Effects of toll removal on Tauranga Harbour Bridge, New Zealand

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An important note for the reader

Land Transport New Zealand is a Crown entity established under the Land Transport Management Act 2003. The objective of Land Transport New Zealand is to allocate resources and to undertake its functions in a way that contributes to an integrated, safe, responsive and sustainable land transport system. Each year, Land Transport New Zealand invests a portion of its funds on research that contributes to this objective.

This report is the final stage of a project commissioned by Transfund New Zealand before 2004, and is published by Land Transport New Zealand.

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Introduction

As toll roads and other forms of road pricing become of more interest to road controlling authorities in New Zealand, the importance of providing robust forecasts of motorists' responses to tolls is increasing. While procedures for forecasting patronage on toll roads are in common use internationally, the applicability of international practice to the New Zealand context is uncertain.

The Tauranga Harbour Bridge, Bay of Plenty, New Zealand, was opened in 1988 and included a $1 toll for its use. Over the next thirteen years, the daily traffic flow on the bridge increased from 10,000 vehicles per day (vpd) to 27,500 vpd because of the continued strong residential development, mostly in the Mount Maunganui and Papamoa areas, across the Harbour from the city centre.

The toll was removed in July 2001, and by 2003 the bridge was operating at capacity with daily flows approaching 40,000 vpd in peak times. Widening of the bridge and improvements to the approaches are currently being planned via the Harbour Link Project, and Government approval has recently been given to impose a toll on the (widened) Harbour Bridge.

The removal of the toll created an opportunity to investigate the effect of tolls on traffic behaviour in New Zealand.

Purpose of study

The main purpose of this study, carried out in 2004, was to undertake an analysis of the observed changes in traffic following the removal of the $1 toll on an existing facility, the Tauranga Harbour Bridge, in July 2001. From this analysis the research was intended to infer parameters and elasticities which could assist in the development and validation of models developed to forecast the effect of new toll projects.

Available before-and-after data

Although detailed monitoring of traffic was undertaken by the Tauranga City Council around the time of the toll removal, this was limited to the traffic counts obtained on the Harbour and Maungatapu Bridges. No origin-destination (O-D) data or directly comparable travel time data were available for this study so the detailed analysis of the changes in travel behaviour was not possible.

Changes in traffic flow following toll removal

In the week immediately following removal of the toll the daily flows on the Harbour Bridge increased by 18% while the daily flows on the Maungatapu Bridge reduced by only 9%, meaning a net increase of 7% in the combined cross-harbour flows.

Analysis of the data collected following toll removal found that the flows on both routes at first increased but appeared to stabilise some 14 weeks after the toll was removed.

Subsequently a trend analysis of the available data was undertaken, with Week 14 used as the reference point for prediction of the short-term stabilised changes in traffic flows.

Although some effects of the toll removal could take longer than 14 weeks to occur, the analysis was constrained to this period to avoid the influence of the high general traffic growth and the opening of the nearby major new Route J expressway in April 2002.

The key findings of this analysis were:

- The daily flows on the Harbour Bridge increased by 26% from 27,600 vpd to 34,900 vpd.
- After the initial reduction, the flows on the Maungatapu Bridge returned to their pre-toll-removal level of 20,100 vpd within the 14-week period, i.e. a change of 0%.
- The combined daily flows on both routes increased by 15%, clearly demonstrating that significant traffic was induced into the corridor following toll removal.
- The effect on heavy commercial vehicles (HCV) was more pronounced than for light vehicles, with an increase of some 1000 trucks per day (74%) on the Harbour Bridge and a reduction of only 150 per day on the alternative route.
- Some evidence of peak spreading was seen with a reduction in the proportion of the daily traffic occurring in the peak periods following toll removal. However these effects are believed to be related mostly to the resulting increase in congestion rather than as a direct response to the removal of the toll.
- Increases in traffic were apparent in the wider Harbour Bridge corridor and feeder routes, and some reductions were noted in the wider arts of the alternative route via Maungatapu. However no strong patterns of change were identified in the wider network.

Capacity assessment

With the Harbour Bridge currently running at capacity, the observed flows are a good indication of the capacity of this type of facility. This analysis indicated that the peak directional capacity was some 1470 vph eastbound and 1520 vph westbound, with the directional differences believed to be related to the different merge length and environments on each approach to the bridge. These values accord with values of between 1450 and 1500 vph observed at other similar sites and are also consistent with the values derived from the Austroads guide.

Initial model testing

The traffic model of the Tauranga and Western Bay of Plenty sub-region is a typical, 3-step car-driver model comprising trip generation, trip distribution and trip assignment. The original model was developed and calibrated to 1996 data with the toll in place. The toll is represented in both the distribution model (which matches trip productions and attractions to create an origin-destination matrix), and the assignment model (which predicts the route vehicles will use between each origin and destination). This means that the toll will affect both the demand pattern and the routes taken through the network.

Initial forecasts of the effect of toll removal showed that the model significantly over-predicted the response to the toll, suggesting an increase in the combined total daily traffic on both routes of some 28%, which is significantly higher than the observed 15% increase in combined flow.

Tests of different model structures and parameters indicated that the parameter which most influenced the response of the model was the weight applied to tolls, and that this implied value of time (VoT) had to be doubled in order to replicate the observed flow changes.

Testing of updated model

During the course of this research the model was re-based to 2001 census data and validated to 2001 post-toll-removal flows. Subsequently, the updated model was tested by adding back the toll and analysing the predicted changes in flows. This test again showed that the toll costs needed to be damped by between 25% and 50% to match the observed change in traffic flows. This test suggests that the VoT applied to tolls needs to be doubled to match the observed traffic patterns.

Similar tests were undertaken on the Route K toll road that was opened in 2003. In this case the presence of parallel routes and hence the limited time savings on Route K meant that the flow forecasts were somewhat insensitive to the VoT applied to tolls in the distribution model, but highly sensitive to the VoT applied to tolls in the assignment model. In these tests doubling the VoT significantly over-predicted the flows on Route K, although the high level of sensitivity to small time savings suggests that Route K is not an appropriate project to use to calibrate revealed VoT.

Implications for toll-forecasting studies

The key implications for toll-forecasting studies derived from this analysis are as follows:

- The effect of tolling can have greater effects than simple diversion to the alternative route, with significant potential for travel demand management including trip suppression or redistribution.[1] Such effects will be most prominent in projects providing a more direct route within dense urban areas, and hence significant time and distance savings over the alternative route. Conversely, for projects providing limited time or distance savings in semi-rural areas, small trip suppression or redistribution effects from tolling are likely, but with a high level of sensitivity to the VoT used in the diversion modelling.
- Typical gravity distribution models, where trip distribution is a function of travel time and toll costs, could be overly sensitive to toll costs when typical VoT parameters of between $10 and $14 are used. Damping the toll costs should be considered in such models, with implied VoT potentially as much as twice these values.

[1] Other effects, such as mode change are also possible, but not able to be assessed from this data.

- The use of single-24-hour distribution models may not be appropriate for forecasting infrastructure or policy scenarios which have a differential effect throughout the day (including congestion relief). In such cases, period-specific distribution models may provide more appropriate forecasts.
- A high level of uncertainty surrounds the appropriate VoT to apply in the route choice model. Although more sophisticated toll-choice models should be used for detailed patronage forecasts on specific toll projects, for general planning purposes the sensitivity to the VoT should be considered and tested.

Abstract

As toll roads and other forms of road pricing become of more interest to road controlling authorities in New Zealand, the importance of providing robust forecasts of motorists' responses to tolls increases. While procedures for forecasting patronage on toll roads are in common use internationally, the applicability of international practice to the New Zealand context is uncertain.

The Tauranga Harbour Bridge, Bay of Plenty, New Zealand, was opened in 1988 and included a $1 toll for its use. Over the next thirteen years, the daily traffic flow on the bridge increased from 10,000 vehicles per day (vpd) to 27,500 vpd because of the continued strong residential development across the harbour from the city centre.

The removal of the toll in 2001 created an opportunity to investigate the effect of tolls on traffic behaviour in New Zealand. This study, carried out in 2004, provides information which could improve or benchmark the forecasting of flows on proposed new facilities. The parameters and elasticities obtained could assist in the development and validation of models developed to forecast the effect of new toll projects.

1. Introduction

A new harbour bridge crossing between central Tauranga and Mount Maunganui was constructed in 1988 and a $1 toll charge applied to light vehicles. The toll on the Tauranga Harbour Bridge was removed in July 2001, some 13 years after its introduction, which has provided a rare opportunity in New Zealand to study driver response to tolls.

Consideration of tolling new facilities is becoming more common in New Zealand and this requires robust tools for predicting traffic flows and associated outputs such as revenues. A key functional requirement of many transport models is to test traffic management, policy or project scenarios involving some form of tolling or road pricing and, therefore, a better understanding of the likely response of motorists to the imposition of tolls is important in the planning and evaluation of such tolling/road pricing projects.

The demonstrated effect of removing the toll on the Tauranga Harbour Bridge has provided information that could help validate forecasting methods for similar projects.

This research project, carried out in 2004, involved analysing traffic count data collected before and after the toll removal, and investigating how the Tauranga sub-regional Traffic Model (TTM) reflects this observed change. Detailed before-and-after surveys capturing travel patterns or journey times were not undertaken and subsequently this research is restricted to analysis of various traffic count data across parts of the network. Therefore this research cannot be extended to an analysis of Revealed Preference (RP).

Subsequent to the commencement of this research, specific Stated Preference (SP) surveys were undertaken on users of the Tauranga Harbour Bridge to assess the monetary value that travellers place on their perceived time savings (that is, their value of time (VoT)). This data has also been referenced in relation to the traffic model predictions.

Additionally, the sub-regional traffic model was updated during the course of this research and hence the tests were undertaken in both the original and updated models.

For patronage forecasting on proposed new toll roads, the common practice is to use more sophisticated choice models than simple single-class assignment models as used in the TTM. Subsequently this research focused more on the response of the distribution model than on the simple assignment model.

1.1 Purpose and objectives

The general purpose of this research is to:

- investigate the observed route diversion and demand elasticity effects from removing the bridge toll,
- investigate the implied motorist willingness-to-pay (WTP) for toll facilities,
- compare modelled with actual changes to improve traffic modelling techniques.

The outputs to achieve these objectives include:

- determination of the overall change in traffic patterns following removal of the bridge toll,
- comparison of the observed traffic flows against the theoretical capacity measures used for many projects in New Zealand,
- determination of the route-diversion effects individually from the demand (induced traffic) effects and hence the demand elasticity,
- estimation, where possible from revealed preference, of the value motorists applied to the toll in their travel choices,
- comparison of the actual changes with those predicted by the traffic model and investigation of the reasons for any discrepancies,
- recommendations for model structures that would be useful in other applications.

1.2 Relevance to Transfund's outcomes

This research would contribute to the following Transfund objective E (Travel Behaviour):

> *To provide a better understanding of travel behaviour and user preferences by:*
>
> – *building better transport models and evaluating transport modelling techniques,*
>
> – *understanding the effect congestion pricing could have on local economies and travel behaviour,*
>
> – *defining/understanding level-of-service requirements and community values/expectations/willingness to pay* (Transfund NZ 1999).

1.3 Report structure

The remainder of this report is structured as follows:

Chapter 2	contains an overview of the study methodology.
Chapter 3	describes the history and context of the Tauranga Harbour Bridge, along with the pre-toll removal traffic conditions.
Chapter 4	details the collation of available before-and-after data and issues associated with that data.
Chapter 5	details the analysis of the before-and-after data.
Chapter 6	contains a brief analysis of the current at-capacity traffic flows and how these relate to theoretically derived values.
Chapter 7	describes the traffic model and details initial testing comparing the predicted and observed flow changes.
Chapter 8	describes further tests undertaken in the updated traffic model.
Chapter 9	contains a summary and conclusions of the research work.

