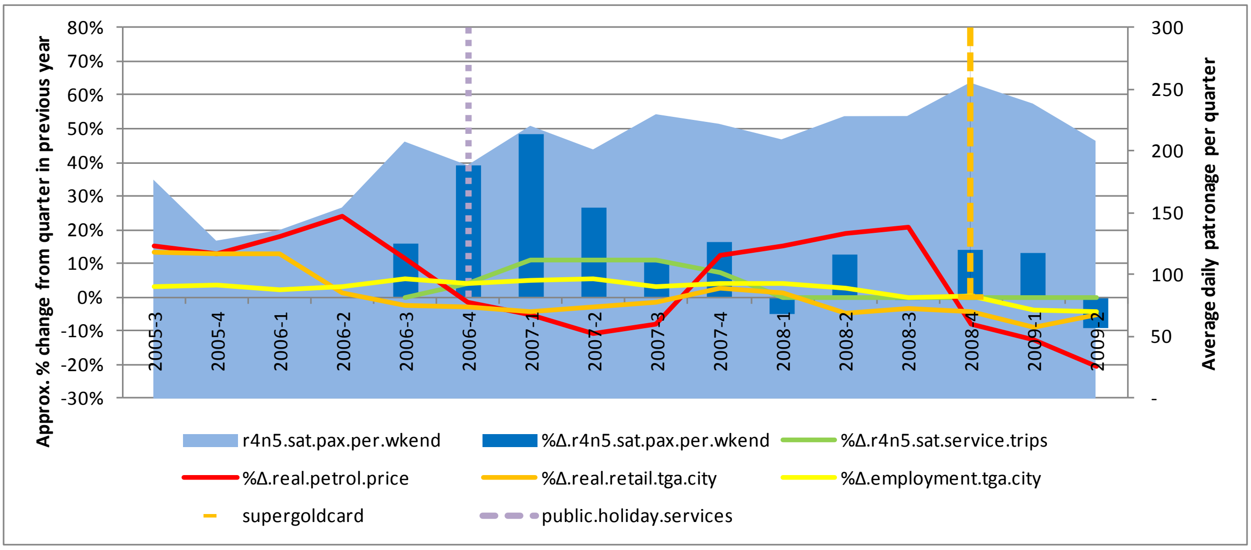


Figure G.8 Matua-Brookfield (4) and Brookfield-Matua (5) – analysis of Saturday patronage growth



G3.5 Graphical analysis of Papamoa (6)

This section shows graphical analysis of ticket sales for route 6. Figures G.9 and G.10, respectively, show growth in weekday and Saturday patronage.

The overall patterns from graphical analysis of route 6 are:

- The improvements to service frequency (via express services) in December 2006 had a noticable impact on weekday patronage growth. There is evidence from figure G.9 that the impact of the express services on patronage was more ‘drawn out’; patronage increased by about 20% following the introduction of express services and then by a further 20% in the subsequent year. We theorise that the patronage response to peak-time services may have been more gradual than with improvements to off-peak services.

- Again, in theory, the introduction of a bus lane on Hewletts Rd in October 2007 (see section G2.3) could have had an impact on weekday patronage, but it is difficult to discern its impact from the delayed impact of the express services in December 2006.
- Saturday patronage showed a dramatic jump in 2006-Q4 and 2007-Q1, attributable to the introduction of the public holiday services, as discussed in section G2.3. Again, as with other routes, there was still strong growth in demand for weekend services throughout the period from 2006 to 2009.
- Saturday patronage showed sharp change from a positive growth rate in 2009-Q1 to a negative growth rate in 2009-Q2.

Figure G.9 Papamoa (6) – analysis of weekday patronage growth

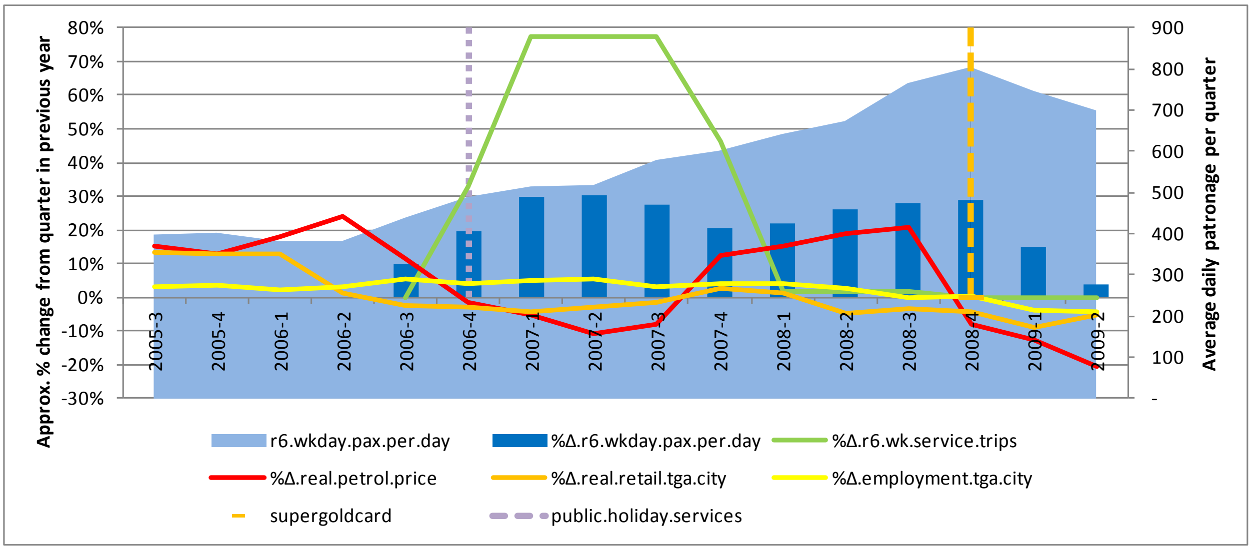
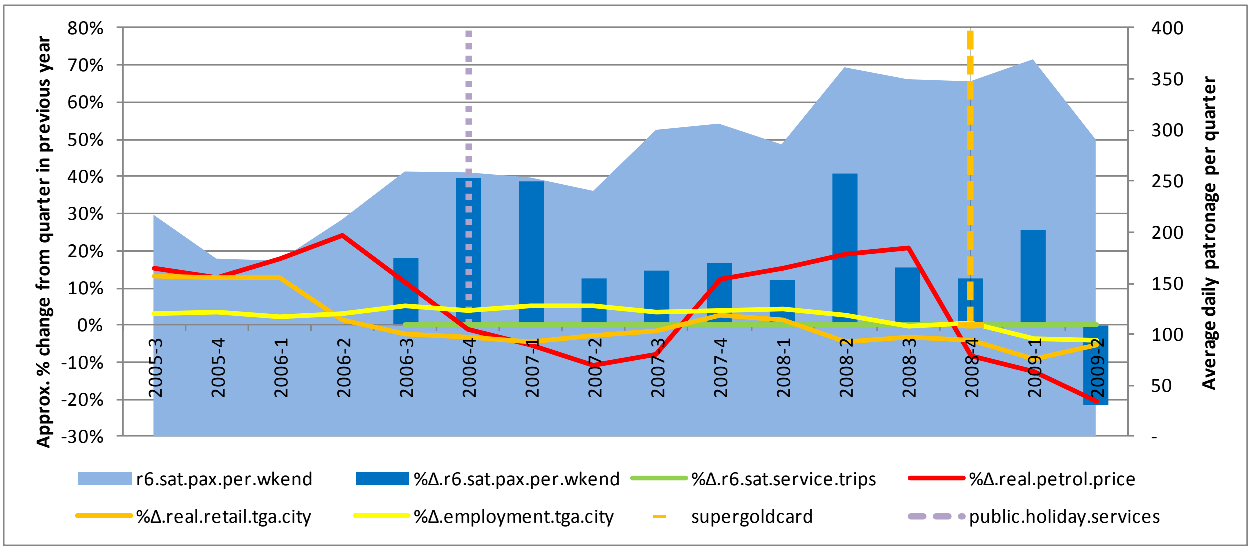


Figure G.10 Matua-Brookfield (4) and Brookfield-Matua (5) services – analysis of Saturday patronage growth



G3.6 Graphical analysis of Greerton (7)

This section shows graphical analysis of ticket sales for route 7. This route previously operated on a standard service with 'Greerton via Merivale' and 'Greeton Direct' services. But in October 2007 it was converted into 'orbiter'-type services that go in both clockwise and anticlockwise directions. This conversion appears to have been accompanied by a slight increase in weekday trips and a large increase in weekend trips.

Figures G.11 and G.12, respectively, show growth in weekday and Saturday patronage. The overall patterns from graphical analysis of route 7 are:

- Weekday patronage was very stable throughout the period covered; weekday patronage appears to have been unaffected by the conversion into an 'orbiter'-type service, even despite the slight increase in weekday trips.
- Saturday patronage showed a dramatic jump in 2006-Q4 and 2007-Q1, attributable to the introduction of the public holiday services, as discussed in section G2.3. There was also an increase in weekend patronage associated with the conversion to an 'orbiter'-type service in October 2007.
- Saturday patronage showed a sharp change from positive growth rate in 2009-Q1 to a negative growth rate in 2009-Q2.

Figure G.11 Greerton (7) – analysis of weekday patronage growth

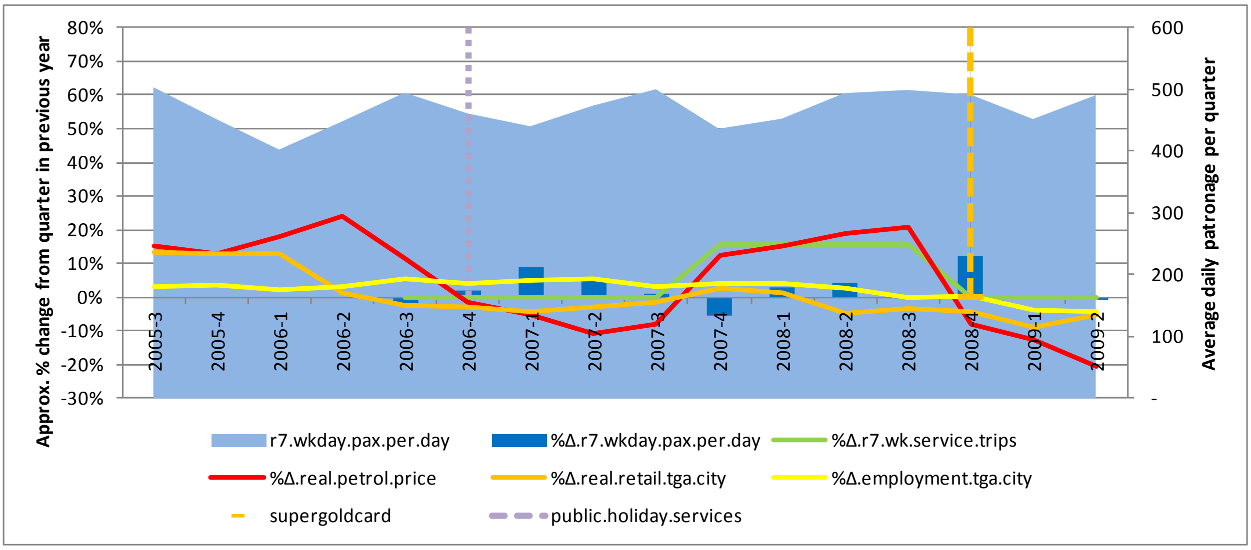
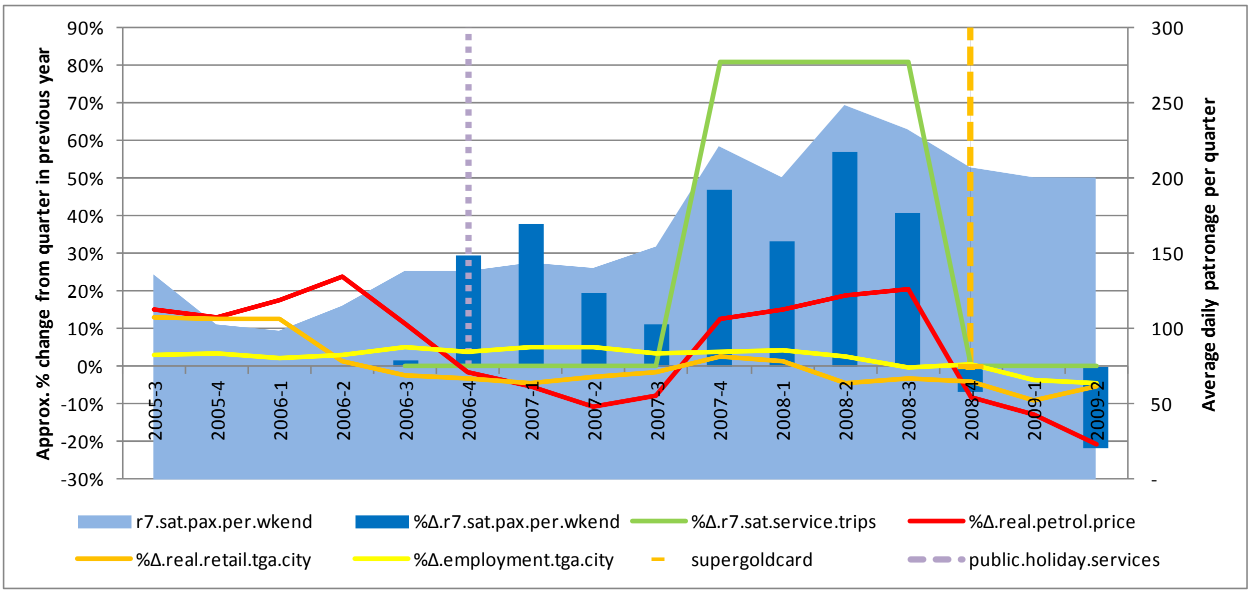


Figure G.12 Greerton (7) – analysis of Saturday patronage growth



G3.7 Graphical analysis of Windermere-Ohauiti (8)

This section shows graphical analysis of ticket sales for route 8. Figures G.13 and G.14, respectively, show growth in weekday and Saturday patronage.