2. Study methodology

The adopted methodology for this study is as follows:

- **Data collation** involved collation of all available traffic count data before and after removal of the toll.
- **Data analysis** involved analysis of the count data by site, direction and time period. The changes on the bridge and the alternative route were analysed to estimate the diversion and induced travel changes. This also included a comparison of the observed at-capacity flows and the theoretical values.
- **Initial traffic model comparison** involved using the existing traffic model with and without the toll, and comparing the predicted change in traffic to observed changes.
- **Model testing** involved testing of alternative model structures or parameters to determine if an improved prediction can be developed. Tests included:
  - use of different parameter values for time and tolls,
  - use of differential values by trip purpose and time of day,
  - use of different cost functions in the demand models,
  - change in model structure from 24-hour to peak-period distribution.
- **Demand elasticity** involved using the changes in traffic flows and journey costs to estimate the demand elasticity and estimate the value motorists applied to the toll.

The initial traffic model used in this work was validated to a 1996 base and included forecasts for the year 2001. Following initial testing, the model was re-based to 2001 using Census land use data and validated to observed data post-toll removal. Subsequently, the testing of the modelled response to the toll removal was repeated using the updated models. Both initial and subsequent test results are presented in this report.

3. Tauranga Harbour Bridge

3.1 History and context

Before the 1998 completion of the Tauranga Harbour Bridge, only one significant route connected the western side of the Tauranga Harbour to the areas to the east of the Harbour which include Mount Maunganui, Papamoa and the wider Eastern Bay of Plenty[2] (Figure 3.1).

This route around the harbour includes four key components:

- SH2/SH29 between Te Maunga and the Maungatapu Bridge, which is a four-lane[3], undivided, high speed (100 km/h) highway,
- SH2/SH29 between the Maungatapu Bridge and the Hairini roundabout, which is a two-lane, undivided, high speed (80 km/h) highway,
- SH2 Turret Road/15th Avenue, which is a two-lane arterial road linking Hairini and Welcome Bay to central Tauranga. The southern/eastern end (Turret Road) is a divided-carriageway expressway while the northern/western end (15th Avenue) is a two-lane urban arterial with numerous property access points, side roads and traffic signals at the junctions with the key north-south arterials of Fraser Street and Cameron Road,
- SH29 between Hairini and Barkes Corner, which is a high-speed rural highway around the southern urban fringe of Tauranga and then over the Kaimai Ranges to the Waikato region.

The two-lane, 70 km/h Harbour Bridge connects the northern end of the Tauranga CBD[4] to Mount Maunganui via the east-west link of Hewletts Road and the north-south connection to central Mount Maunganui via Totara Street. The location of the bridge in the wider network is indicated in Figure 3.1, while the surrounding local road network is shown in Figure 3.2.

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[2] Welcome Bay Road does provide an additional route between these areas, but it is a low-capacity, low-speed rural road which does not act as an effective alternative to the Harbour Bridge.

[3] Lane numbers refer to total lanes in both directions.

[4] Central Business District.

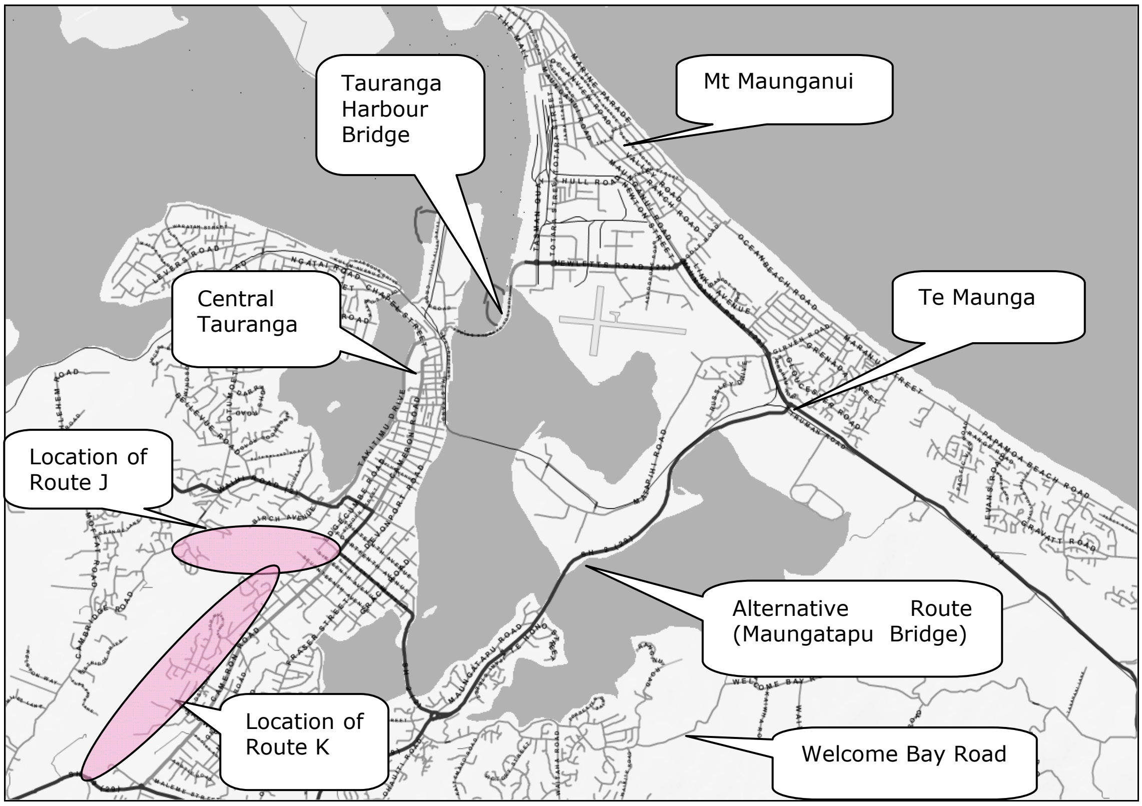


Figure 3.1 Map of Tauranga city and environs, Bay of Plenty.

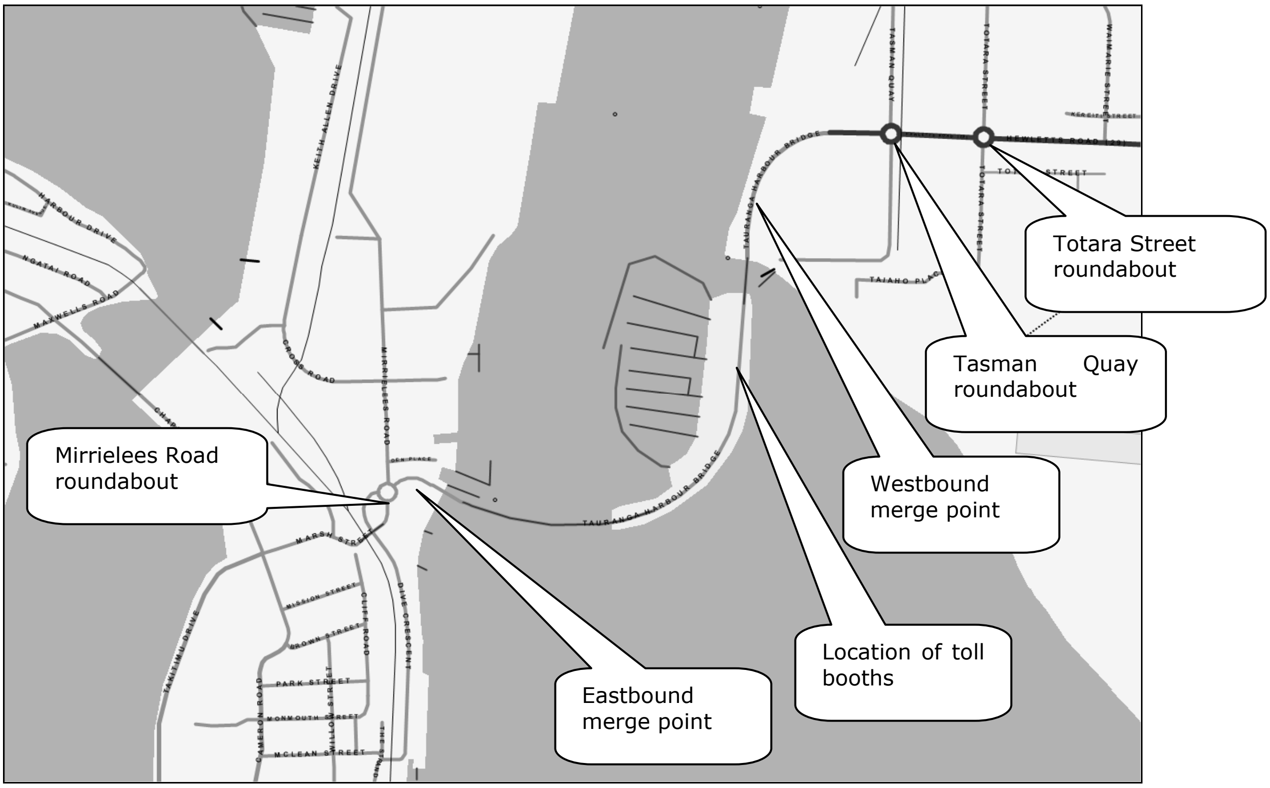


Figure 3.2 Local road network about the Tauranga Harbour Bridge.

3.2 Toll operations

Between 1988 and July 2001, the bridge operated with a $1 toll each way for light vehicles and $4 for heavy vehicles between 0600h and 2300h. The toll charge was collected manually at a toll booth on the eastern side of the bridge and between 2300h and 0600h the toll booth was closed and no toll was charged for use of the road.

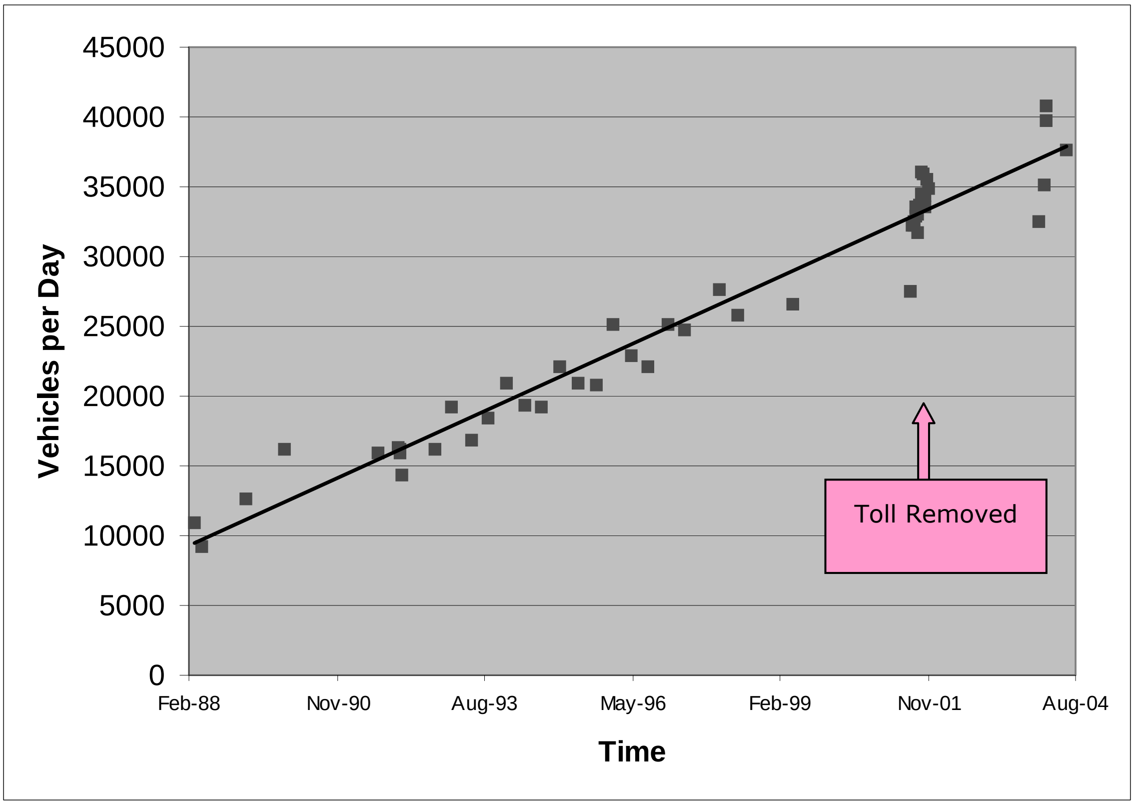


Figure 3.3 Daily flow counts on Tauranga Harbour Bridge.