The overall patterns from graphical analysis of route 8 are:

- The improvements to weekday service frequency (doubling from hourly to 30 minute headway) in December 2006 had a large and noticeable impact on weekday patronage growth.
- Saturday patronage showed a dramatic jump in 2006-Q4 and 2007-Q1, and some of this is attributable to the introduction of the public holiday services, as discussed in section G2.3.
- The extension of Saturday hours of operation in December 2006 appear to have had an even more noticeable impact on Saturday patronage; however, we acknowledge that some of this could be due to 'network effects': the improvements to weekday service frequency may make the public transport be seen as a feasible transport option, hence increasing the appeal of weekend use.

Figure G.13 Windermere-Ohauiti (8) – analysis of weekday patronage growth

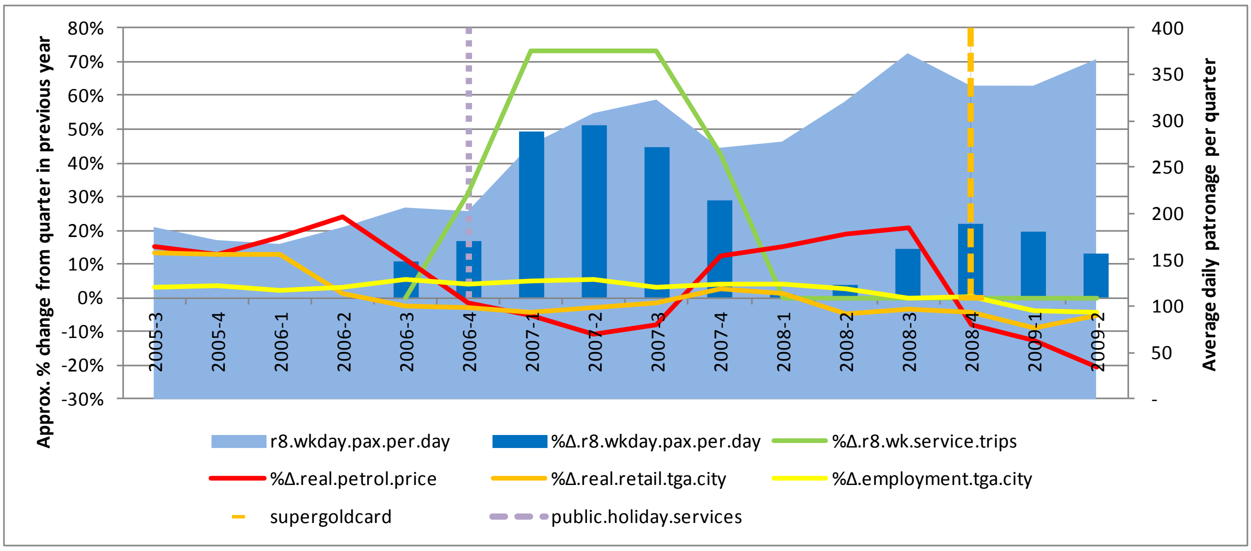
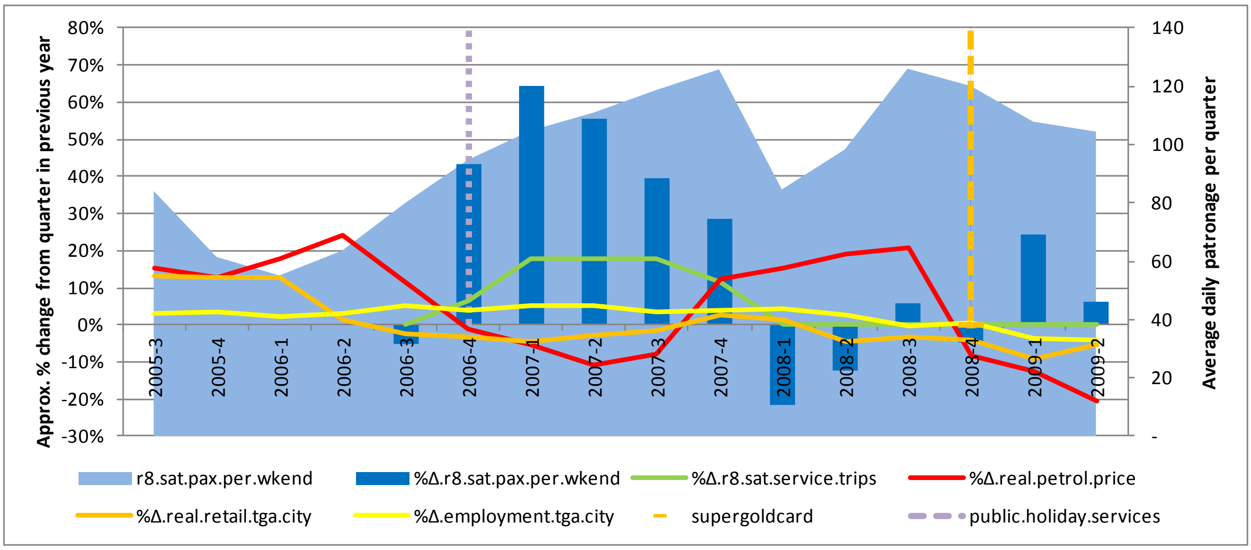


Figure G.14 Windermere-Ohauiti (8) – analysis of Saturday patronage growth



G3.8 Graphical analysis of Welcome Bay (9)

This section shows graphical analysis of ticket sales for route 9. Figures G.15 and G.16, respectively, show growth in weekday and Saturday patronage.

The overall patterns from graphical analysis of route 9 are:

- The improvements to weekday service frequency (doubling from hourly to 30 minute headway) in December 2006 had a large and noticeable impact on weekday patronage growth.
- The extension of Saturday hours of operation in December 2006 appear to have had an even more noticeable impact on Saturday patronage; however, we acknowledge that some of this could be due to 'network effects': the improvements to weekday service frequency may make the public transport be seen as a feasible transport option, hence increasing the appeal of weekend use.
- Saturday patronage showed sharp change from positive growth rate in 2009-Q1 to a negative growth rate in 2009-Q2.

Figure G.15 Welcome Bay (9) – analysis of weekday patronage growth

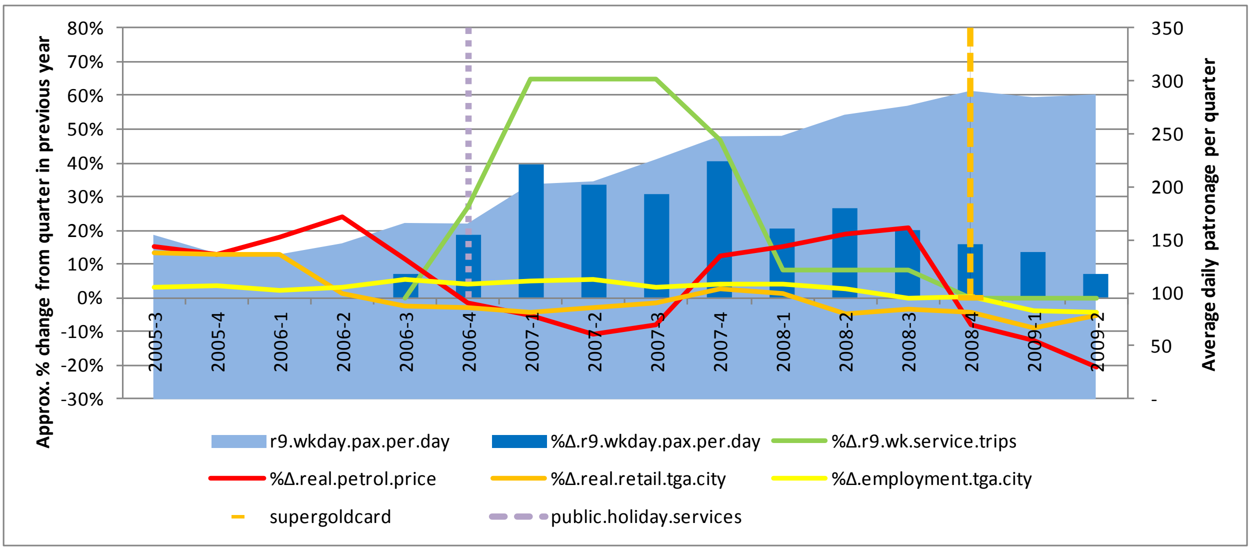
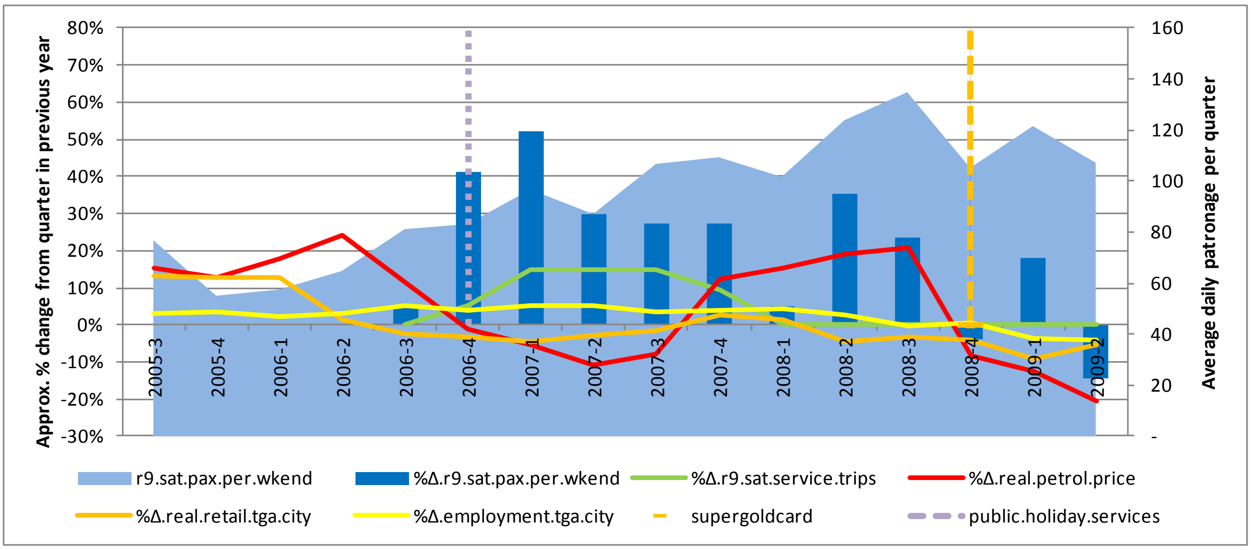


Figure G.16 Welcome Bay (9) – analysis of Saturday patronage growth



G3.9 Graphical analysis of Bethlehem Brookfield (10)

This section shows graphical analysis of ticket sales for route 10. Figures G.17 and G.18, respectively, show growth in weekday and Saturday patronage.

The overall patterns from graphical analysis of route 10 are:

- The improvements to weekday service frequency (doubling from hourly to 30 minute headway) in October 2007 had a large and noticeable impact on weekday patronage growth.
- Saturday patronage showed a dramatic jump in 2006-Q4 and 2007-Q1, attributable to the introduction of public holiday services, as discussed in section G2.3.
- There is also graphical evidence of further 'network effects'. There were no improvements to the Saturday service timetable on route 10, but we still see a slight jump in Saturday patronage around 2007-Q4; this coincides with the improvements to weekday service frequency.
- Saturday patronage showed sharp change from a positive growth rate in 2009-Q1 to a negative growth rate in 2009-Q2.

Figure G.17 Bethlehem Brookfield (10) – analysis of weekday patronage growth

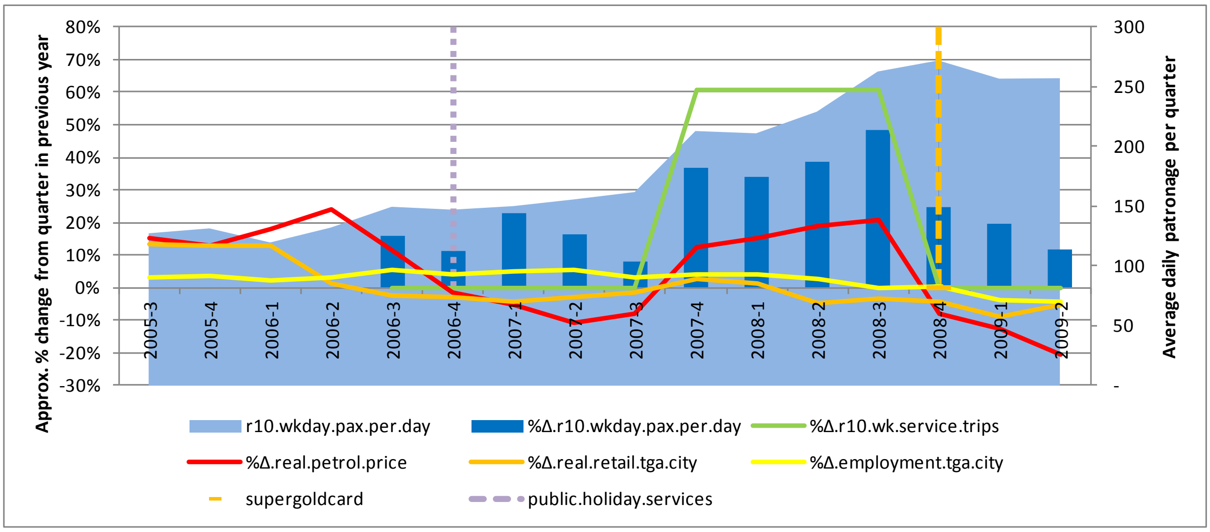
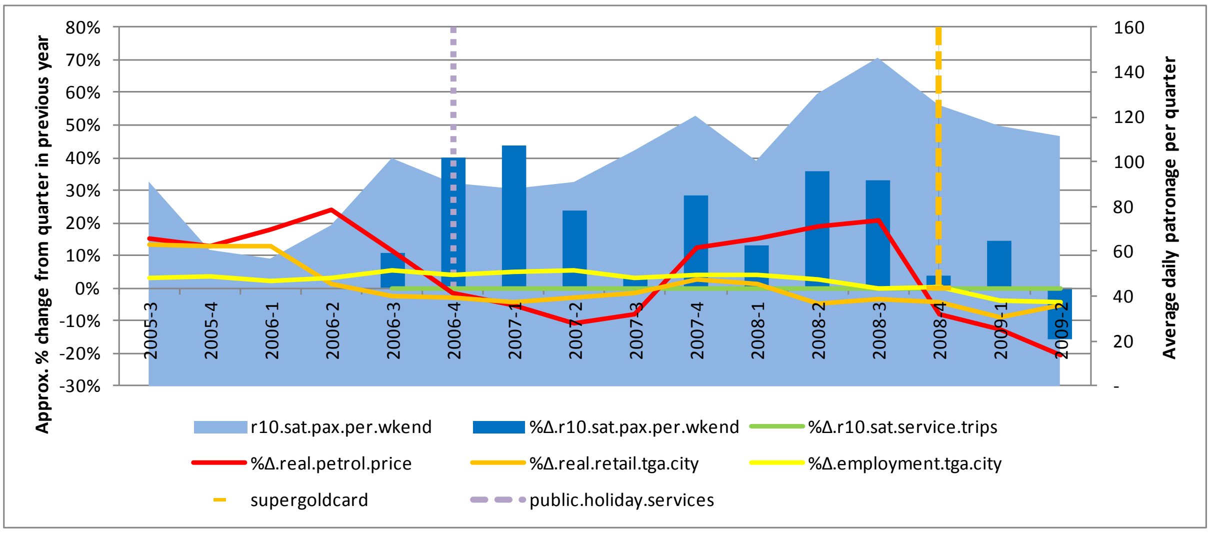


Figure G.18 Bethlehem Brookfield (10) – analysis of Saturday patronage growth



G3.10 Graphical analysis of Pyes Pa (11)

This section shows graphical analysis of ticket sales for route 11. Figures G.19 and G.20, respectively, show growth in weekday and Saturday patronage.

The overall patterns from graphical analysis of route 11 are:

- There were no improvements to the weekday service timetable. There was, however, a slight increase in patronage (c.+10%) 2007-Q4, and this is unexplained.
- Saturday patronage showed a dramatic jump in 2006-Q4 and 2007-Q1, attributable to the introduction of the public holiday services, as discussed in section G2.3.
- Saturday patronage showed sharp change from a positive growth rate in 2009-Q1 to a negative growth rate in 2009-Q2.

Figure G.19 Pyes Pa (11) – analysis of weekday patronage growth

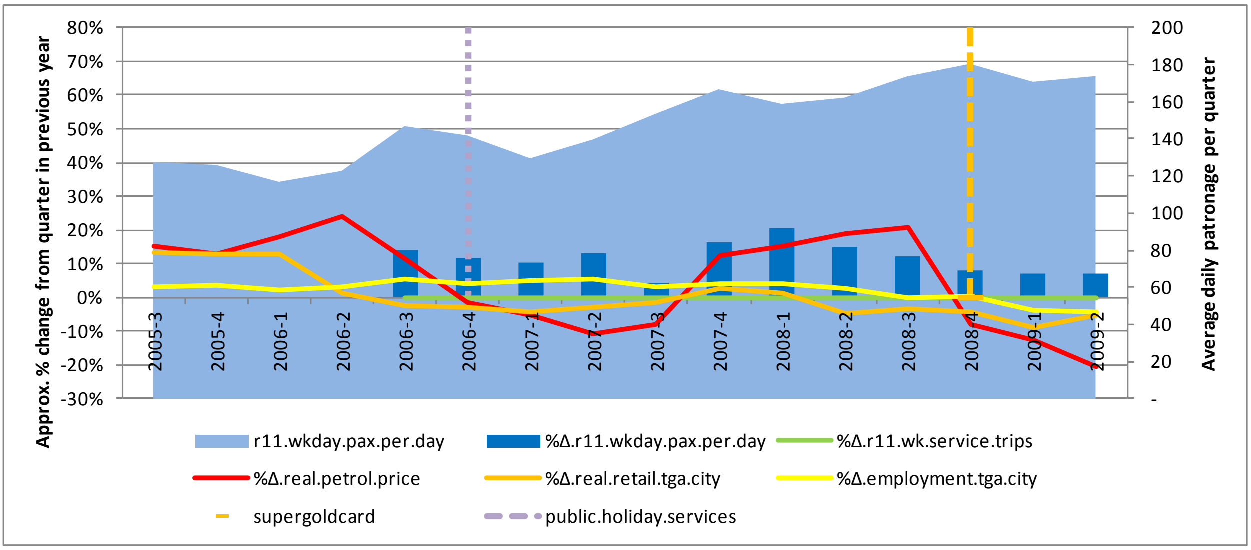
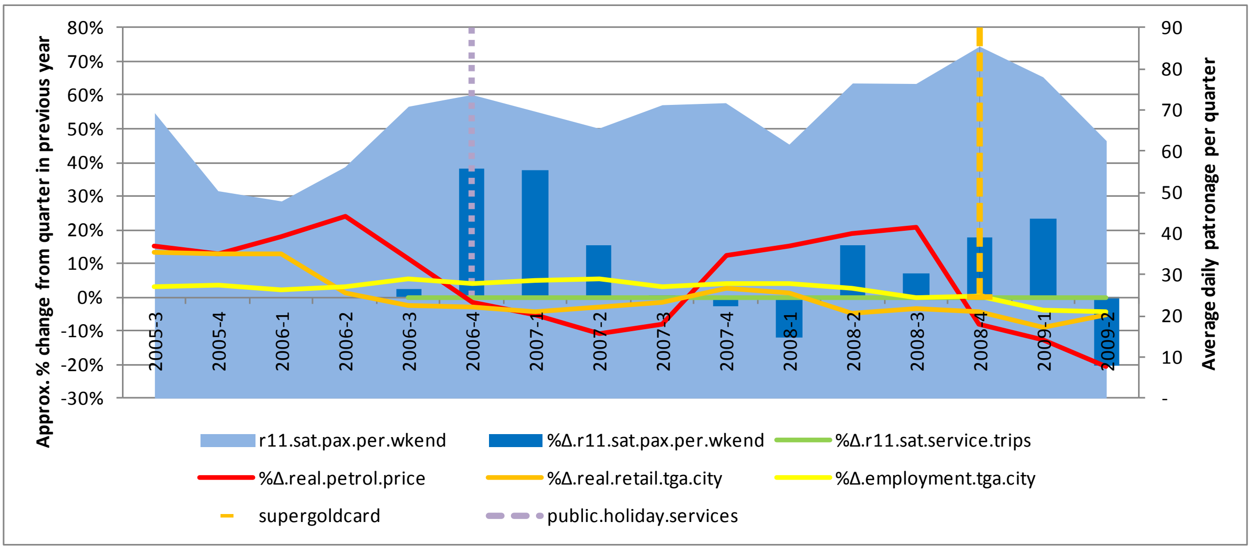


Figure G.20 Pyes Pa (11) – analysis of Saturday patronage growth



G4 Data analysis

G4.1 Multicollinearity analysis

As noted in section 2.4.1 of the main report, high correlations between explanatory variables can make econometric estimation difficult. This section uses correlation tables to examine the extent to which such correlations might be problematic.

Table G.5 shows the correlations between the explanatory variables for the period from 2005-Q3 to 2009-Q2.

- There are a number of +1.0 correlations between service variables. These are due to the fact that services were improved on weekday and Saturday timetables at the same time. However, this correlation is irrelevant since weekday and Saturday patronage were modelled separately.
- The introduction of bus lanes on Hewlett's Road in October 2007 could (hypothetically) have had an impact on certain routes (1&2 and 6). However, these routes also had timetable service improvements around the same time, creating correlations of +0.7 and +0.6 and making estimation of the impact of the bus lane difficult. We have assumed that the bus lane would have a negligible impact on patronage (at least relative to the timetable service improvements) so bus lanes were omitted from the econometric models tested and presented in section G5.
- There is a +0.7 correlation between petrol price elasticities and the crossing of the $2.00 nominal petrol price threshold. This means that the coefficients relating to these variables need to be interpreted with some caution.
- There are also high correlations between the introduction of the SuperGold Card and key economic variables associated with recession in 2008 (falling petrol prices, retail sales and employment). These correlations are concerning. One solution to this problem is to disaggregate patronage demographically (ie adult, senior, child, tertiary student) because one would expect that SuperGold only affected senior patronage while employment and petrol prices would primarily affect adult, child and tertiary patronage. Although this approach has considerable merit it requires more time and resources than were available for this research project.
- There is a perfect (1.0) correlation between the Tauranga Jazz Festival and Easter because the jazz festival occurs every Easter. To address this, the jazz festival was removed from further analysis and we assumed that the Easter variable encompassed a number of factors including the jazz festival.

Table G.5 Correlations between explanatory variables for period from 2005-Q3 to 2009-Q2

	r1_2.wk.service.frequency_hours.Oct07	r4_5.sat.service.hours.Dec06	r4_5.wk.service.frequency.Dec06	r4_5.wk.service.frequency_hours.Oct07	r6.wk.service.express.Dec06	r6.wk.service.express.Dec06.lag1	r7.sat.service.frequency.orbiter.Dec06	r7.wk.service.frequency.orbiter.Oct07	r8.sat.service.hours.Dec06	r8.wk.service.frequency.Dec06	r9.sat.service.hours.Dec06	r9.wk.service.frequency.Dec06	r9.wk.service.hours.Oct07	r10.wk.service.frequency.Oct07	r7.paxgrowth.route12	r8.paxgrowth.route12	r11.paxgrowth.route12	r3.pillans.rd.route.change.dummyOct06	r4n5.larger.buses.dummy.Oct08	r6.larger.buses.dummy.Oct08	r10.larger.buses.dummy.Oct08	all.sat.public.holiday.services.dummy.Oct06	all.wk.bus.lanes.introduced.dummy.Oct07	real.petrol.price	nominal.petrol.price.threshold.dummy	supergoldcard.dummy	all.sat.public.holiday.services.dummy.2006Q4	all.sat.public.holiday.services.dummy.2007Q1	all.sat.jazz.festival	Easter.dummy	real.retail.tga.city	employment.tga.city
r1_2.wk.service.frequency_hours.Oct07	1.0																															
r4_5.sat.service.hours.Dec06	0.0	1.0																														
r4_5.wk.service.frequency.Dec06	0.0	1.0	1.0																													
r4_5.wk.service.frequency_hours.Oct07	0.0	0.1	0.1	1.0																												
r6.wk.service.express.Dec06	0.0	0.0	0.0	0.0	1.0																											
r6.wk.service.express.Dec06.lag1	0.0	0.0	0.0	0.0	0.0	1.0																										
r7.sat.service.frequency.orbiter.Dec06	0.0	0.0	0.0	0.0	0.0	0.0	1.0																									
r7.wk.service.frequency.orbiter.Oct07	0.0	0.0	0.0	0.0	0.0	0.0	1.0	1.0																								
r8.sat.service.hours.Dec06	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.0																							
r8.wk.service.frequency.Dec06	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.0	1.0																						
r9.sat.service.hours.Dec06	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.0																					
r9.wk.service.frequency.Dec06	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.0	1.0																				
r9.wk.service.hours.Oct07	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.1	1.0																			
r10.wk.service.frequency.Oct07	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.0																		
r7.paxgrowth.route12	0.0	0.0	0.0	0.0	0.0	0.0	0.4	0.4	0.0	0.0	0.0	0.0	0.0	0.0	1.0																	
r8.paxgrowth.route12	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.0																
r11.paxgrowth.route12	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.0															
r3.pillans.rd.route.change.dummyOct06	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.0														
r4n5.larger.buses.dummy.Oct08	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.0													
r6.larger.buses.dummy.Oct08	0.0	0.0	0.0	0.0	0.0	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.0												
r10.larger.buses.dummy.Oct08	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.0											
all.sat.public.holiday.services.dummy.Oct06	-0.1	0.2	0.2	-0.1	0.2	-0.1	-0.1	-0.1	0.2	0.2	0.2	0.2	-0.1	-0.1	-0.1	-0.1	-0.1	0.3	-0.1	-0.1	-0.1	1.0										
all.wk.bus.lanes.introduced.dummy.Oct07	0.7	-0.1	-0.1	-0.1	0.1	0.6	-0.1	-0.1	-0.1	-0.1	-0.1	-0.1	-0.1	-0.1	-0.1	-0.1	-0.1	-0.1	0.0	0.0	0.0	-0.2	1.0									
real.petrol.price	0.2	-0.1	-0.1	0.2	-0.1	0.2	0.2	0.2	-0.1	-0.1	-0.1	-0.1	0.2	0.2	0.0	0.0	0.0	-0.1	-0.2	-0.2	-0.2	-0.4	0.3	1.0								
nominal.petrol.price.threshold.dummy	0.2	0.0	0.0	0.2	0.0	0.2	0.2	0.2	0.0	0.0	0.0	0.0	0.2	0.2	0.1	0.1	0.1	0.0	-0.1	-0.1	-0.1	-0.1	0.2	0.7	1.0							
supergoldcard.dummy	-0.1	-0.1	-0.1	-0.1	-0.1	-0.1	-0.1	-0.1	-0.1	-0.1	-0.1	-0.1	-0.1	-0.1	0.2	0.2	0.2	-0.1	0.3	0.3	0.3	-0.4	-0.2	-0.6	-0.5	1.0						
all.sat.public.holiday.services.dummy.2006Q4	-0.1	0.0	0.0	-0.1	0.0	-0.1	-0.1	-0.1	0.0	0.0	0.0	0.0	-0.1	-0.1	-0.1	-0.1	-0.1	0.1	-0.1	-0.1	-0.1	0.4	-0.1	-0.1	-0.1	-0.2	1.0					
all.sat.public.holiday.services.dummy.2007Q1	-0.1	0.1	0.1	-0.1	0.1	-0.1	-0.1	-0.1	0.1	0.1	0.1	0.1	-0.1	-0.1	-0.1	-0.1	-0.1	0.1	-0.1	-0.1	-0.1	0.4	-0.1	-0.1	-0.1	-0.2	-0.1	1.0				
all.sat.jazz.festival	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	-0.1	-0.1	-0.1	0.0	0.0	0.0	0.0	0.0	0.0	-0.1	-0.6	0.0	0.0	0.0	1.0			
Easter.dummy	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	-0.1	-0.1	-0.1	0.0	0.0	0.0	0.0	0.0	0.0	-0.1	-0.6	0.0	0.0	0.0	1.0	1.0		
real.retail.tga.city	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	-0.2	-0.2	-0.2	0.0	-0.2	-0.2	-0.2	0.0	0.2	0.5	0.0	-0.6	0.0	-0.1	0.5	0.5	1.0	
employment.tga.city	0.0	0.1	0.1	0.0	0.1	0.0	0.0	0.0	0.1	0.1	0.1	0.1	0.0	0.0	-0.2	-0.2	-0.2	0.1	-0.2	-0.2	-0.2	0.5	0.0	0.4	0.2	-0.8	0.2	0.3	0.0	0.0	0.6	1.0

G4.2 Stationarity analysis

In section 2.4.2 of the main report we noted that the conventional approach in transport economics is to carry out econometric regressions with all of the variables defined in levels. However, with this approach, there is a risk that the regressions can lead to spurious results if the variables are classed as nonstationary (ie they exhibit strong trends over time).