3.3 Daily traffic flows and traffic growth

After opening in 1988 the daily flow on the bridge was some 10,000 vehicles per day (vpd), while in 2004 the daily flow was some 37,500 vpd. Figure 3.3 shows the daily traffic counts between 1988 and 2004 across the bridge, and indicates the long-term growth trend. The data points in the graph cover a range of months throughout the year and hence do not represent annual average flows. The increase in traffic with the toll removal in 2001 is quite apparent. The long-term (1998-2004) linear growth on the bridge is 4.6% per annum over the 2004 base flows of 37,500 vpd.

3.4 Flow profiles

The typical weekday hourly flow profiles on the Harbour Bridge for the week before the toll removal are shown in Figure 3.4. The profiles show typical urban morning and evening commuter peak profiles, but low tidal flow patterns of traffic. For example, in the westbound direction the evening peak flow is only 4% less than the morning peak flow, while in the eastbound direction the morning peak flows are only 12% less than the evening peak flows.

Peak period flows by 2004 were constrained by the capacity of the merges on each approach to the bridge. At the western end, a two-lane roundabout feeds the bridge, and it is followed by a very short merge to a single eastbound lane. This merge effectively defines the capacity of the bridge. In the westbound direction, the two-lane to single-lane merge west of the Tasman Quay roundabout effectively defines the westbound capacity of the bridge.

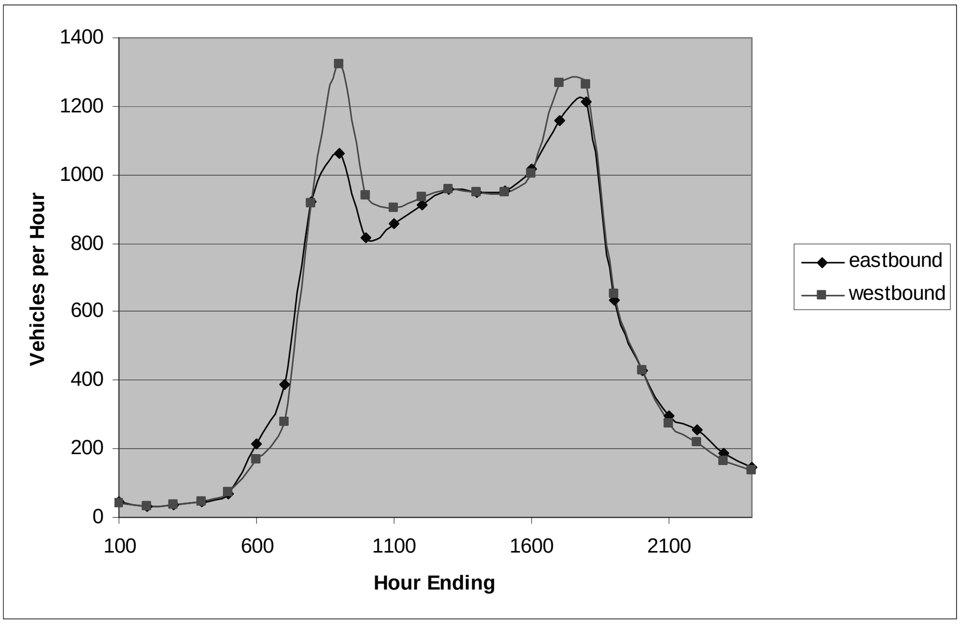


Figure 3.4 Typical flow profile (before toll removal) in vph, showing morning and evening peak traffic.

4. Data collection

This chapter outlines the data available for this study and how it was collected, and discusses some issues related to its source and reliability for the analysis. The analysis of the data is described in Chapter 5.

4.1 Available data

A full analysis would require an extensive before-and-after dataset of travel patterns by mode, route, origin and destination and time of day. Unfortunately, such information is not available because before-and-after data are restricted to traffic count data on selected roads.

As the full effects of the toll removal on travel behaviour could take some time to occur, a longer period of monitoring of the changes would provide more confidence that the change in traffic volumes had stabilised. Working against this, however, is the concern that, as the analysis period is extended, the changes caused by the toll removal would become indistinguishable from the longer term effects of natural background growth, or from changes in the wider network capacity.

In the case of the Tauranga Harbour Bridge, the length of time adopted for the 'after' test is limited because Route J was opened in April 2002 and the decision was not to use counts from the 'summer' months of December, January, and February.

Although data from journey time surveys are available after toll removal, a comprehensive set using the same survey methodology is not available immediately before toll removal. Therefore limited actual data exists on changes in travel times following toll removal.

4.2 Data collected

The key data used in this analysis were traffic count data, collected from Tauranga City Council and Transit New Zealand regular traffic count programmes. A total of 41 sites were identified where data were available both before and after toll removal, as shown in Figures 4.1 and 4.2.

For the cross-harbour sites, namely Tauranga Harbour Bridge and at Maungatapu, 17 continuous weeks of counts were obtained, including the last week before toll removal and the 16 weeks after removal of the toll.

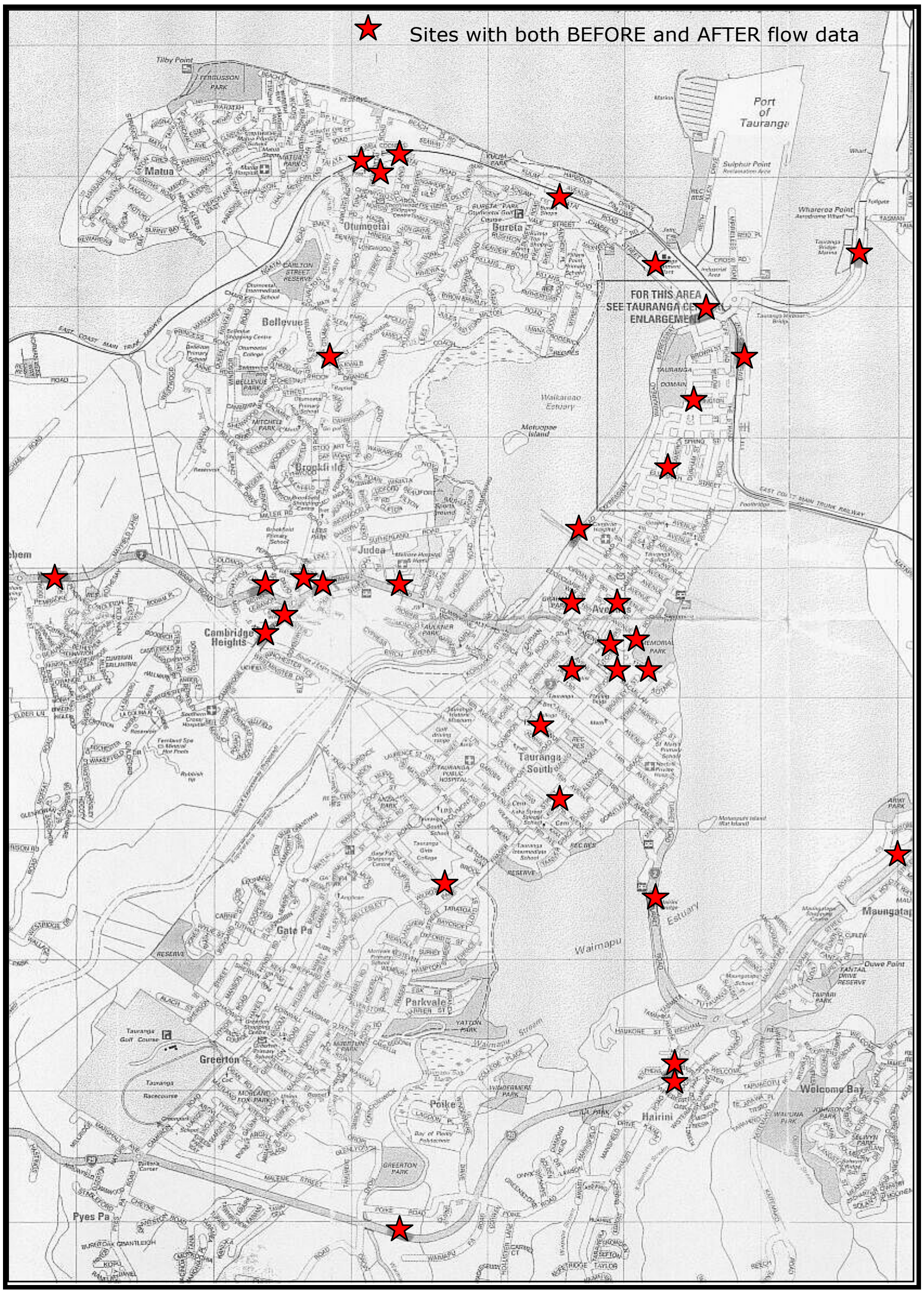


Figure 4.1 Locations west of Harbour Bridge from which before-and-after count data were obtained.

Figure 4.2 Locations east of Tauranga Harbour Bridge from which before- and after-count data were obtained.

4.3 Data adjustments

4.3.1 Survey year adjustment

The available data at some sites were older than year 2001 and so were adjusted by an annual growth[5] factor of 4.5% so that they more closely reflected the month of toll removal (July 2001). This 4.5% annual growth rate is based on recent observed traffic growth over a five-year period at five sites. This growth adjustment factor was obtained from four separate sites shown in Table 4.1.

5 Background traffic growth is growth caused by changing land use and any general increase in trip generation from existing land use.

Table 4.1 Traffic growth rates from 1995-1999 on locations around Tauranga City.

Road	Description	Annual Growth Rate (%)
Ngatai Road	Residential arterial in well established area	3.1
Fraser Street	Residential arterial connecting southern Tauranga to the CBD	4.5
Otumoetai Road	Residential arterial in well established area	4.0
Welcome Bay Road	Arterial in fast-growing residential area	5.8

4.3.2 Time period adjustment

The time periods used in the analysis were those defined in the existing traffic model as follows:

Morning (am) period	0730-0930
Interpeak	0700-0730 + 0930-1600 + 1800-1900
Evening (pm) period	1600-1800

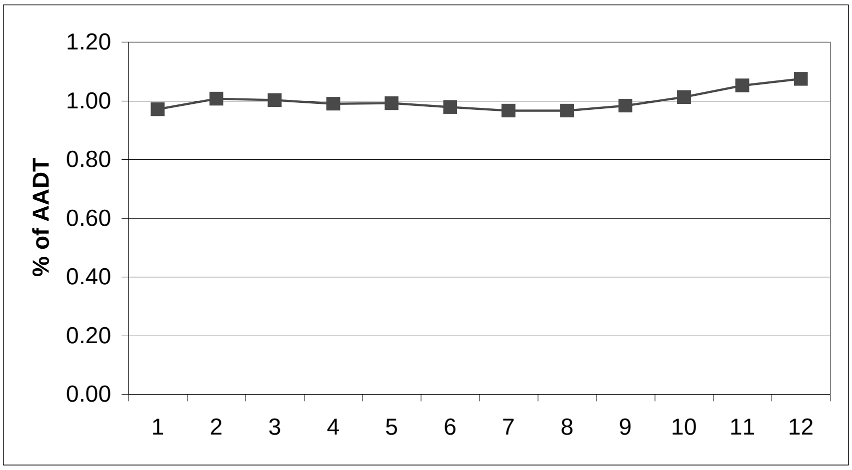
Some of the traffic count data obtained had only hourly count summaries. Because the am peak period used in the model starts and ends on the half-hour (0730 to 0930), it was necessary to factor 0700 to 0900 counts to mimic the 0730 to 0930 period. The factor of 1.074 was calculated from data available in 15-minute periods and has a low standard deviation (3.5%), which suggests that the use of hourly data should not introduce significant inaccuracies.

4.3.3 Seasonal fluctuations in traffic volumes

Seasonal fluctuations in traffic volumes can be significant and are an issue for this research given that Mount Maunganui is a recognised summer recreational area.

Some attempt was made to assess the seasonal fluctuations in traffic volumes from available data. However until recently continuous count stations in the study area from which to develop seasonal correction factors had not been installed. Twelve-month data are now available on SH2 north of Tauranga at Te Puna, but, as that area is heavily influenced by the seasonal fruit-harvesting seasons, it is not representative of seasonal patterns in central Tauranga.