Our approach to mitigate this risk is to take seasonal differences and to look at growth rates in patronage and explanatory variables between one quarter and the preceding quarters. There is still some risk of nonstationarity and/or insufficient variation in the explanatory variables so we have proceeded with formal testing to further mitigate against the risk of spurious results.

Table G.6 shows testing for stationarity or nonstationarity of key explanatory variables and tables G.7 to G.8 show testing for stationarity or nonstationarity of dependent variables. These tests were inconclusive. But this is unsurprising due to the short period covered (ie four years of data). However, a glance at the graphs of the data shown in section F3 gives weight to our assumption of stationarity.

Table G.6 Stationarity of continuous explanatory variables

		Augmented Dickey Fuller Test for stationarity[a]			KPSS test for nonstationarity[a]			
		Null hypothesis: variable is nonstationary			Null hypothesis: variable is stationary			
Variable[b]	**Period**	**Critical value**	**p-value**	**Decision**	**Critical value**	**p-value**	**Decision**	**Conclusion**
%Δ in real petrol prices	2005-Q4 to 2009-Q4	-0.73	0.96	Do not reject null → series is nonstationary	0.103	>0.10	Do not reject null → series is stationary	Inconclusive
%Δ in Tauranga city real retail sales	2005-Q4 to 2009-Q4	-1.42	0.79	Do not reject null → series is nonstationary	0.180	>0.10	Do not reject null → series is stationary	Inconclusive
%Δ in Tauranga city employment	2005-Q4 to 2009-Q4	0.08	0.99	Do not reject null → series is nonstationary	0.313	>0.10	Do not reject null → series is stationary	Inconclusive

(a) The ADF test incorporated 4 lags and the KPSS test employed long version of the truncation lag parameter

(b) Service variables and real fare were excluded from the analysis because they representation 'one-off' structural changes that cannot plausibly be regarded as stationary, regardless of the results of empirical testing.

Table G.7 Stationarity of dependent variable (weekday patronage)

			Augmented Dickey Fuller Test for stationarity[(a)]			KPSS test for nonstationarity[(a)]			
			Null hypothesis: variable is nonstationary			Null hypothesis: variable is stationary			
Variable	**Route**	**Period**	**t-statistic**	**p-value**	**Decision**	**t-statistic**	**p-value**	**Decision**	**Conclusion**
%Δ in weekday patronage	1n2	2005-Q4 to 2009-Q4	-1.29	0.84	Do not reject null → series is nonstationary	0.114	>0.10	Do not reject null → series is stationary	Inconclusive
%Δ in weekday patronage	3	2005-Q4 to 2009-Q4	-3.57	0.05	Do not reject null → series is nonstationary	0.262	>0.10	Do not reject null → series is stationary	Inconclusive
%Δ in weekday patronage	4n5	2005-Q4 to 2009-Q4	-0.94	0.93	Do not reject null → series is nonstationary	0.158	>0.10	Do not reject null → series is stationary	Inconclusive
%Δ in weekday patronage	6	2005-Q4 to 2009-Q4	-1.47	0.77	Do not reject null → series is nonstationary	0.147	>0.10	Do not reject null → series is stationary	Inconclusive
%Δ in weekday patronage	7	2005-Q4 to 2009-Q4	-1.22	0.87	Do not reject null → series is nonstationary	0.167	>0.10	Do not reject null → series is stationary	Inconclusive
%Δ in weekday patronage	8	2005-Q4 to 2009-Q4	-3.32	0.09	Do not reject null → series is nonstationary	0.087	>0.10	Do not reject null → series is stationary	Inconclusive
%Δ in weekday patronage	9	2005-Q4 to 2009-Q4	-2.59	0.35	Do not reject null → series is nonstationary	0.151	>0.10	Do not reject null → series is stationary	Inconclusive
%Δ in weekday patronage	10	2005-Q4 to 2009-Q4	-0.48	0.98	Do not reject null → series is nonstationary	0.135	>0.10	Do not reject null → series is stationary	Inconclusive
%Δ in weekday patronage	11	2005-Q4 to 2009-Q4	-0.81	0.95	Do not reject null → series is nonstationary	0.104	>0.10	Do not reject null → series is stationary	Inconclusive

(a) The ADF test incorporated 4 lags and the KPSS test employed long version of the truncation lag parameter

Table G.8 Stationarity of dependent variable (Saturday patronage)

			Augmented Dickey Fuller Test for stationarity[(a)]			KPSS test for nonstationarity[(a)]			
			Null hypothesis: variable is nonstationary			Null hypothesis: variable is stationary			
Variable	**Route**	**Period**	**t-statistic**	**p-value**	**Decision**	**t-statistic**	**p-value**	**Decision**	**Conclusion**
%Δ in Saturday patronage	1n2	2005-Q4 to 2009-Q4	-1.16	0.89	Do not reject null → series is nonstationary	0.128	>0.10	Do not reject null → series is stationary	Inconclusive
%Δ in Saturday patronage	3	2005-Q4 to 2009-Q4	-0.98	0.92	Do not reject null → series is nonstationary	0.145	>0.10	Do not reject null → series is stationary	Inconclusive
%Δ in Saturday patronage	4n5	2005-Q4 to 2009-Q4	-1.25	0.86	Do not reject null → series is nonstationary	0.109	>0.10	Do not reject null → series is stationary	Inconclusive
%Δ in Saturday patronage	6	2005-Q4 to 2009-Q4	-0.85	0.94	Do not reject null → series is nonstationary	0.145	>0.10	Do not reject null → series is stationary	Inconclusive
%Δ in Saturday patronage	7	2005-Q4 to 2009-Q4	-1.27	0.85	Do not reject null → series is nonstationary	0.126	>0.10	Do not reject null → series is stationary	Inconclusive
%Δ in Saturday patronage	8	2005-Q4 to 2009-Q4	-1.65	0.70	Do not reject null → series is nonstationary	0.102	>0.10	Do not reject null → series is stationary	Inconclusive
%Δ in Saturday patronage	9	2005-Q4 to 2009-Q4	-1.87	0.62	Do not reject null → series is nonstationary	0.132	>0.10	Do not reject null → series is stationary	Inconclusive
%Δ in Saturday patronage	10	2005-Q4 to 2009-Q4	-0.93	0.93	Do not reject null → series is nonstationary	0.113	>0.10	Do not reject null → series is stationary	Inconclusive
%Δ in Saturday patronage	11	2005-Q4 to 2009-Q4	-1.21	0.87	Do not reject null → series is nonstationary	0.102	>0.10	Do not reject null → series is stationary	Inconclusive

(a) The ADF test incorporated 4 lags and the KPSS test employed a long version of the truncation lag parameter

G4.3 Endogeneity issues

In section 2.4.3 we noted that endogeneity or 'reverse causation' is another statistical issue that needs to be given careful consideration. In particular, the econometric models adopted in this research project assume that patronage growth is 'caused' by service improvements. However, it is conceivable that transport operators improve service levels as a means of coping with patronage demand.

That said, we are confident that the employment of route-level data, in conjunction with our econometric methodology guards considerably against endogeneity:

- First, we carry out a graphical analysis of the data before proceeding to econometric analysis. A key part of this graphical analysis is about looking at the impact of service improvements and checking that any 'bursts' in patronage follow the service improvement, rather than the other way around. Figures F.3 to F.20 in section F3 show clearly that this is indeed the case.
- Second, we use 'seasonally differenced' data: both patronage and service trips are expressed in terms of growth between a given quarter and the same quarter in the previous year. This means that the model only attributes patronage growth to a service change based on the extent to which patronage growth 'jumps' within a year of the service change occurring. For example, figure F.17 shows an example of a service – Bethlehem Brookfield (10) – with generally high 'normal' patronage growth of about 10% per annum. It is possible that the doubling of frequency in October 2007 was in response to that high patronage growth. However, the model will only attribute the impact of the service change to a difference between the 'normal' 10% growth in patronage and the burst in patronage growth of about 30% to 40% following the service change.
- Third, we look at changes in service trips at a route level, rather than across the whole city. While growth in service trips across a whole city might increase gradually over time, growth in service trips on a particular route is often very 'lumpy' and the timing and nature of those changes to service trips vary considerably from route to route, as shown by figures F.3 to F.20. This all makes it easier for the econometric model to isolate and estimate the patronage impact of any service improvements.

G5 Model building process

G5.1 Development of the weekday patronage model

The model building process began with building a general model that encompassed a broad collection of explanatory variables and key factors. This general model included variables relating to:

- route-specific time trends
- variables for service improvements, specified by route and date
- variables to control for the extent to which the new Lakes (12) service 'cannibalised' patronage off other routes that have overlapping catchment areas: Greerton (7); Ohauiti (8); and Pyes Pa (11)
- dummy variables to control for miscellaneous events (ie a route change relating to Pillans Road, and the replacing of a few existing buses with larger buses)
- various 'standard' explanatory variables (petrol prices, SuperGold, Easter, real retail sales and employment).

Table G.9 shows how the general model was whittled down to produce the preferred model.

The first problem noted with the general model was an implausible positive sign on the Easter variable, given that we are looking at weekday patronage. We considered the possibility that the Tauranga Jazz Festival was having a positive impact on surrounding weekday patronage; however, we regarded this as implausible and judged that it would be safer to remove this variable.

Model 2 includes estimates for the amount of patronage on the new Lakes (12) service that was 'cannibalised' off other routes that have overlapping catchment areas (Greerton (7), Ohauiti (8) and Pyes Pa (11)). The estimate for patronage gained at the expense of Windermere Ohauiti (8) was an incorrect sign but this is not unexpected because the overlap between route 8 and the new route 10 is very low. This variable was dropped.

Model 2 also includes the impact of the introduction of larger buses. We had anticipated that the larger buses would not have had a statistically discernible impact on patronage; we were proved correct and these variables were subsequently dropped.

Model 3 represents our preferred model and the estimates produced using this model all seemed to be plausible.

Table G.9 Development of the model for weekday patronage

Time trends and explanatory variables		General model	Model 2	Model 3 (preferred)
Time trend	Mount-Bayfair (1&2)	0%	3%	3%
	Belvedere Brookfield (3)	-11%***	-9%***	-9%***
	Matua-Brookfield (4&5)	1%	4%	3%
	Papamoa (6)	3%	5%	5%
	Greerton (7)	-4%	-2%	-2%
	Windermere Ohauiti (8)	-2%	0%	3%
	Welcome Bay (9)	-2%	1%	1%
	Bethlehem Brookfield (10)	6%**	8%***	8%***
	Pyes Pa (11)	5%*	7%***	7%***
Doubling of frequency from hourly to 30min + extension of hours:				
	Mount-Bayfair (1&2), Oct 07	0.47**	0.47**	0.46**
	Matua-Brookfield (4&5), Oct 07	0.34*	0.33‘	0.32‘
Doubling of frequency from hourly to 30min:				
	Matua-Brookfield (4&5), Dec 06	0.18	0.16	0.17
	Windermere Ohauiti (8), Dec 06	0.57***	0.57***	0.51***
	Welcome Bay (9), Dec 06	0.46***	0.45***	0.46***
	Bethlehem Brookfield (10), Oct 07	0.42***	0.41***	0.41***
Extension of hours:				
	Welcome Bay (9), Oct-07	1.72***	1.68***	1.65***
Introduction of express service:				
	Papamoa (6), Dec 06, SR impact (0–4 qtrs)	0.24*	0.24*	0.25*
	MR impact (5–8 qtrs)	0.12	0.14	0.14
Transition to orbiter-type service:				

Time trends and explanatory variables	General model	Model 2	Model 3 (preferred)
Greerton (7), Oct 07	-0.35	-0.37	-0.37
Proportion of patronage on new Lakes (12) service (introduced May 08) that was 'cannibalised' off other routes:			
Greerton (7)	9%	6%	9%
Windermere Ohauiti (8)	-17%	-19%	Implausible sign
Pyes Pa (11)	11%‘	10%	11%‘
Route change relating to Pillans Rd			
Belvedere Brookfield (3), Oct 06	16%***	16%***	16%***
Impact of replacing existing buses with larger buses (Oct 07):			
Matua-Brookfield (4&5)	8%	7%	Implausible sign
Papamoa (6)	-1%	-1%	Implausible sign
Bethlehem Brookfield (10)	-1%	-1%	Implausible sign
Real petrol price	0.19	0.25*	0.25*
Nominal $2.00 petrol price threshold	16%*	6%	8%
Introduction of SuperGold Card (Oct 08)	18%***	15%***	16%***
Easter	3%*	Implausible sign	
Real retail sales (Tauranga city)	-0.21	0.03	0.06
Employment (Tauranga city)	1.50***	1.23***	1.22***

Note for symbols of statistical significance: *** → 0.1%, ** → 1%, * → 5%, ‘ →10%

G5.2 Development of the Saturday patronage model

We developed a general model for Saturday patronage, which was similar to that for weekdays except that we made allowances for a few other factors:

- As section G3.1 notes, there was modest evidence of ‘network effects’ (ie the improvement to weekday timetables seemed to increase patronage on the Saturdays) so we controlled for this by incorporating weekday service improvements as an explanatory variable.
- We noted in section G2.3 that the introduction of holiday services in October 2006 caused a distortion to growth in Saturday patronage. Therefore, we included dummy variables to control for this.

Table G.10 shows how the general model was whittled down to produce the preferred model.

A few problems were noted with the general model. However, we decided to first examine the contribution of the variable for ‘network effects’ by removing it, hence creating model 2. The coefficient of 0.12 implies that a 100% increase in weekday service trips produces a 12% increase in demand for Saturday services. This coefficient was not statistically significant. However, the service elasticities for extension of weekend hours in model 2 do seem excessive so we decided in favour of the general model.

Model 3 was created by removing a number of variables from the general model: petrol price was removed (due to an incorrect sign) as were all variables relating to the introduction of the Lakes (12) service (due to statistical insignificance). Model 3 was the preferred model.

Table G.10 Development of the model for Saturday patronage

Time trends and explanatory variables		General model	Model 2	Model 3 (preferred)
Time trend	Mount-Bayfair (1&2)	15%*	18%**	13%*
	Belvedere Brookfield (3)	7%	8%	4%
	Matua-Brookfield (4&5)	5%	8%	2%
	Papamoa (6)	11%‘	15%**	9%
	Greerton (7)	8%	9%	5%
	Windermere Ohauiti (8)	-1%	0%	-1%
	Welcome Bay (9)	11%	12%‘	7%
	Bethlehem Brookfield (10)	13%*	16%**	11%‘
	Pyes Pa (11)	2%	3%	2%
Extension of hours:				
	Matua-Brookfield (4&5)	0.41	0.74	0.69
	Windermere Ohauiti (8)	1.61*	2.07**	1.55*
	Welcome Bay (9)	0.51	0.97	0.75
Transition to orbiter-type service:				
	Greerton (7), Oct 07	0.41**	0.41**	0.35*
Network effect' of service improvements to the weekday timetables:		0.12	Omitted	0.12
Impact of introduction of public holiday services				
	2006-Q4 dummy	31%***	31%***	32%***
	2007-Q1 dummy	28%***	29%***	27%***
Proportion of patronage on new Lakes (12) service (introduced May 08) that was 'cannibalised' off other routes:				
	Greerton (7)	-0.32	-0.33	Insignificant
	Windermere Ohauiti (8)	0.15	0.14	Insignificant
	Pyes Pa (11)	0.13	0.12	Insignificant
Route change relating to Pillans Rd				
	Belvedere Brookfield (3), Oct-06	-1%	-1%	2%
Real petrol price		-0.25	-0.25	Implausible sign
Nominal $2.00 petrol price threshold		47%**	49%**	41%***
Introduction of SuperGold Card (Oct 08)		7%	7%	9%‘
Easter		-9%**	-9%**	-8%**
Real retail sales (Tauranga city)		1.91*	2.14*	1.48‘
Employment (Tauranga city)		0.90	0.78	0.94

Note for symbols of statistical significance: *** → 0.1%, ** → 1%, * → 5%, ‘ →10%

G6 Diagnostic analysis

G6.1 Overview

The following sections show diagnostic analysis of the residuals from the preferred models for predicting weekday patronage and Saturday patronage on the Tauranga bus system.

Our general findings are as follows:

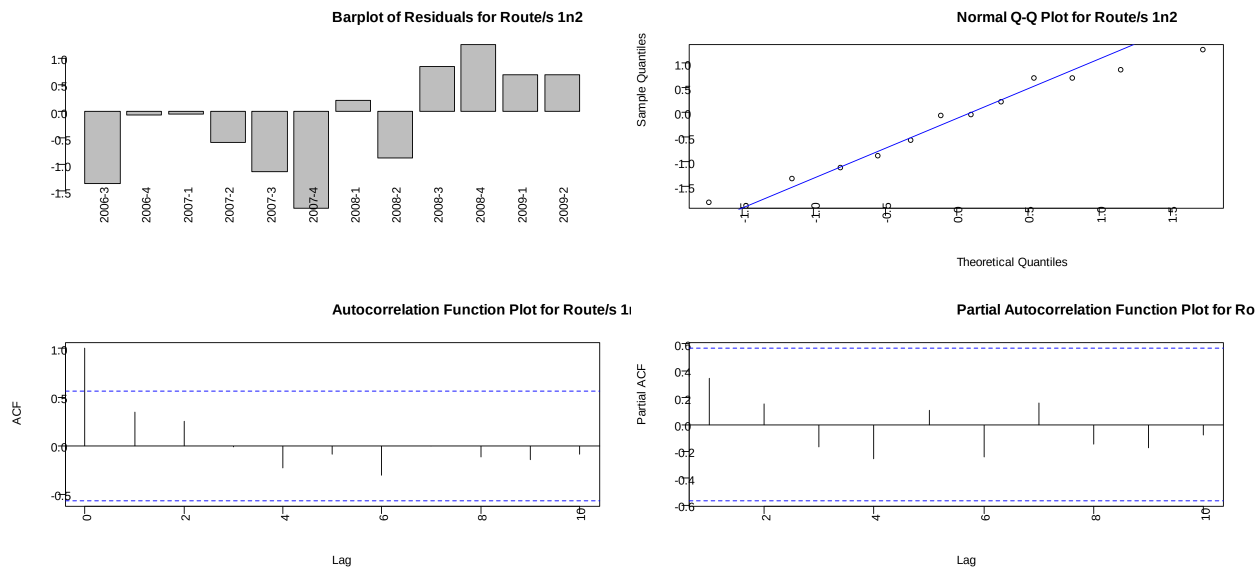
- Overall, the diagnostic plots for the weekday model look reasonable. The routegroup 1&2 shows evidence of autocorrelation but the general impression is that the model explains weekday patronage reasonably well.
- The diagnostic plots for the Saturday patronage are more con cerning. There is evidence of 'clustering' of residuals on a number of routes.

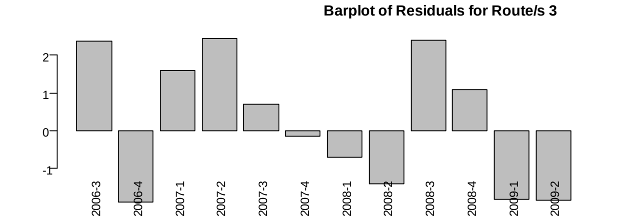
G6.2 Diagnostic analysis for the weekday patronage model

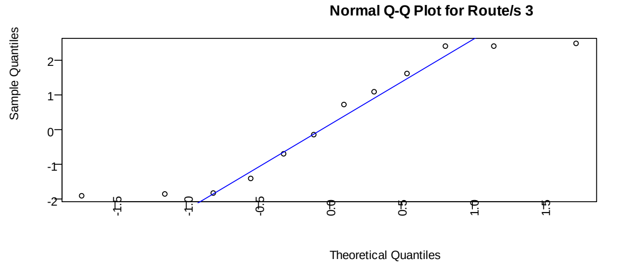
The figures below show diagnostic plots for the residuals from model 3 (the preferred model) for weekday patronage (see table G.9, section G5.1).

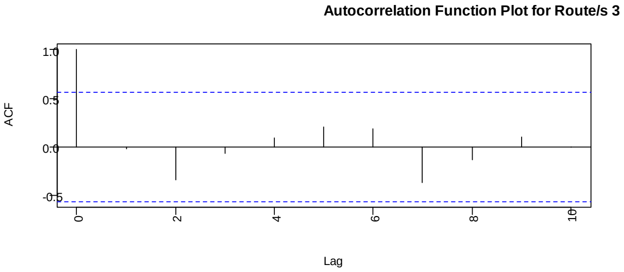
The diagnostic plots show that the residuals are generally consistent with the key assumption of normality. There is some evidence of a few outliers in the distribution of residuals on routes 3, 9 and 10 but, overall, taking all routes into consideration, the overall picture is one of normality.

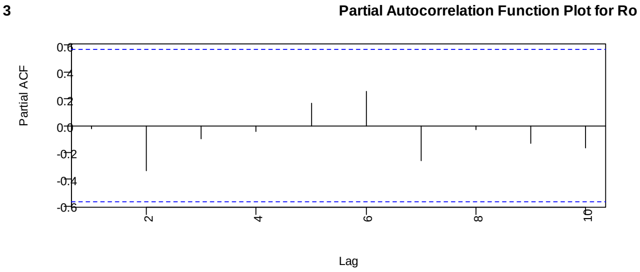
The route group 1&2 shows evidence of some autocorrelation and clustering of residuals: residuals are mostly negative up until 2003-Q3 and then positive from that point onwards. However, the overall impression from looking at the diagnostic plots for all the routes is that the autocorrelation is low for the residuals for the weekday patronage model.

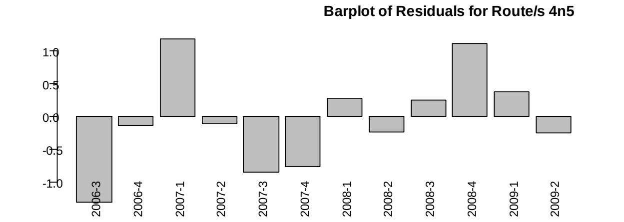


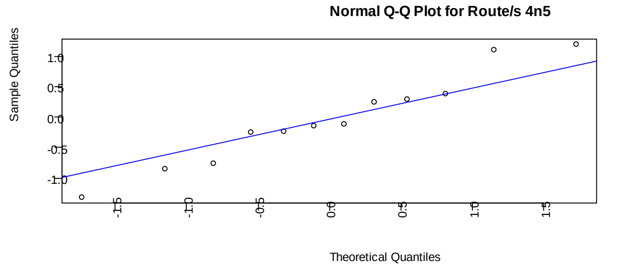

Barplot of Residuals for Route/s 3

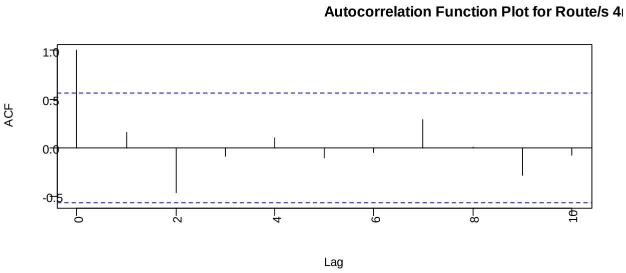

Normal Q-Q Plot for Route/s 3
Sample Quantiles
Theoretical Quantiles

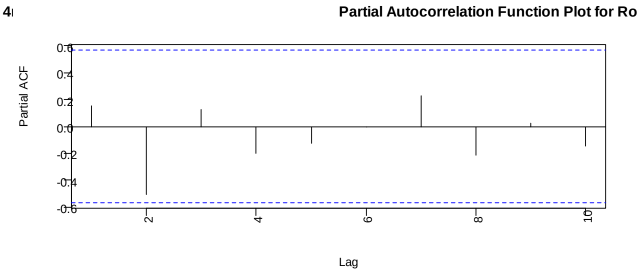

Autocorrelation Function Plot for Route/s 3
ACF
Lag

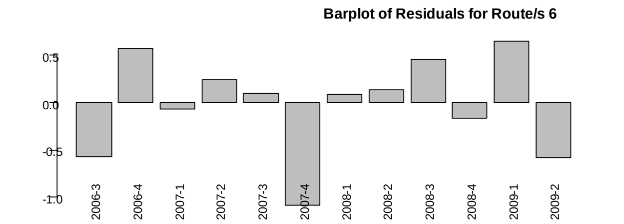

Partial Autocorrelation Function Plot for Ro
Partial ACF
Lag

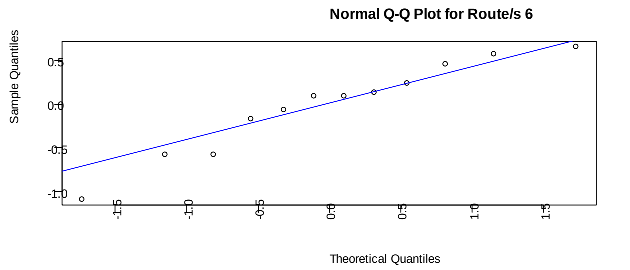

Barplot of Residuals for Route/s 4n5

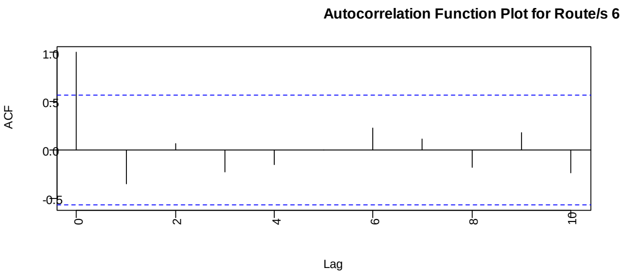

Normal Q-Q Plot for Route/s 4n5
Sample Quantiles
Theoretical Quantiles

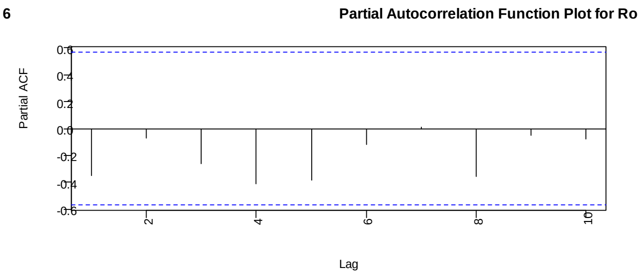

Autocorrelation Function Plot for Route/s 4
ACF
Lag

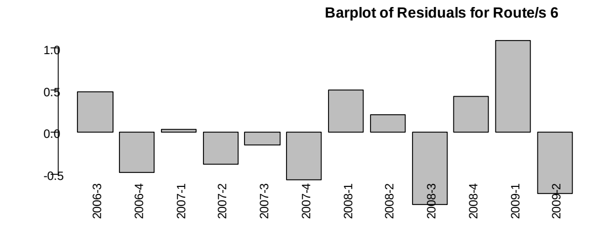

Partial Autocorrelation Function Plot for Ro
Partial ACF
Lag

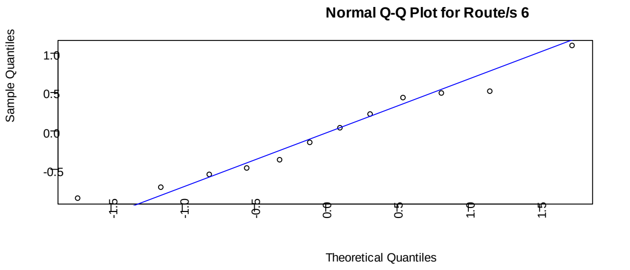

Barplot of Residuals for Route/s 6

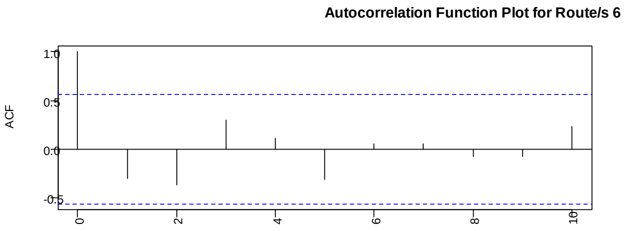

Normal Q-Q Plot for Route/s 6
Sample Quantiles
Theoretical Quantiles

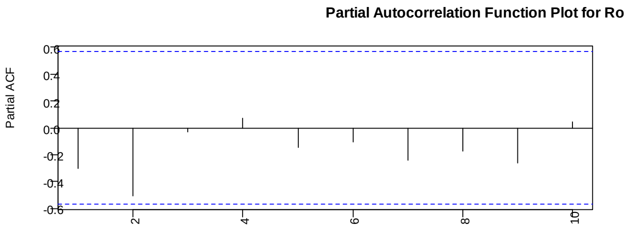

Autocorrelation Function Plot for Route/s 6
ACF
Lag

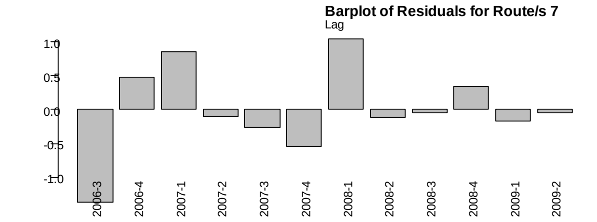

Partial Autocorrelation Function Plot for Ro
Partial ACF
Lag

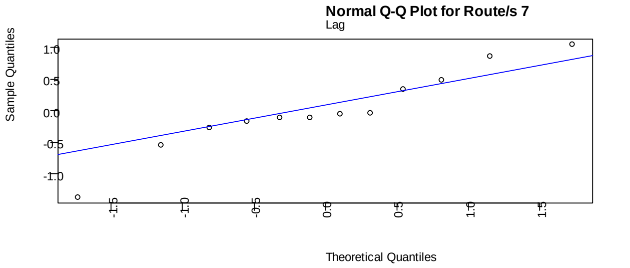

Barplot of Residuals for Route/s 6
2006-3
2006-4
2007-1
2007-2
2007-3
2007-4
2008-1
2008-2
2008-3
2008-4
2009-1
2009-2