Figure 4.3 shows the seasonal variation on Cameron Road as recorded in 1997, and it shows that the flows between February and October are reasonably stable but that November and December flows are noticeably higher than the annual average. However, the Cameron Road data might not be representative of the seasonal variations on the Harbour Bridge because it is located on the western side of the CBD where the recreational attractions of Mount Maunganui are likely to provide a much greater summer peak than is apparent in the Cameron Road data.



AADT – Annual average daily traffic volume; 1-12 months of the year

Figure 4.3 Seasonal variation in traffic (by % AADT) on Cameron Road (1997), which may not be representative of traffic flows on the Harbour Bridge.

Consequently the decision was to discard traffic counts from the months of December, January and February as these 'summer' traffic levels on the Harbour Bridge could not be expected to represent traffic distribution and generation for the rest of the year. This assumption was tested by looking at the data available on the Harbour Bridge, and is illustrated in Figure 4.4, which shows that the December/January data are generally higher but more variable than the other months.

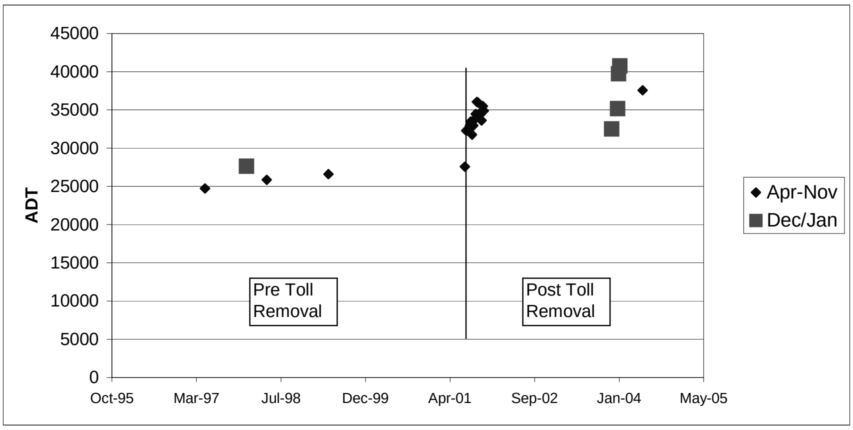


Figure 4.4 Seasonal variation on the Harbour Bridge showing the effects the toll on the 'summer' traffic flows.

Between early July and early November, the seasonal trend on Cameron Road suggests an increase in monthly average flows of 2.4%. Again assuming an average annual growth rate of 4.5%, this suggests that some 1.5% of this observed increase is likely to have been caused by natural growth. Therefore the normal seasonal effect could account for 0.9% of the assessed increase through the 17-week monitoring period. However, because this seasonal data was pre-2001 and because of the location of the count, this 0.9% adjustment was not directly considered in the calculations, although it was considered in the development of the conclusions.

5. Data analysis

This chapter details the analysis of the count data to identify the effect of the toll removal on traffic patterns. In considering the analysis requirements, the likely range of responses to the toll removal were considered, as outlined below. Assessment of the traffic flow variations in 2001 following toll removal are also discussed.

5.1 Expected response to toll removal

The effect of the toll removal was expected to include the following responses:

- **Re-routeing (diversion)** would involve traffic that previously used the alternative route across the Maungatapu Bridge, changing route to the Harbour Bridge.
- **Redistribution** would involve a change of destination, probably now involving a crossing of the harbour. This response could be expected to be higher for discretionary-type trips with various destination choices (such as shopping trips), than for trips constrained by other factors (such as commute or business trips).
- **Mode-change effects**, given the lack of an extensive public transport system providing a viable alternative to car travel, could be expected to be very minor. However, a decrease in vehicle occupancy could be expected as the toll could have acted as an incentive for ride-sharing.
- **Generated trips** would involve creation of new cross-harbour trips which previously did not occur.
- **Time of travel changes**, given the fixed all-day toll level, would not be expected as a primary response to the toll removal (other than late night trips near the 11:00 pm (2300 h) closure of toll booths[6]). However, some re-timing could occur as a response to the secondary effects of increased congestion.
- **Land use changes** would involve changes to decisions regarding locations of new developments or to relocations of existing activities.

The change in trip routeing can be estimated by comparing the traffic counts on the two routes and the proportion of total cross-harbour trips carried by each route. No origin-destination data are available before or after toll removal so the true effects on trip distribution (destination choice) cannot be determined. Again for the lack of data, estimates of the trip generation effects cannot be explicitly determined.

However, an estimate of the combined effects of distribution, generation and mode change can be made by analysis of the change in total cross-harbour trips (that is, the change in combined flows on both routes).

The data available for this research does not permit analysis of the effects on land-use location decisions.

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[6] Before removal of the toll, vehicles were occasionally observed to park before the toll booth for periods of up to 10 minutes awaiting the closure of the booth at 11:00 pm, to avoid paying a toll.

The time frame of the response is also likely to vary across the expected responses. Specifically, trip re-routeing would be expected to alter over a very short time while changes to trip distributions, travel modes or times of travel would take some time to stabilise. Changes to land-use location decisions would be long-term effects.

5.2 Snap shot of flow changes

5.2.1 Change in bridge flows

Over the 4-month period following toll removal over which the flows were monitored, the average daily flow on the bridge increased from 27,600 vpd to 34,900 vpd. The effect on the hourly profiles is shown in Figure 5.1, where it is apparent that the most significant increase occurred during the interpeak period. The identified lower proportionate change in the peak periods is expected as motorists would have less flexibility to alter their destination choice, mode or time or travel than they would during the interpeak period. Additionally, the increase in flows during the peak periods is likely to be constrained because the bridge is now running at capacity during peak periods.

The flow profiles for the weekend show a change in traffic more proportionate to the flow levels, as shown in Figure 5.2.

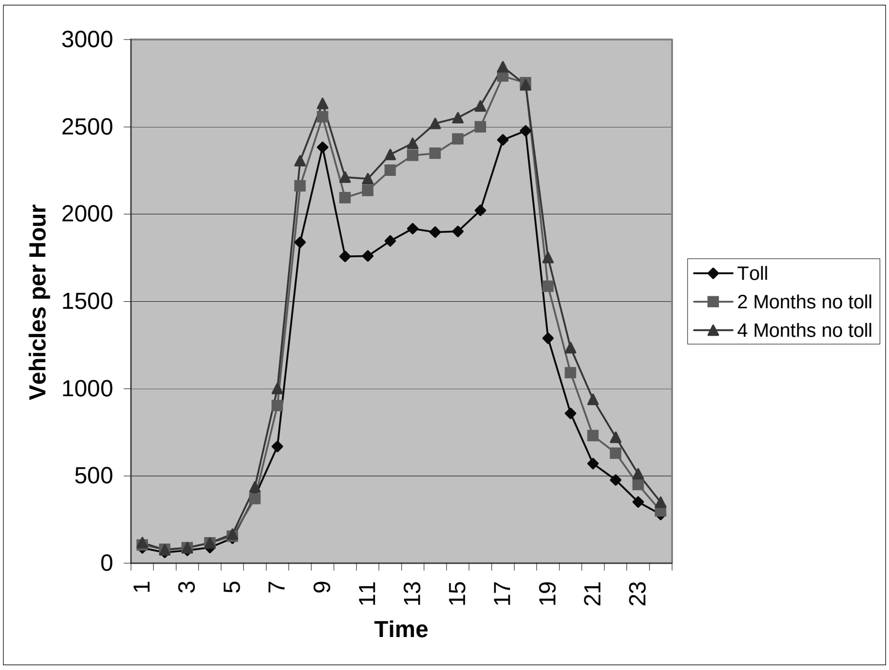


Figure 5.1 Change in weekday hourly bridge flows (both directions).

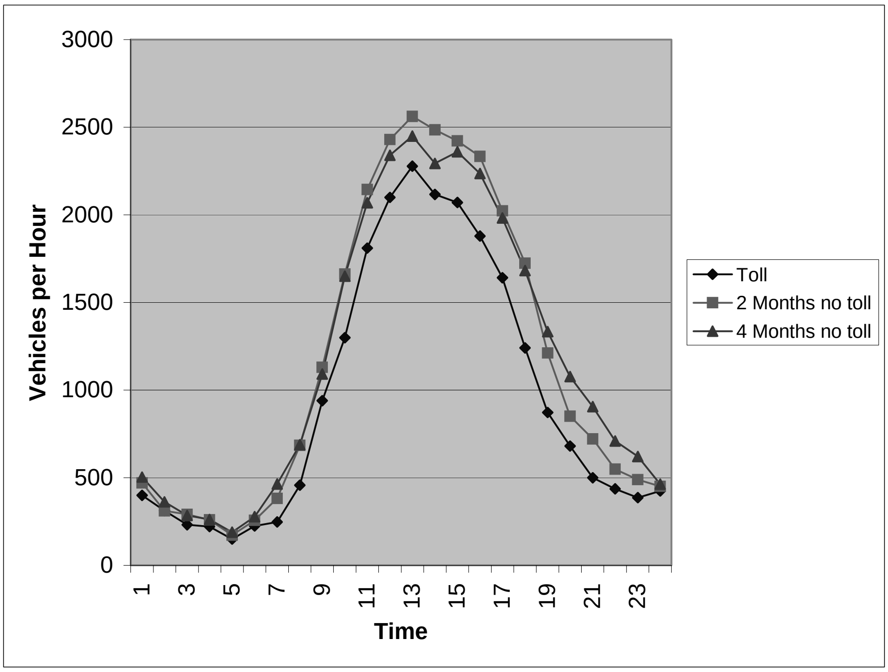


Figure 5.2 Change in weekend hourly bridge flows (both directions).

5.2.2 Change in flows on the alternative route (Maungatapu Bridge)

The average daily flows on the Maungatapu Bridge dropped initially by nearly 10%, but over the same 4-month monitoring period the total daily flows on this route had returned to the same level as pre-toll removal. This is indicated in Figure 5.3, where it can be seen that post-toll-removal flows are similar to pre-toll-removal, albeit with marginally lower interpeak flows and higher peak period flows. The increased flows during the afternoon peak are believed to be related to the high levels of congestion now experienced on the Harbour Bridge route during peak periods, especially the evening peak period.

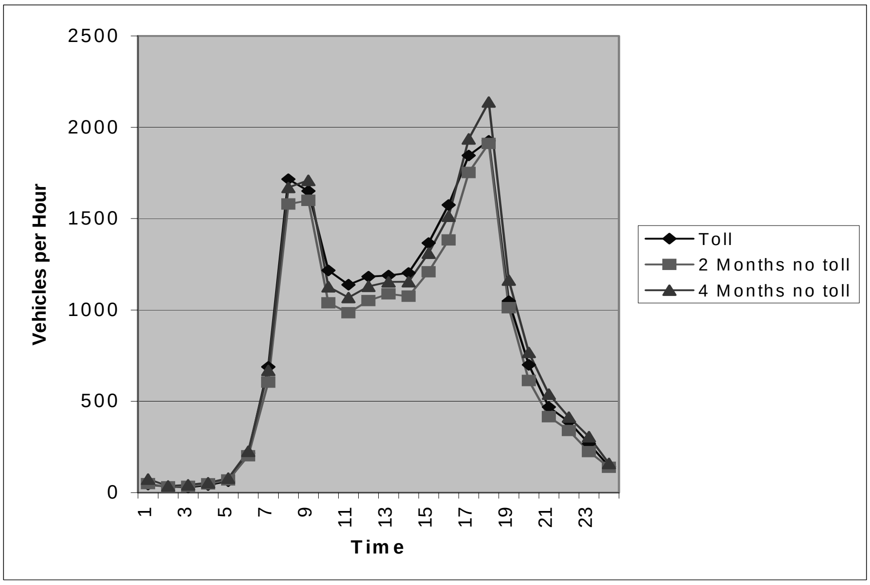


Figure 5.3 Change in weekday hourly flows on the Maungatapu Bridge.

5.2.3 Effect on heavy commercial vehicles

The observed change on heavy commercial vehicles (HCV) was more marked than for general traffic, with an increase of 1000 trucks per day (74%) on the bridge between the 1st and 17th week of monitoring, and a reduction of 150 trucks per day on the alternative route (10%). These effects are indicated in Figures 5.4 and 5.5.