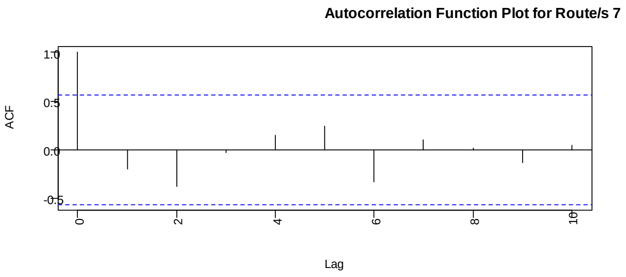

Normal Q-Q Plot for Route/s 6
Sample Quantiles
Theoretical Quantiles

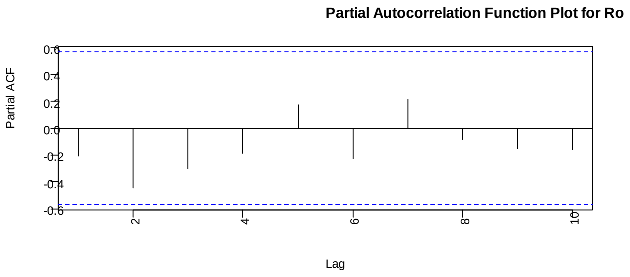

Autocorrelation Function Plot for Route/s 6
ACF
Lag

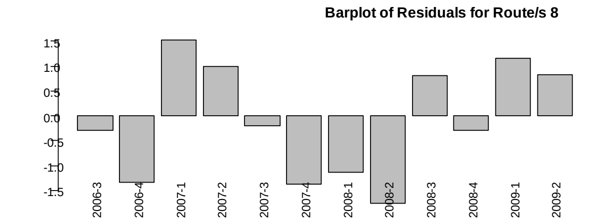

Partial Autocorrelation Function Plot for Ro
Partial ACF
Lag

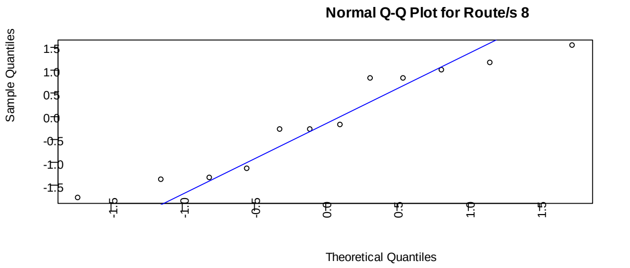

Barplot of Residuals for Route/s 7
2006-3
2006-4
2007-1
2007-2
2007-3
2007-4
2008-1
2008-2
2008-3
2008-4
2009-1
2009-2

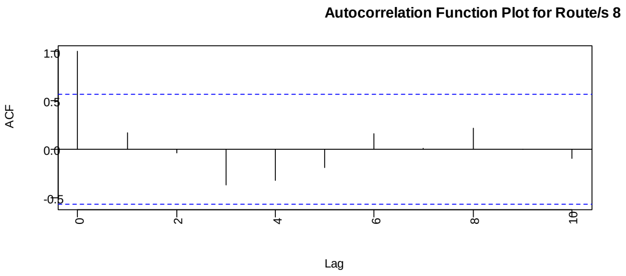

Normal Q-Q Plot for Route/s 7
Sample Quantiles
Theoretical Quantiles

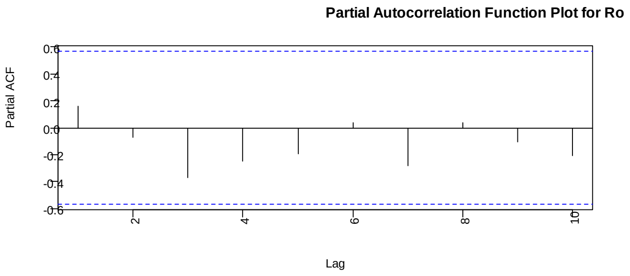

Autocorrelation Function Plot for Route/s 7
ACF
Lag

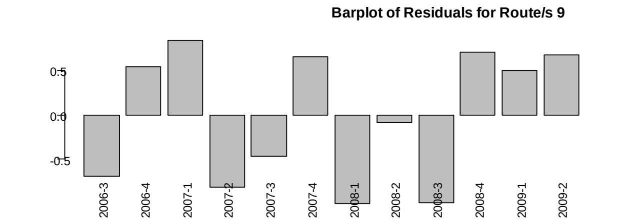

Partial Autocorrelation Function Plot for Ro
Partial ACF
Lag

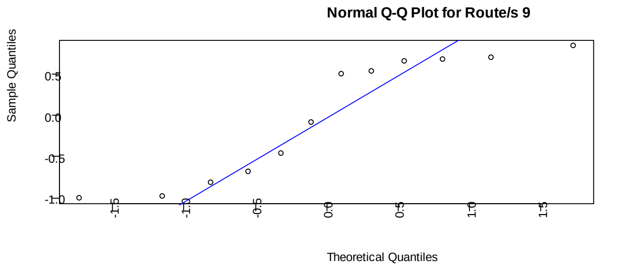

Barplot of Residuals for Route/s 8
2006-3
2006-4
2007-1
2007-2
2007-3
2007-4
2008-1
2008-2
2008-3
2008-4
2009-1
2009-2

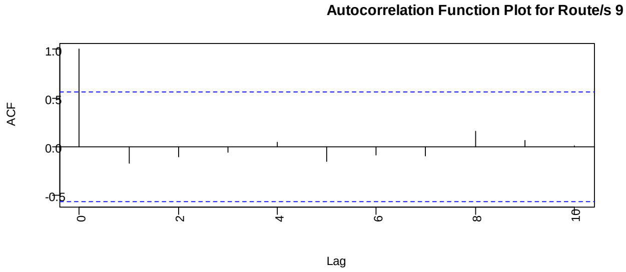

Normal Q-Q Plot for Route/s 8
Sample Quantiles
Theoretical Quantiles

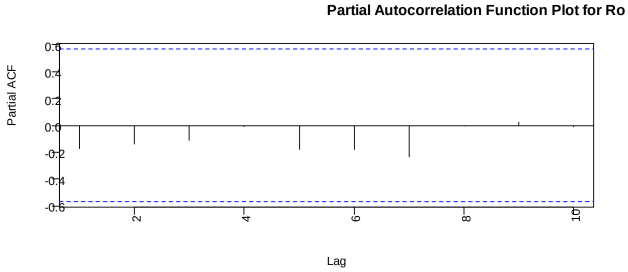

Autocorrelation Function Plot for Route/s 8
ACF
Lag

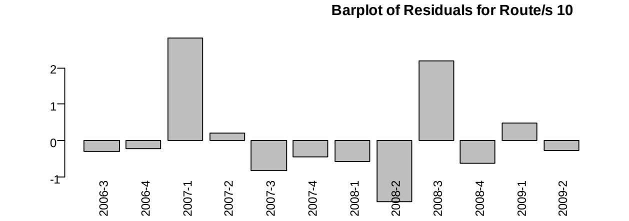

Partial Autocorrelation Function Plot for Ro
Partial ACF
Lag

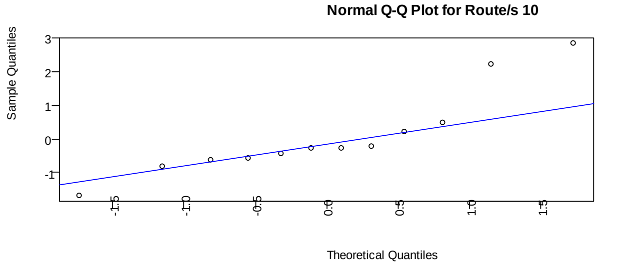

Barplot of Residuals for Route/s 9

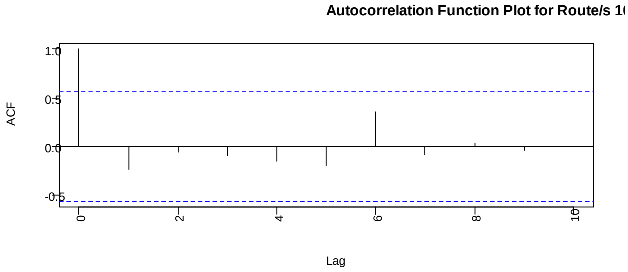

Normal Q-Q Plot for Route/s 9
Sample Quantiles
Theoretical Quantiles

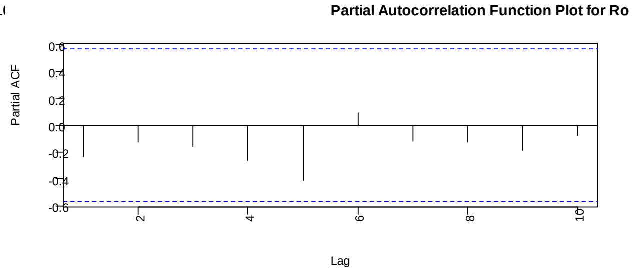

Autocorrelation Function Plot for Route/s 9
ACF
Lag

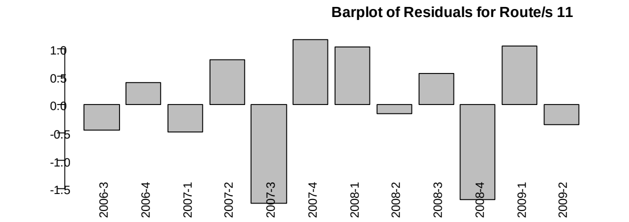

Partial Autocorrelation Function Plot for Ro
Partial ACF
Lag

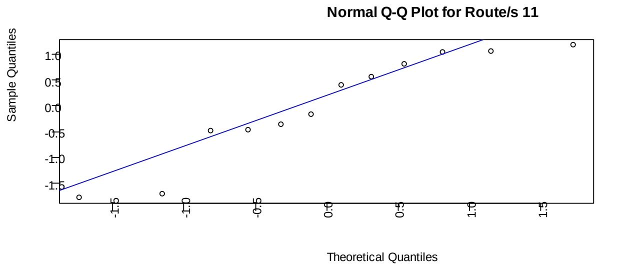

Barplot of Residuals for Route/s 10

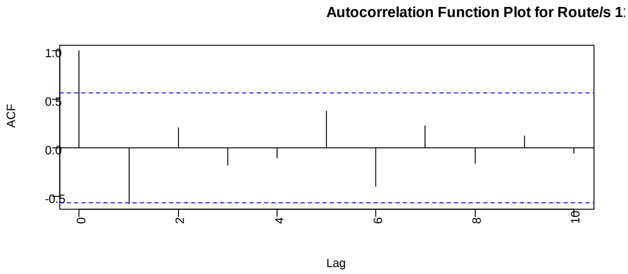

Normal Q-Q Plot for Route/s 10
Sample Quantiles
Theoretical Quantiles

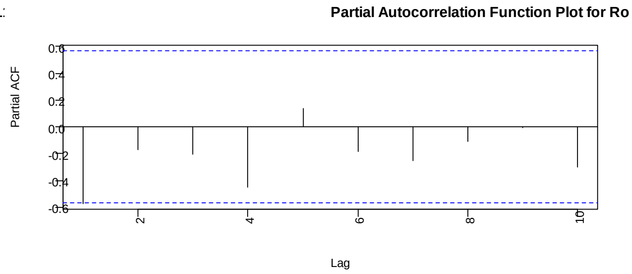

Autocorrelation Function Plot for Route/s 1
ACF
Lag


Partial Autocorrelation Function Plot for Ro
Partial ACF
Lag


Barplot of Residuals for Route/s 11


Normal Q-Q Plot for Route/s 11
Sample Quantiles
Theoretical Quantiles


Autocorrelation Function Plot for Route/s 1
ACF
Lag

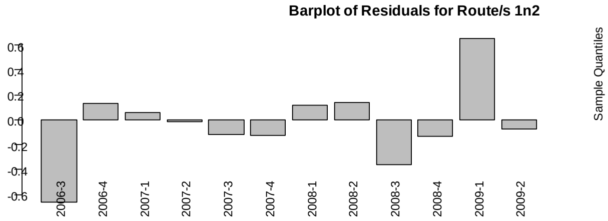

Partial Autocorrelation Function Plot for Ro
Partial ACF
Lag

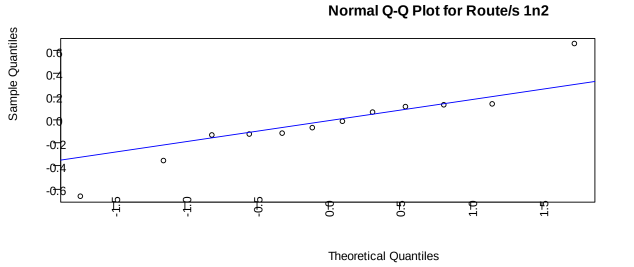
G6.3 Diagnostic analysis for the Saturday patronage model

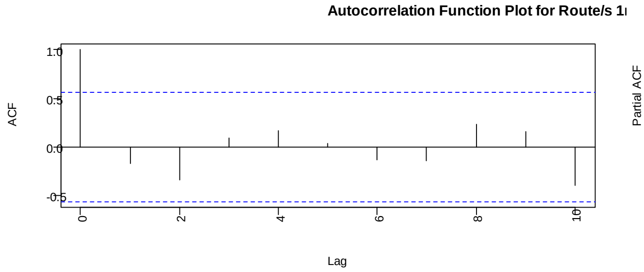
The figures below show diagnostic plots for the residuals from model 3 (the preferred model) for Saturday patronage (see table G.10, section G5.2).

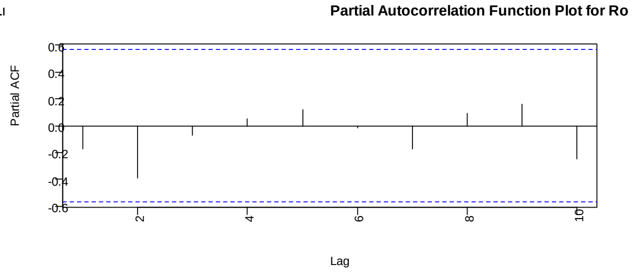
The diagnostic plots show that the residuals are generally consistent with the key assumptions of normality. There are, however, a few outliers most notably on route group 1&2, and routes 7 and 9.

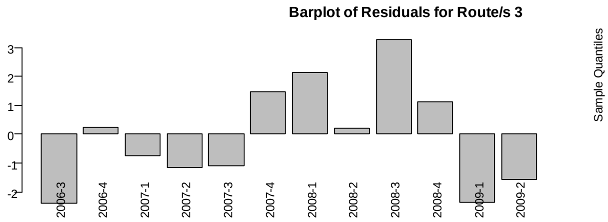
There is no overwhelming evidence of autocorrelation from examination of the ACF and PACF plots but an examination of the barplots shows 'clusters' of positive and negative residuals that is somewhat concerning. This clustering is most obvious on routes 3, 7 and 11.

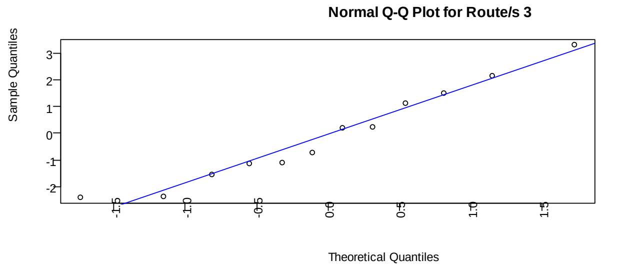


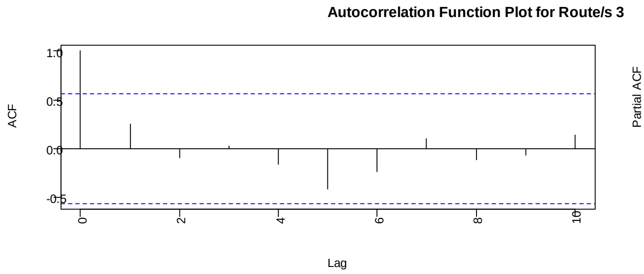


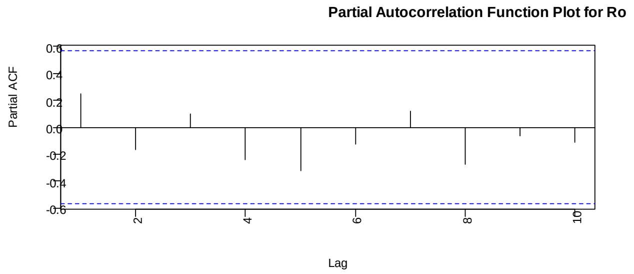




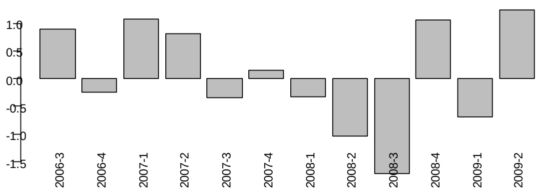




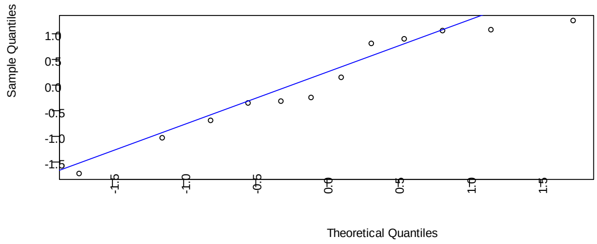




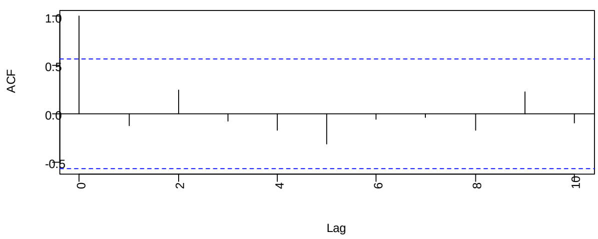
Barplot of Residuals for Route/s 4n5



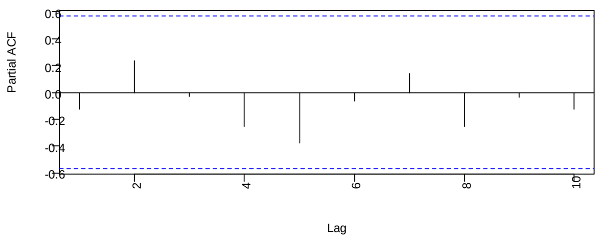
Normal Q-Q Plot for Route/s 4n5



Autocorrelation Function Plot for Route/s 4

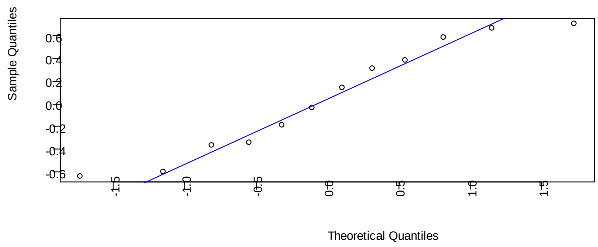


Partial Autocorrelation Function Plot for Ro

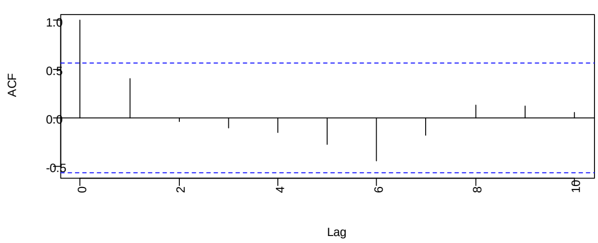


Barplot of Residuals for Route/s 7

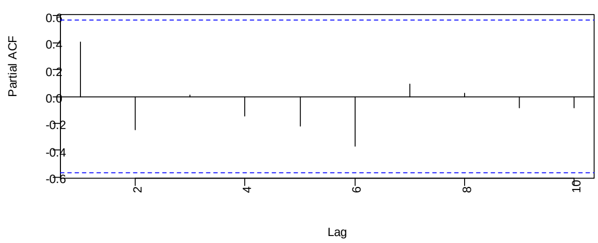
Normal Q-Q Plot for Route/s 7



Autocorrelation Function Plot for Route/s 7

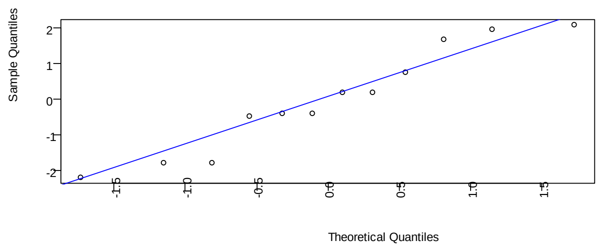


Partial Autocorrelation Function Plot for Ro

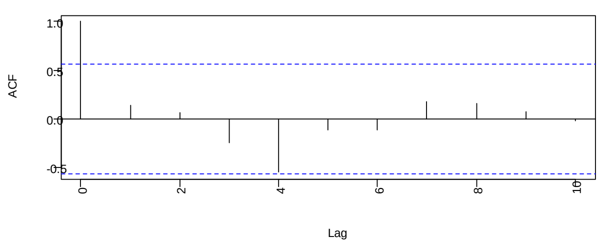


Barplot of Residuals for Route/s 8

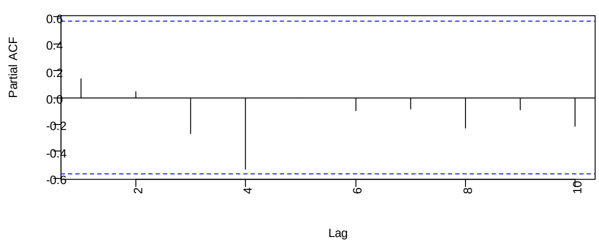
Normal Q-Q Plot for Route/s 8

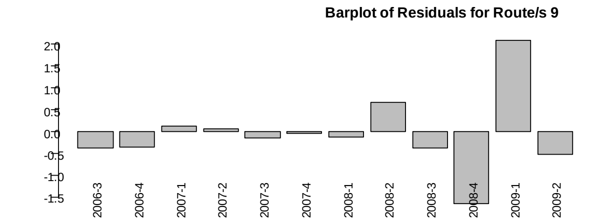


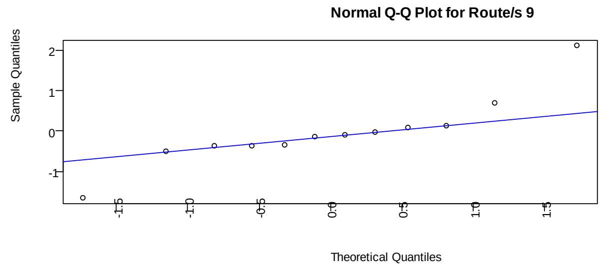
Autocorrelation Function Plot for Route/s 8

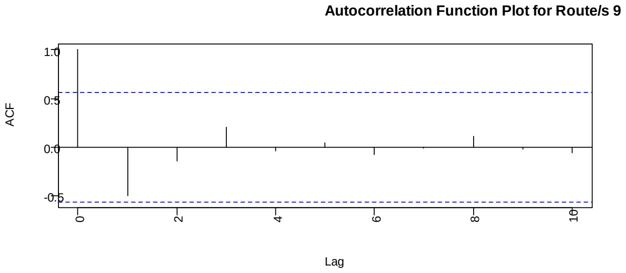


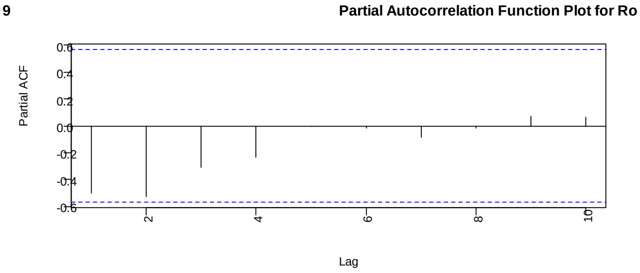
Partial Autocorrelation Function Plot for Ro