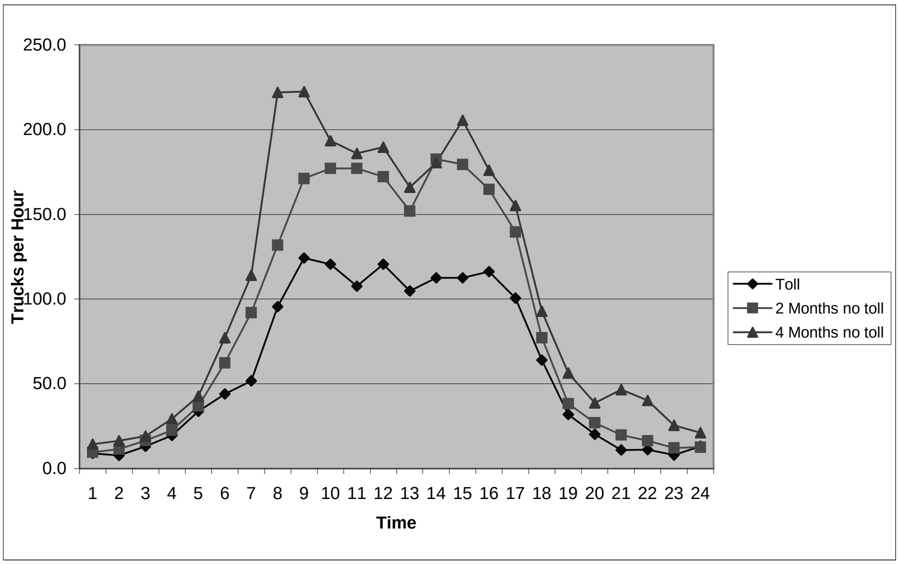


Figure 5.4 Change in weekday hourly HCV flows on the Tauranga Harbour Bridge.

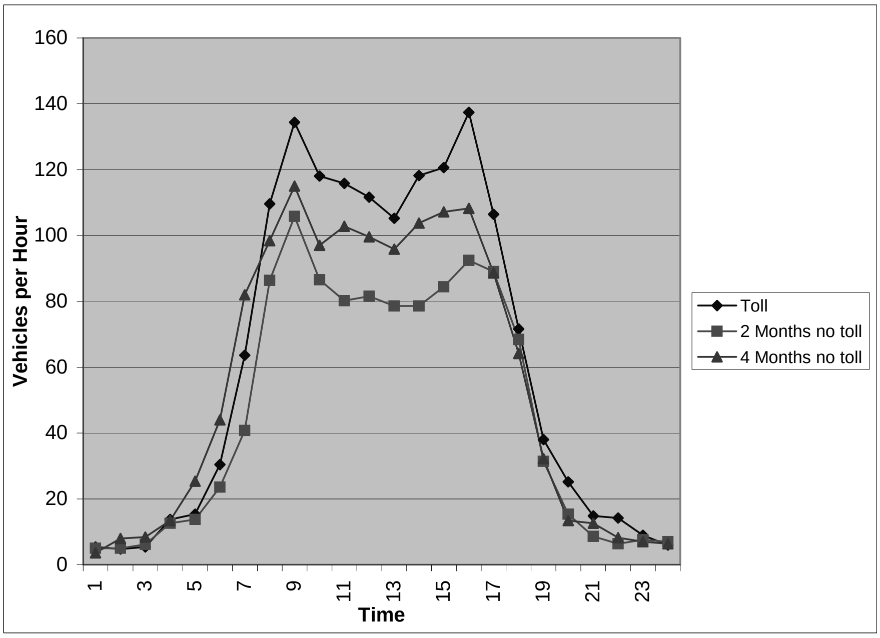


Figure 5.5 Change in weekday hourly HCV flows at the Maungatapu Bridge.

5.2.4 Effect on peak spreading

The potential effect of toll removal on peak spreading was estimated by comparing the proportion of the daily flow occurring in each hour before and after toll removal. This comparison was undertaken over both the short term (within 4 months of toll removal), and over the longer term (1997-2004).

Hourly flow profiles for just before toll removal, 8 weeks post-toll removal and 17 weeks post-toll-removal are shown in Figure 5.6. Similar profiles are shown in Figure 5.7 for counts in the month of May in 1997, 1999 and 2004.

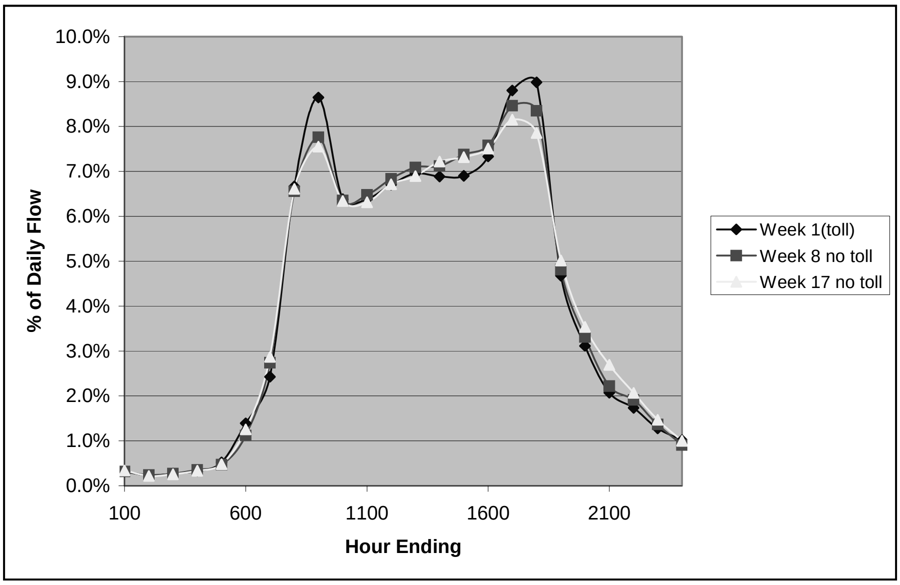


Figure 5.6 Short-term change in hourly flow proportions at Tauranga Harbour Bridge.

The short-term analysis clearly shows a reduction in the proportion of traffic occurring in the morning and evening peak periods, with consequential increases in the early afternoon and late evening periods. This corresponds to a 13% reduction in the proportion of daily traffic occurring during the morning peak between weeks 1 and 17 and a corresponding 7% reduction during the evening peak (although the actual proportions only change by some 1.1 and 0.7 percentage points respectively).

Over the longer term (Figure 5.7), the current (2004) profiles show a lower proportion of daily traffic in the morning and evening peak periods than previously, with marginally higher proportions during the early part of the morning peak and around midday. This corresponds to a 4% reduction in the proportion of daily traffic occurring during the morning peak between 1997 and 2004, and a corresponding a 8% reduction during the evening peak (again, the actual change in percentage points is less than 1%).

Comparison of the three sets of pre-toll-removal data (1997, 1999 and 2001) does however indicate that the 2001 profiles showed higher proportions during the peaks than the earlier data. As such the magnitude of short-term change in peak intensity is possibly somewhat over-stated, although the effects are apparent in both short- and long-term comparisons.

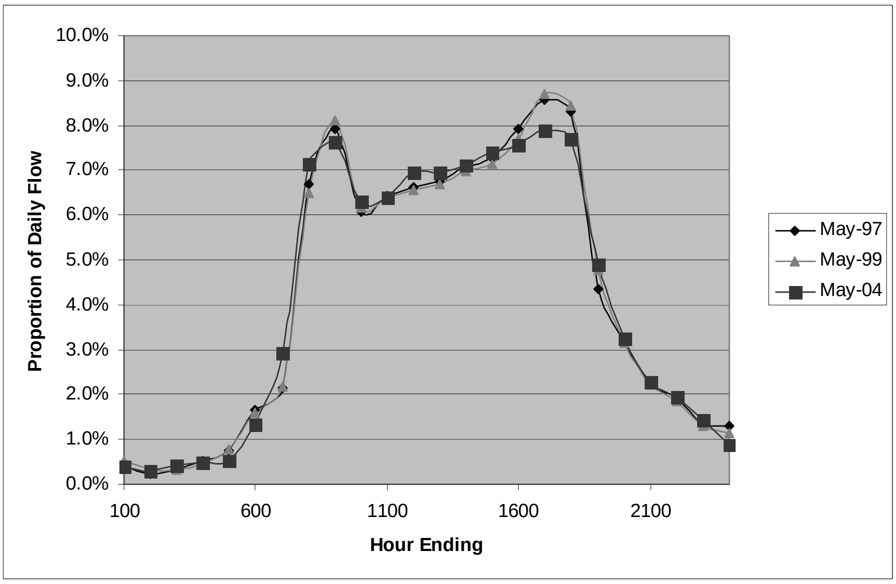


Figure 5.7 Long-term change in hourly flow proportions at Tauranga Harbour Bridge.

Overall, while evidence of some peak spreading is found, the magnitude is not highly significant and the cause is believed to be due less to the removal of the toll than to the resulting increase in peak period congestion on both routes.

5.3 Trend analysis of flows after toll removal

5.3.1 Flow changes through the monitoring period

In the first week after toll removal the weekday total cross-harbour trips increased by 7%, comprising an 18% increase in traffic on the Tauranga Harbour Bridge route, and a 9% reduction on the alternative route via the Maungatapu Bridge. The flows on both routes continued to increase for the 17 weeks following toll removal, as shown in Figure 5.8.

In order to calculate the change in cross-harbour traffic patterns caused by toll removal, the assumption was that by the end of the 17-week count period the change in trip patterns had stabilised. A search of international literature did not find any directly relevant research or case studies which could confirm this time frame. However, in undertaking toll revenue forecasts it is common to use a 'ramp-up' period which defines the length of time over which traffic on new toll facilities builds up to meet the steady-state forecast flows.

These periods have been observed to range from 12 to 20 months and reflect motorists adapting to the introduction of tolls. In Tauranga motorists were very familiar with tolls and hence it is arguable that the period of change following removal of tolls could be much shorter than that associated with the introduction of a new toll.

However, as outlined in Chapter 4, the opening of the nearby Route J project in April 2002 and the desire to omit the high seasonal flows in December through February restricted this analysis to the 4-month period following toll removal.

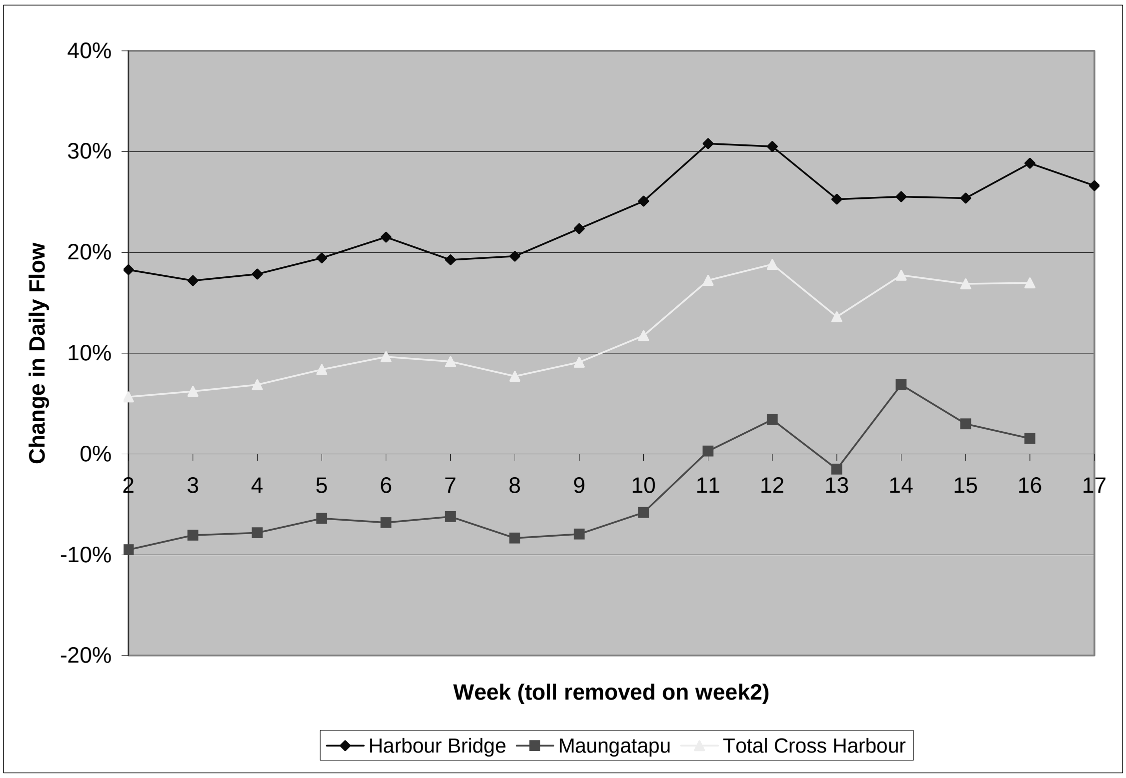


Figure 5.8 Change in daily flows post-toll removal (for Harbour Bridge, Maungatapu Bridge and total cross-harbour flows).