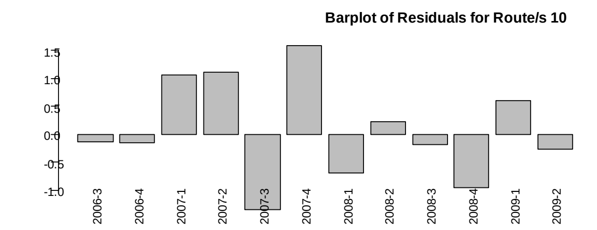


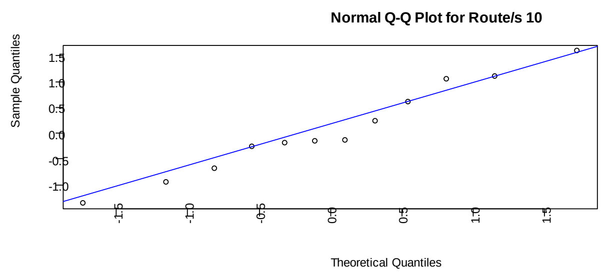

Barplot of Residuals for Route/s 9

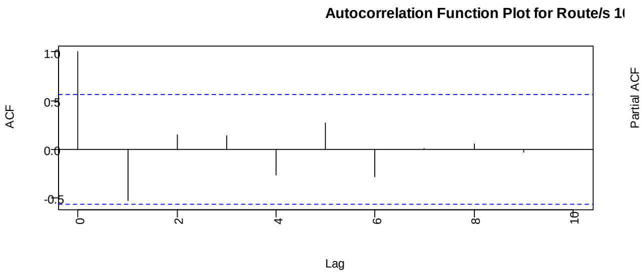

Normal Q-Q Plot for Route/s 9
Sample Quantiles
Theoretical Quantiles

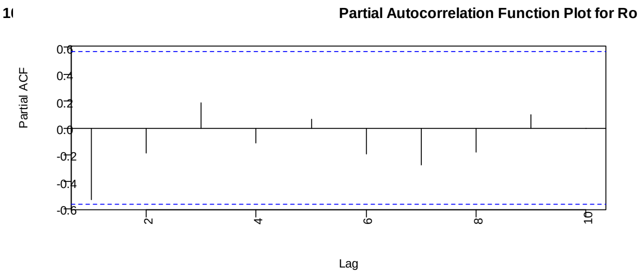

Autocorrelation Function Plot for Route/s 9
ACF
Lag

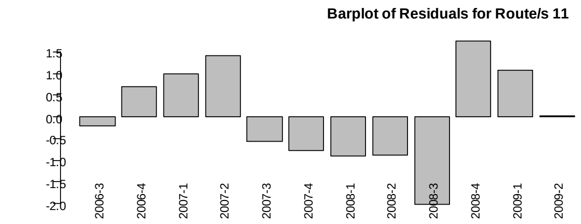

Partial Autocorrelation Function Plot for Ro
Partial ACF
Lag

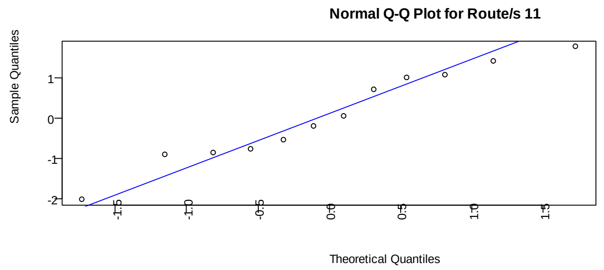

Barplot of Residuals for Route/s 10

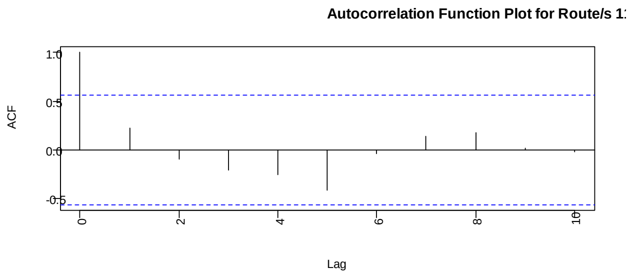

Normal Q-Q Plot for Route/s 10
Sample Quantiles
Theoretical Quantiles

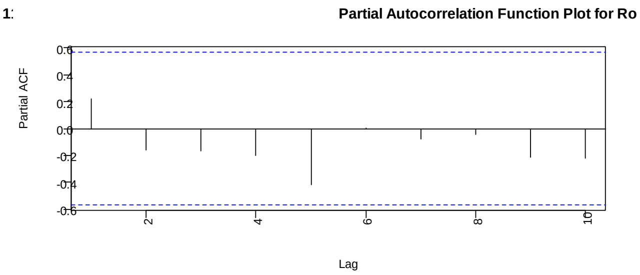

Autocorrelation Function Plot for Route/s 1
ACF
Lag


Partial Autocorrelation Function Plot for Ro
Partial ACF
Lag


Barplot of Residuals for Route/s 11


Normal Q-Q Plot for Route/s 11
Sample Quantiles
Theoretical Quantiles


Autocorrelation Function Plot for Route/s 1
ACF
Lag


Partial Autocorrelation Function Plot for Ro
Partial ACF
Lag

G7 Final model estimates

Tables G.11 and G.12 show our estimates for the models for weekday and Saturday patronage. These estimates were produced using the final models identified in section G5.

Key findings that can be drawn from the analysis of economic factors in table G.11 are:

- The impact of petrol prices on weekday patronage is represented by a combination of petrol price elasticity of +0.25 and a nominal petrol price threshold of 8%.
- The impact of petrol prices on weekend patronage appears to be solely affected by a nominal petrol price threshold of 41%, but that does seem implausibly high.
- The introduction of the SuperGold Card had a statistically discernible impact on both weekday and Saturday patronage.
- Interestingly, a growth in real retail sales is associated with growth in Saturday patronage but not weekday patronage; this is plausible given that a lot of Saturday patronage is associated with retail shopping.
- Employment is estimated to have a positive impact on both weekday and Saturday patronage but, as expected, the estimate for the impact on employment on weekday patronage has more accuracy and hence a smaller confidence interval.

Table G.11 Elasticities and event dummies for economic variables, by time period

Economic variables and events	Weekday	Saturday
Real petrol price	0.25* (0.01, 0.49)	Removed due to implausible sign
Nominal $2.00 petrol price threshold	8% (-2%, 18%)	41%*** (20%, 62%)
Introduction of SuperGold Card (Oct 08)	16%*** (11%, 21%)	9%‘ (-1%, 20%)
Easter/Jazz Festival	Removed due to implausible sign	-8%** (-14%, -3%)
Real retail sales (Tauranga city)	0.06 (-0.48, 0.59)	1.48‘ (0.01, 2.94)
Employment (Tauranga city)	1.22*** (0.80, 1.65)	0.94 (-0.35, 2.24)

Note for symbols of statistical significance: *** → 0.1%, ** → 1%, * → 5%, ‘ →10%

Table G.12 Elasticities and event dummies for economic variables, by time period

Service elasticities	**Weekday**	**Saturday**
Doubling of frequency from hourly to 30 min + extension of hours:		
Mount-Bayfair (1&2), Oct 07	0.46** (0.13, 0.78)	
Matua-Brookfield (4&5), Oct 07	0.32‘ (-0.01, 0.66)	
Doubling of frequency from hourly to 30 min:		
Matua-Brookfield (4&5), Dec 06	0.17 (-0.13, 0.47)	
Windermere Ohauiti (8), Dec 06	0.51*** (0.38, 0.65)	
Welcome Bay (9), Dec 06	0.46*** (0.32, 0.60)	
Bethlehem Brookfield (10), Oct 07	0.41*** (0.29, 0.52)	
Extension of hours:		
Matua-Brookfield (4&5), Dec 06		0.69 (-1.54, 2.93)
Windermere Ohauiti (8), Dec 06		1.55* (0.23, 2.87)
Welcome Bay (9), Oct 07, Dec 06	1.65*** (0.75, 2.56)	0.75 (-0.67, 2.18)
Introduction of express service:		
Papamoa (6), Dec 06, SR impact (0–4 qtrs)	0.25* (0.06, 0.44)	
MR impact (5–8 qtrs)	0.14 (-0.06, 0.33)	
Transition to orbiter-type service:		
Greerton (7), Oct 07	-0.37 (-1.08, 0.33)	0.35* (0.08, 0.62)
Network effects of weekday timetable service improvements on Saturday patronage		0.12 (-0.07, 0.31)
Weighted averages:		
Service changes involving doubling of frequency		**0.4**
Service changes involving an extension of hours		**1.2**
Service changes involving an express service		**0.4**

Note for symbols of statistical significance: *** → 0.1%, ** → 1%, * → 5%, ‘ →10%

Key findings that can be drawn from the analysis of economic factors in table G.12 are:

- The average impact of most service improvements can be represented by a service elasticity of +0.4; there was a consistent finding around this.
- The only exception is the impact of extension of hours, for which the service elasticity is +1.2. This suggests that an extension of hours could be a strong value-for-money investment.

Table G.13 Event dummies for service-related events, by time period

Dummy variables for service-related events	Weekday	Saturday
Impact of introduction of public holiday services:		
2006–Q4 dummy		32%*** (24%, 40%)
2007–Q1 dummy		27%*** (20%, 35%)
Route change relating to Pillans Rd		
Belvedere Brookfield (3), Oct 06	16%*** (11%, 22%)	2% (-8%, 11%)
Proportion of patronage on new Lakes (12) service (introduced May 08) that was 'cannibalised' off other routes:		
Greerton (7)	-9% (-59%, 41%)	Removed due to insignificance
Windermere Ohauiti (8)	Removed due to implausible sign	Removed due to insignificance
Pyes Pa (11)	-11% ' (-23%, 2%)	Removed due to insignificance

Note for symbols of statistical significance: *** → 0.1%, ** → 1%, * → 5%, ' →10%

Key findings that can be drawn from the analysis of economic factors in table G.13 are:

- The introduction of public holiday services in October 2006 was associated with an upward spike in patronage on Saturday. We conclude that this was probably because services did not operate when Saturday fell on a public holiday. However, the ticketing system calculated 'Patronage per Saturday' based on all Saturdays rather than just Saturdays in which services operated.
- There is evidence that the introduction of the new Lakes (12) service took patronage away from both the Greerton (7) and Pyes Pa (11).

G8 Model for 'net patronage' from the Lakes (12) service

We also developed a method for evaluating the net patronage that Tauranga gained from the introduction of the Lakes (12) service. This method is shown in table G.14 and discussed below.

Table G.14 Calculation of net 'service elasticity' for the introduction of the Lakes (12) route

Calculation steps	Weekday	Saturday
% increase in trips across city	8%	6%
% increase in patronage in city that was directly associated with the new Lakes (12) service	4%	2%
Gross 'service elasticity'	0.49***	0.29***
less patronage 'cannibalised' from Pyes Pa (11)	-11%‘	Dropped
Net service elasticity	0.44	0.29

Note for symbols of statistical significance: *** → 0.1%, ** → 1%, * → 5%, ‘ →10%

Figures G.39 and G.40 both demonstrate the strong relationship between the increase in service trips associated with the Lakes (12) service and the subsequent patronage. A simple regression of these growth rates produced the gross 'service elasticities' of +0.49 and +0.29 shown in table G.14.

Figure G.39 Growth in Tauranga patronage and service trips attributable to new Lakes (12) service

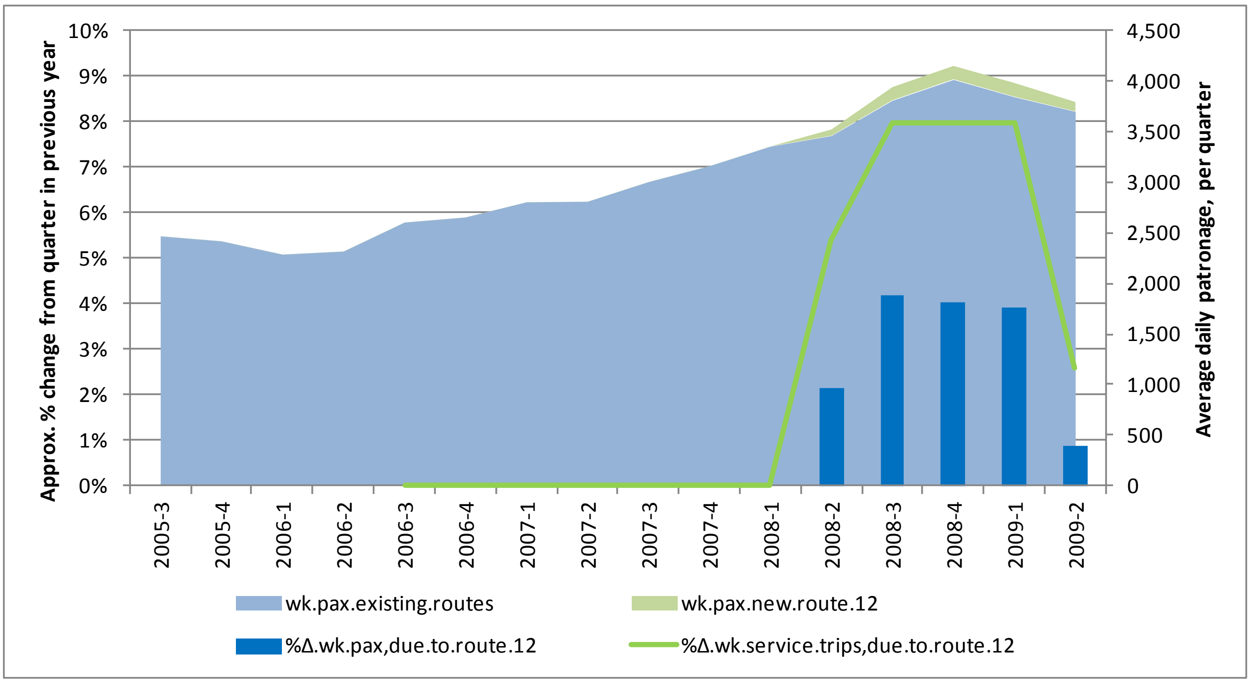
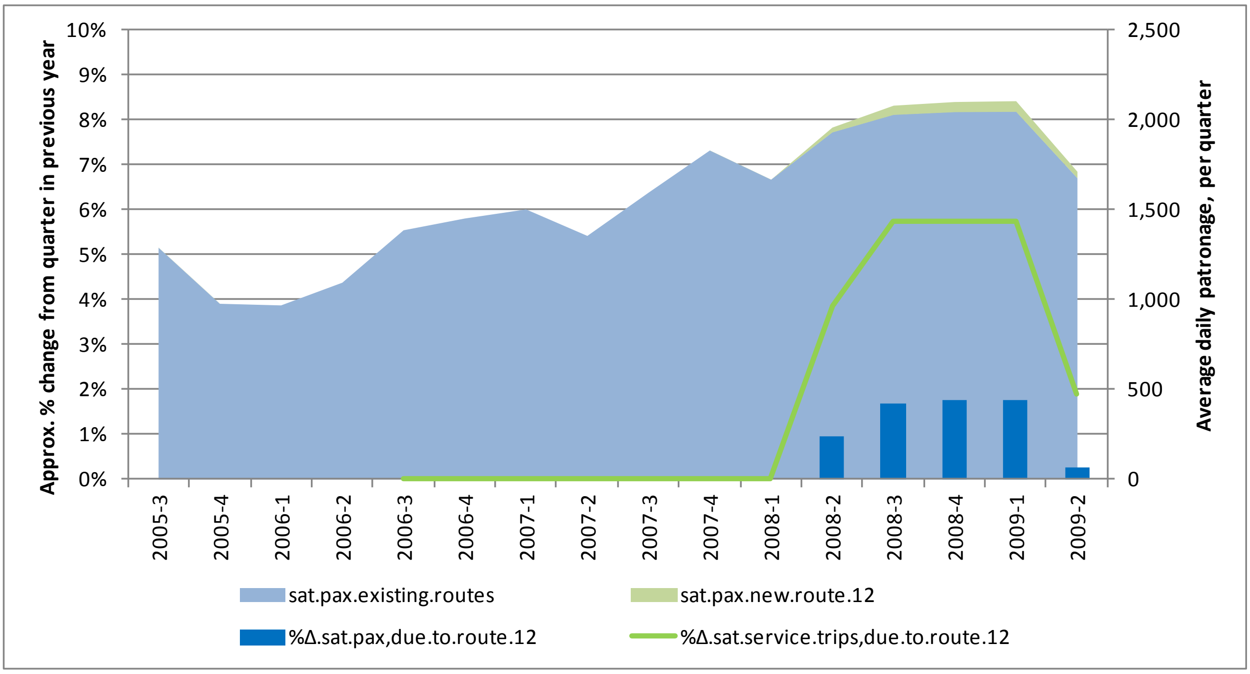


Figure G.40 Growth in Tauranga patronage and service trips attributable to new Lakes (12) service



However, as discussed in section G7, there is evidence from our panel data model that the Lakes (12) service actually detracted patronage from the neighbouring Pyes Pa (11) service, at least during the weekday. Therefore, we used that model to subtract the patronage 'cannibalised' off the Pyes Pa (11) hence producing the net 'service elasticity' shown in table G.14.