From observation of the trends shown in Figure 5.8, it appears that the general upward trend had stopped by Week 14, although some weekly fluctuations were still apparent. Subsequently the decision was to use Week 14 as the reference point for the short-term stabilised change in flows related to toll removal.

5.3.2 Trend analysis of percentage flow change

To calculate the change in traffic volumes, linear trend-lines were assigned to each traffic flow series through the monitoring period. The slope of these lines (less the 4.5% per annum assumed background traffic growth), was used to estimate the traffic volume after 14 weeks. These calculations were undertaken for each peak period and in each direction, to provide the results shown in Table 5.1.

Table 5.1 Percentage change in before and after counts by direction and time period as a result of toll removal.

AM peak	e/b	w/b	Both directions
Tauranga Harbour Bridge	14%	16%	15%
Maungatapu Bridge	−3%	−5%	−4%
Total cross harbour	7%	7%	7%
Interpeak	**e/b**	**w/b**	**Both directions**
Tauranga Harbour Bridge	29%	30%	30%
Maungatapu Bridge	−1%	−1%	−1%
Total cross harbour	17%	17%	17%
PM peak	**e/b**	**w/b**	**Both directions**
Tauranga Harbour Bridge	15%	11%	13%
Maungatapu Bridge	7%	5%	6%
Total cross harbour	12%	8%	10%
24-h	**e/b**	**w/b**	**Both directions**
Tauranga Harbour Bridge	26%	25%	26%
Maungatapu Bridge	0%	0%	0%
Total cross harbour	15%	15%	15%

e/b, w/b = eastbound and westbound

These flows represent the percentage change in the before flows following toll removal. For comparison with forecasts of adding a new toll facility, the effective change in flow relative to the after flows are presented later (Table 5.5) in Section 5.7.

A point of interest is that, while a net reduction in flows on the alternative (Maungatapu) route occurs in the morning peak period, an increase in flows occurs during the afternoon peak period. A probable explanation for this is the increased congestion generated on the Harbour Bridge Route following toll removals, which is most apparent during the evening peak commuter peak.

The change in flows is obviously similar in the morning and evening peaks, but quite different from that observed in the interpeak.

5.3.3 Effect of choice of reference week

A sensitivity test was carried out to examine the bound of change by using other weeks as the reference point instead of Week 14. The bound of change in total cross-harbour traffic was found to be between 14% and 18%, as summarised in Table 5.2 below.

Table 5.2 Sensitivity test using different reference weeks.

Reference Week	Harbour Bridge flow change (%)	Maungatapu Bridge flow change (%)	Total cross-harbour flow change (%)
Week 12	24	−2	14
Week 13	25	−1	14
Week 14	**26**	**0**	**15**
Week 15	26	1	16
Week 16	27	2	17
Week 17	28	3	18
Range	24 to 28	−2 to 3	14 to 18

5.3.4 Effect of weekly fluctuations

Although counts were monitored for a significant period after toll removal, only a single week was counted before removal. The potential effect of the weekly fluctuations in traffic counts on the assessed change in flows was estimated by considering the standard deviation of the weekly count data (Table 5.3). The standard deviation was found to be 4% of the average count from Week 2 to Week 17 for the Harbour Bridge, 5% for the Maungatapu Bridge, and 4% for the total cross-harbour traffic. Applying these standard deviations to both the Week 1 and Week 14 trend-line flows provides an indication of the likely fluctuation at each end of the trend line. Combining the standard deviations at each end indicates the likely boundary of possible effect on the slope of the trend line.

Table 5.3 Potential effect of weekly fluctuations (daily flows).

Site	Before count (vpd)	Trend line % change	Trend line flow change	After count (vpd)	SD (%)	Combined SD (vpd)	Error as % of change	Bound on % change
Harbour Bridge	27,500	26	7,100	34,600	4	1,626	23	26 ± 6
Maungatapu Bridge	20,140	0	0	20,140	5	1,562	NA	NA
Total	47,700	15	7,150	54,850	4	3,019	42	15 ± 6

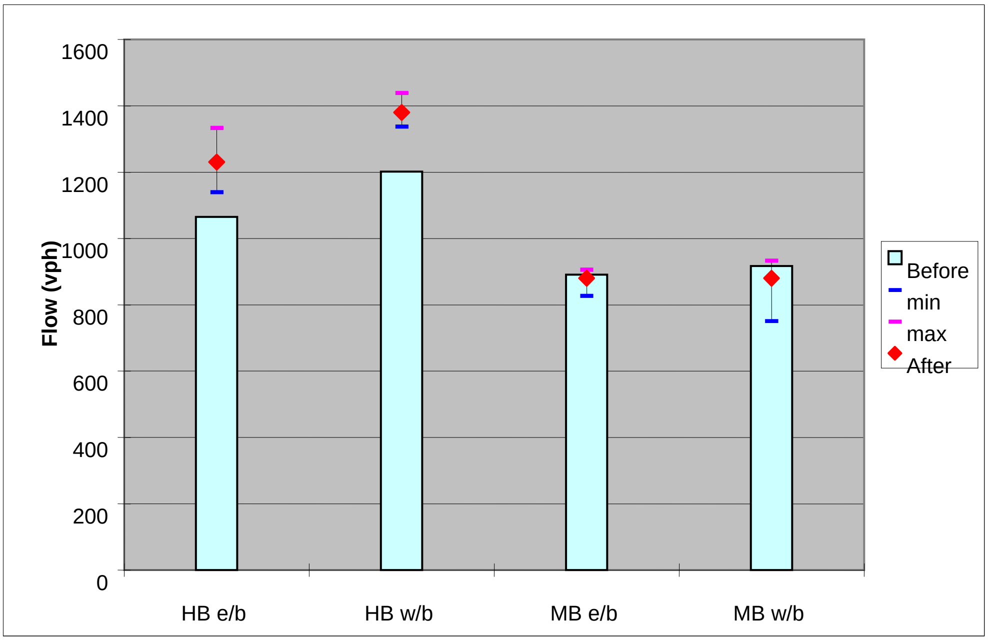
Thus the trend-line assessment of the change in traffic following toll removal is statistically significant, with the estimated change significantly higher than the potential error bound. The period following toll removal could also be expected to have much less stable flows than at other times as motorists adjusted to changing travel patterns and congestion. As such the weekly fluctuations, and hence error bounds suggested here, could be over-stated.

5.3.5 Assessed flows after toll removal

The percentage change in traffic from the trend analysis was then applied to the before counts to estimate the stabilised after counts. These counts are shown by peak period and direction in Table 5.4 and are shown graphically in Figures 5.9 to 5.12.

Table 5.4 Before and after counts by direction and time period.

Time / location	Before toll removal		After toll removal					
			Stabilised		Max		Min	
AM peak	**e / b**	**w / b**	**e / b**	**w / b**	**e / b**	**w / b**	**e / b**	**w / b**
Harbour Bridge	1065	1201	1230	1380	1333	1439	1139	1337
Maungatapu Bridge	891	917	880	880	906	933	827	751
Total cross harbour	1956	2118	2110	2260	2240	2372	1966	2088
Interpeak	**e / b**	**w / b**	**e / b**	**w / b**	**e / b**	**w / b**	**e / b**	**w / b**
Harbour Bridge	869	891	1130	1170	1211	1248	1035	1037
Maungatapu Bridge	610	598	600	600	654	636	540	522
Total cross harbour	1479	1489	1730	1770	1865	1883	1575	1559
PM peak	**e / b**	**w / b**	**e / b**	**w / b**	**e / b**	**w / b**	**e / b**	**w / b**
Harbour Bridge	1185	1266	1370	1430	1410	1454	1301	1294
Maungatapu Bridge	961	924	1030	930	1084	1029	891	886
Total cross harbour	2147	2190	2400	2360	2495	2482	2191	2180
24-h	**e / b**	**w / b**	**e / b**	**w / b**	**e / b**	**w / b**	**e / b**	**w / b**
Harbour Bridge	13601	13957	16910	17690	17898	18147	16053	16244
Maungatapu Bridge	10254	9887	10050	9850	10632	10364	9302	8926
Total cross harbour	23855	23844	26960	27540	28529	28512	25355	25170



HB = Harbour Bridge, MB = Maungatapu Bridge

Figure 5.9 Before and after morning peak flows.

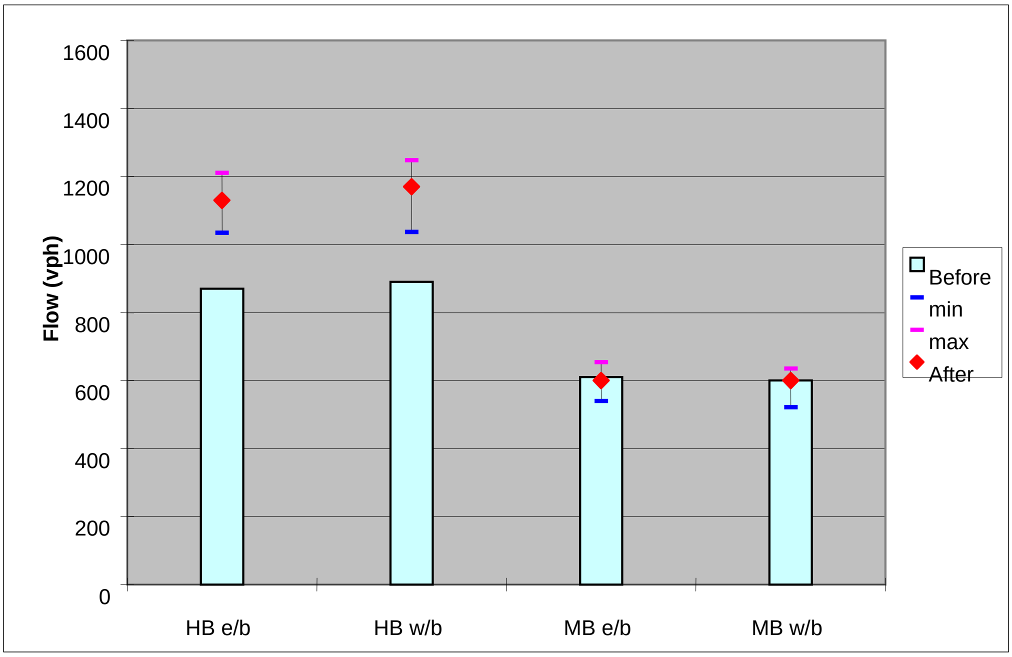


Figure 5.10 Before and after toll removal interpeak flows.

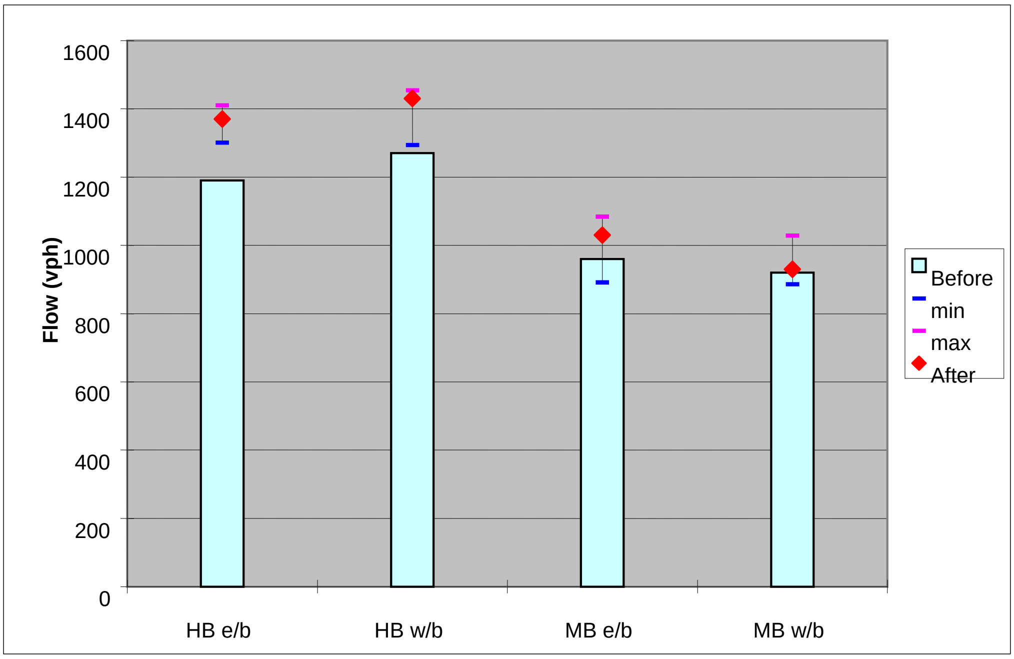


Figure 5.11 Before and after toll removal evening peak flows.

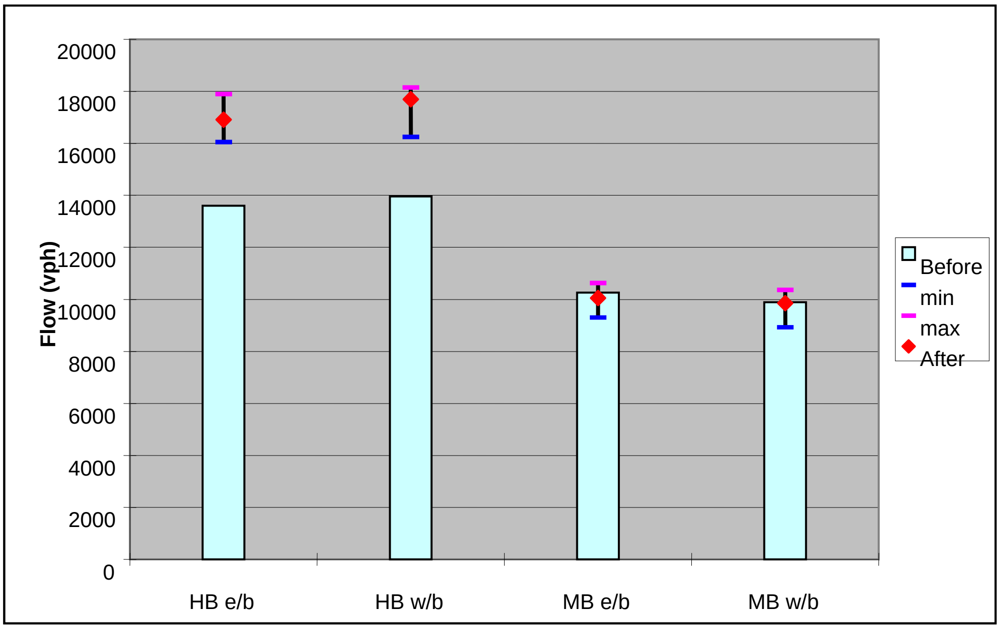


Figure 5.12 Before and after toll removal daily flows.

With the short-run change in flows showing a significant increase on the Harbour Bridge and a net change of zero on the alternative route via Maungatapu, it is clear that additional traffic was induced to the corridor, over and above any diversion effects. From these data alone, determining whether that induced traffic was caused by trip redistribution or from generation of new trips is not possible, although it is likely to be caused by a combination of both effects.

5.4 Change in traffic elsewhere

A total of 39 sites, excluding the two bridges, that have both before-and-after counts are located both on the east and the west of the harbour.

To do the comparisons, all before counts were projected to the last day before toll removal (22 July 2001) using 4.5% annual growth. Similarly, all after counts were projected backwards to the first day of toll removal (23 July 2001).

5.4.1 Changes in traffic around the Harbour Bridge

Most of the sites in the CBD have increased traffic after toll removal and a consistent increase in traffic volumes occurs for the sites near the Tauranga Harbour Bridge:

- Dive Crescent shows an increase over the three peak periods for both directions.
- Marsh Street shows an average of 20% increase over the peak periods for both directions.
- Hewletts Road (approximately 300 m east of Totara Street) has around 5% increase in the eastbound direction for morning and interpeak, and a 10% increase in the westbound direction for morning and interpeak.

5.4.2 Changes in traffic around Maungatapu Bridge

Sites near Maungatapu Bridge show a decrease in traffic volumes after toll removal:

- Both directions of SH2 (approximately 300 m south of Te Maunga Road) have an approximately 10% decrease in traffic volumes for the three traffic peaks.
- Both directions of SH2 (Turret Road, south of Hairini Causeway Bridge) have an average of 20% decrease in traffic volumes for the three peaks.

15th Avenue is the main route connecting the Maungatapu Bridge to the CBD and both directions of 15th Avenue show a decrease in all three periods. The magnitude of the decrease is higher than expected but, given that the count is a sample of seven days, the magnitude could be explained by week-to-week variation.

5.4.3 Wider network effects

If the traffic induced to the Harbour Bridge corridor following toll removal were caused by trip redistribution, then there should be some evidence of a reduction in traffic elsewhere in the network. With the interpeak period showing the highest proportional change in traffic across the harbour, this period would probably also show the largest effects in the wider network. Subsequently any significant percentage changes in interpeak flows were identified. The standard deviation of the weekly counts was previously found to be some 5% and hence sites with changes in excess of 5% were identified.

This assessment did not identify any strong patterns outside the areas directly affected by the traffic diversion. Some areas such as Otumoetai and Judea had counts showing a decrease in traffic after toll removal, but in some cases these were contradicted by increases in flows at other adjacent sites. Any effects of redistribution are likely to be small and spread widely over the network and hence difficult to distinguish within the normal flow fluctuations.

Trip redistribution is likely to be most apparent for discretionary trips where multiple destinations exist, such as shopping or recreational trips. Because the Harbour Bridge connected the main shopping centres in this area (Central Tauranga, Mount Maunganui and Bayfair), any redistribution effects to/from these areas will not be distinguishable from the diversion and/or generation effects seen in this same corridor.

Subsequently, although no strong evidence of trip redistribution can be identified (other than the general overall induced-traffic effects seen on the Harbour Bridge), this does not imply that such effects did not occur.

5.5 Travel times

Unfortunately little comparable data are available on observed travel times before and after toll removal. While some data exist for 2001 and 2003, the surveys used different routes and different methodologies preventing direct comparisons. Specifically, the 2003 surveys were used for congestion monitoring so all survey runs commence at a common fixed time, while the 2001 surveys used different start times within each peak period.

Additionally, minor improvements were made to the roundabout at the western end of the bridge following toll removal, making direct comparisons inappropriate.

Anecdotally the travel times across the Harbour Bridge have increased significantly and also become more variable. This is not surprising given the nearly 10,000 vpd increase in traffic on the bridge between early 2001 and 2004, on a facility which was already believed to be close to capacity in 2001.

Because of the lack of comparable before-and-after travel time data, estimating implied elasticities and/or revealed VoT from the observed data has not been possible.

5.6 Longer term effects

The current (2004) daily flow on the Harbour Bridge ranges between 35,000 vpd and 40,000 vpd with an average value of 38,000 vpd. This is some 7% higher than flows observed post-toll removal in 2001. However, this flow level was reached in 2003 and, with the bridge now believed to be running at its maximum capacity, any further growth in this corridor is believed to have been highly constrained.

Similarly, the current flow on the Maungatapu Bridge is some 22,000 vpd, representing a 9% increase in the three years since the toll was removed. With these growth levels consistent with the long-term historic growth trends and both corridors now operating at capacity during peak periods, any longer term effects of the toll removal are difficult to distinguish from the general background growth.

5.7 Change relative to after flows

The percentage change in flows presented earlier is based on the change relative to the before (with toll) flows. Most forecasting studies relate to predictions of the flow changes caused by the imposition of a new toll, so to allow direct comparisons the effective change in flow has been assessed relative to the after flows (the change relative to the before flows was presented in Table 5.1). These effective values are shown in Table 5.5. Because the after-case flows in the peak periods are constrained by the capacity of the bridge, the percentage change in flows is also likely to be constrained. As such, care should be taken in comparing these values with other studies.

Table 5.5 Percentage change in traffic volumes relative to after flows (indicative of the effect of 'adding' the toll).

AM peak	% e/b	% w/b	% both directions
Tauranga Harbour Bridge	−13	−13	−13
Maungatapu Bridge	1	4	3
Total cross harbour	−7	−6	−7
Interpeak	**% e/b**	**% w/b**	**% both directions**
Tauranga Harbour Bridge	−23	−24	−23
Maungatapu Bridge	2	0	1
Total cross harbour	−14	−16	−15
PM peak	**% e/b**	**% w/b**	**% both directions**
Tauranga Harbour Bridge	−13	−11	−12
Maungatapu Bridge	−7	−1	−4
Total cross harbour	−11	−7	−9
24-h	**% e/b**	**% w/b**	**% both directions**
Tauranga Harbour Bridge	−20	−21	−20
Maungatapu Bridge	2	0	1
Total cross harbour	−12	−13	−12

6. Capacity assessment

With the bridge now operating at capacity during peak periods, the observed flows are a good measure of that capacity. This can provide useful calibration data for other planning and modelling studies where the capacity limit can be difficult to assess when flows still operate below this limit.

6.1 Daily flow rates

Before toll removal in 2001, the bridge was believed to be operating close to capacity with a daily flow of 27,500 vpd. However, current daily flows are typically 38,000 vpd and during peak seasonal periods have been observed to reach 40,000 vpd.

6.2 Peak hourly flow

The maximum hourly flows before toll removal were between 1200 and 1270 vph. Currently the peak hour flows regularly reach 1520 vph in the westbound direction and 1470 vph in the eastbound direction.

After the toll was removed, the roundabout at the western end of the bridge was widened to provide two entry lanes onto the bridge, followed by a fairly short merge down to the single eastbound bridge lane. This merge point is now the capacity constraint rather than the roundabout itself. This means that, in both directions, the capacity of the bridge corridor is controlled by the merges at either end.

The maximum hourly flows observed here of between 1470 and 1520 vph are very consistent with the observed throughput of similar merges, such as those at the Paremata Bridge in Wellington (1450 vph before recent widening), and the Orewa south bridge (1500 vph before widening).

The reason that the westbound peak directional flow is higher than the typical eastbound peak flow is likely to be the much shorter merge length on the eastbound approach to the bridge.

The Austroads guide to roadway capacity (Austroads 1988) provides capacity estimates for various road types. This corridor is a mix of uninterrupted single-lane flow across the bridge and causeway, and roundabout controls at each end (with associated downstream merges). The Austroads procedures for uninterrupted single-lane flow facilities suggest a capacity of some 1540 vph per lane (assuming 5% HCVs, 3.7 m lane widths and 1 m lateral clearances).

The Austroad guide for urban arterials with interrupted flow suggest mid-block capacities reaching 1400 vph only under the most ideal conditions.

This shows that the peak directional flows observed on the Harbour Bridge are consistent with the Austroads guide.

7. Initial traffic model predictions

This chapter describes the testing of the removal of tolls in the traffic model of the Tauranga and Western Bay of Plenty sub-region, and comparison of the forecasts against the observed changes.

Initial testing was undertaken in an earlier version of the model (version 2.1), which had a base year of 1996 and a forecast year of 2001. That model was subsequently re-based to 2001 census data and calibrated to observed 2001 data (post-toll removal). Additional tests on the response to tolls were undertaken using that version of the model (4.0), and are also reported here.

7.1 Initial model structure

The initial (version 2.1) Tauranga Transport Model (TTM2.1) is a traditional 3-step car-driver model structured as follows:

Trip Generation: 24-hour vehicle driver productions/attractions for five trip purposes based on a household category model. The trip purposes are:

- Home-based work (HBW),
- Home-based shopping (HBS),
- Home-based other (HBO),
- Non-home-based (NHB),
- Commercial vehicles (CV).

Trip Distribution: 24-hour distribution by purpose, using gravity models with exponential impedance functions related to generalised costs of travel comprising time, vehicle operating cost and tolls. HBW distribution was based on travel costs skimmed from morning peak model, with all other purposes using costs skimmed from the interpeak models.

Time Period: Fixed proportions applied to distributed production/attraction matrices to generate morning peak, interpeak, and afternoon peak trip matrices by purpose.

Assignment: Peak period assignments of the combined matrices using all-or-nothing path-building iterated with full capacity-restraint (including intersection modelling), using volume-averaging methods.

The same generalised cost function was used in the assignment and distribution models:

$$\text{Generalised Cost} = \text{Time (min)} \times T + \text{Distance (km)} \times D + \text{Toll (cents)} \times TL$$

where: T, D and TL represent weightings applied to each cost component.

Because the costs are expressed in generalised minutes, the weighting on time, T, was set to 1 so that the D and TL parameters effectively represent Values of Time (VoT), converting monetary costs to units of time.

Different weightings on toll were applied throughout the day in the assignment models, as shown in Table 7.1. As indicated above, the home-based work (HBW) trips were distributed using the costs from the morning peak assignment model, while all other purposes used the interpeak travel costs.

Table 7.1 Weighting on generalised cost components. [7]

Time	Trip purposes distributed from costs	Time, T	Distance, D	Toll, TL minutes/cent	Toll, TL $/hour
Morning peak	HBW	1	0.8	0.058	10.3
Interpeak	HBS, HBO, NHB, CV	1	0.8	0.050	12.0
Evening peak		1	0.8	0.054	11.11

The toll on the Harbour Bridge was represented in the model by a toll charge of $1 plus a delay function representing the (manual) toll collection facility. In the 2001 models these toll-collection delays represented some 50 seconds.

7.2 Initial model testing

Version 2.1 of the TTM had a base year of 1996 to which it was calibrated on census and household travel survey data and validated to observed 1996 counts and travel times. Land use forecasts were provided by planners from the Tauranga City and Western Bay of Plenty Councils, and they were used to create future year models, including one for 2001.

Table 7.2 Initial model testing of toll removal (TTM version 2.1).

Time/location	AM		Interpeak		PM	
	Obs	Model	Obs	Model	Obs	Model
With toll	**vph**	**vph**	**vph**	**vph**	**vph**	**vph**
Harbour Bridge	2260	1810	1760	1690	2460	2200
Maungatapu Bridge	1810	1970	1210	1650	1880	2290
Total cross harbour	4070	3780	2970	3340	4340	4490
Without toll	**vph**	**vph**	**vph**	**vph**	**vph**	**vph**
Harbour Bridge	2610	3250	2300	3130	2800	3540
Maungatapu Bridge	1760	1460	1200	1220	1960	2040
Total cross harbour	4370	4710	3500	4350	4760	5580
Percentage change	**%**	**%**	**%**	**%**	**%**	**%**
Harbour Bridge	15	80	31	85	14	61
Maungatapu Bridge	−3	−26	−1	−26	4	−11
Total cross harbour	7	25	18	30	10	24

Obs = observed

[7] Although applied as fixed weightings on distance, these costs represent vehicle operating costs. Using the values of time implicit in the toll weightings, these operating costs represent costs between $0.14/km and $0.16/km.

The forecast 2001 model included the $1 toll and toll booth delay so this was removed from both the distribution and assignment modules to test the predicted effect of toll removal. The results of this test are shown in Table 7.2 (all flows are two-way).

From this initial testing the model obviously significantly over-predicted the increase in total cross-harbour trips and also over-predicted the diversion from the Maungatapu route to the Bridge route. The forecast 2001 model (with toll) also obviously failed to closely match the observed 2001 flows.

The potential reasons for the over-sensitivity of the distribution model were considered as outlined below:

- **Use of interpeak travel costs in 24-hour distribution**. The travel time costs are generally lower in the interpeak than during the peaks, meaning that the toll costs contribute a more significant proportion of the total generalised cost. As such, removal of the toll would have a bigger proportional impact on the generalised cost, and hence trip distribution pattern. The second impact of this is that the interpeak time costs do not reflect the increased journey times on the bridge during the peaks caused by the additional flows following toll removal. The increased congestion now experienced in the Harbour Bridge corridor has, to some extent, compensated for the removal of the toll cost. However this congestion effect is not fully captured in the 24-hour distribution models.
- **Use of common generalised costs across all purposes**. This means that all purposes have the same average generalised cost parameters (and especially value of time), and hence the same response to tolls. The trip purposes with the higher values of time (such as commercial vehicles) could be expected to have a lower response to tolls, while those with lower VoT, such as shopping trips, would be more sensitive to tolls.
- **Use of 24-hour distribution model**. The observed data make it clear that the change in cross-harbour trips is much higher in the interpeak than during the peaks. The use of a 24-hour distribution model does not allow the particular costs and VoT attributes to be used individually for each peak.
- **Non-segmented attraction model**. The trip attraction model is primarily a function of retail and non-retail employment in each zone (some additional factors are based on zone type). This means that the same aggregate land use data (retail/non-retail employment) controls the distribution of all trip purposes. Subsequently the model will treat the attractions as fairly interchangeable, i.e. the model will allow a high level of choice between competing destinations due to the aggregate attraction model, when many destinations could be constrained by other non-modelled factors.

  An example could be a home-based other trip (HBO) where a trip is made to a specialist service located in only a few specific sites. That service, being represented only by the number of employees, will be indistinguishable from other unrelated services, and the model will allow that trip to be made to other destinations which have employment, but may not include the specific activity. A high level of segmentation of trip purposes is not feasible from the type of data available, but the simple retail/non-retail split could make the distribution model overly sensitive to changes in cost.

- **Generalised cost function**. The generalised cost function used in the distribution model includes time, operating cost and tolls, which is standard for such models. However, little information is available on the appropriate weights to apply to these attributes, or whether these attributes alone are sufficient to replicate travellers' destination choices. The over-responsiveness of the model indicates that the weight applied to tolls is too high (i.e. the VoT is too low). It could also be that other relevant attributes are not included meaning that tolls represent a disproportionately high proportion of the total generalised cost. The other attributes could include parking costs (although these currently only exist in the central Tauranga CBD), quality of travel time, travel time reliability, etc.
- **Other induced travel effects**. Other effects such as mode change, trip re-timing or generation of new trips are not explicitly modelled. Trip re-timing would not be expected as a primary response to the toll removal as the same toll was applied all day. However, some re-timing could occur as a secondary response to the resulting increased peak period congestion. Analysis of the flow profiles shows evidence of this having occurred, although these were found to be relatively small-order effects. Similarly, the lack of significant public transport services would make a change of public transport very unlikely, and the location of the corridor in an industrial area remote from any residential areas makes change of slow modes (walking/cycling) very unlikely. Generation of some new trips across the harbour is likely as a response to toll removal, but it would not be possible to distinguish these effects from any distribution effects from the available data.

7.3 Testing of modified models

Some of the above issues were investigated by a running a series of tests using modified versions of the model. The tests included using different model parameters and/or structures. The aim of the tests was for the model to replicate:

- the observed percentage change in total cross-harbour volumes before and after toll removal,
- the observed split between Tauranga Harbour Bridge and Maungatapu Bridge both for the before and after cases.

7.3.1 Calibration to 2001

The distribution model was calibrated for the 1996 base-year model using the cost parameters and period costs described above. All tests described here were only undertaken using the 2001 forecast year.

Changes made to the form of the generalised cost function will alter the demand patterns and subsequently some tests were undertaken with recalibration of the model.

A simplistic recalibration was undertaken, where the gravity model was calibrated to fit the base 2001 matrix (i.e. the matrix from the current model structure developed from the with-toll scenario). This was done rather than using the observed 1996 matrices as the network and flow patterns changed significantly between 1996 and 2001.

The parameters of the exponential deterrence function were recalibrated to best match the base with-toll matrices. The intra-zonal adjustments were also modified to retain the same number of intra-zonal trips.

7.3.2 Test method

The initial tests were undertaken in isolation (i.e. only one component of the model was altered for each test), with combinations of changes being considered following analysis of the preliminary tests.

Each model test involved model runs with and without the toll as appropriate (obviously tests where only toll-related aspects of the model were altered did not need to be run for the 'no-toll' scenario). The tests undertaken were as follows:

Base Test Running the full, existing, 2001 TTM with and without the toll on the Harbour Bridge (as detailed in Section 7.1).

Base Assign Running only the assignment model of the existing 2001 TTM. This meant that the demand matrix developed with the toll in place was assigned to a network without a toll.

Test 1 Testing the sensitivity of the models to different toll weightings (TL), in the generalised cost formulations.

Test 1.1 involved reducing the toll weighting by 20% in both the distribution and assignment models.

Test 1.2 involved reducing the toll weighting parameter by 20% only in the distribution model, leaving the original toll weightings in the assignment model. The distribution models were simply run with these new cost formulations, with no recalibration.

Test 2 Effectively the same as Test 1.1, but the parameters of the gravity model impedance functions were recalibrated to fit the original 'with-toll' trip matrices from the base model.

Test 3 Using generalised cost components (skimmed time, distance and toll), obtained from different combinations of the peak periods. The toll removal has generated extra congestion on the Harbour Bridge route during peak periods but these peak period delays are not reflected in the distribution of all but the HBW trips. The 24-hour distribution models were recalibrated using different generalised costs, made up from weighted-average costs from the three modelled periods. The proportions of each peak period used in the distribution models were based on the amount of travel undertaken in each peak for that purpose. The values used are indicated in Table 7.3.

Table 7.3 Cost proportions used in the 24-hour distribution (Test 3).

Trip purpose	Source of skim costs (Time, distance, toll)		
	AM	Interpeak	PM
HBW	0.62	0.34	0.04
HBS	0.15	0.70	0.15
HBO	0.31	0.57	0.12
NHB	0.13	0.72	0.15
CV	0.16	0.63	0.21

Test 4 Using different generalised cost weightings for each trip purpose, rather than the single, global values used for all purposes in the base model. All motorists would respond differently to tolls related to variations in their value of time (VoT) and/or their willingness to pay (WTP) for tolls. The WTP values would also vary depending on the purpose (and hence value) of the trip being undertaken. It is not practical to model each motorist's response individually, but it is possible to use different WTP values for each trip purpose rather than a global average value. The source of the cost components (morning or interpeak skims) was that used in the base model, however the distribution models were recalibrated to use purpose-specific weightings as indicated in Table 7.4. These weightings were derived from recent research by Transfund and are similar to those used in the update of the Wellington Regional Transport Strategy Model.

Table 7.4 Generalised cost weighting factors used in Test 4.

Trip Purpose	Time, T	Distance, D	Toll, TL (min/c)*	VoT ($/hour)
HBW	1	0.66	0.0440	13.6
HBS	1	0.88	0.0588	10.2
HBO	1	0.74	0.0496	12.1
NHB	1	0.74	0.0496	12.1
CV	1	0.45	0.0150	40.0

* minutes/cent

Test 5 Combining the elements of Tests 2, 3, and 4. The trip-specific generalised costs weightings from Test 4 were used with the time-period combinations of costs components of Test 3. Two sub-tests were undertaken using different toll weightings.

Test 5.1 in which the toll weightings from Table 7.1 were reduced by 50% in the distribution model.

Test 5.3[8] in which the full TL values in Table 7.1 were used. In both tests the full TL values were used in the assignment models. These tests were focused

[8] A Test 5.2 was undertaken but, as Test 5.3 rendered it redundant, it was not analysed.

on the change in total cross-harbour traffic as predicted by the distribution models. Additional tests of the parameters used in the assignment models were applied in Test 6.

Test 6 Using the structure and parameters of the distribution model tested in Test 5.1, different weightings were applied to the distance component of the generalised costs in the assignment models. The focus of this test was to test the sensitivity of the assignment model to alternative costs weightings, and especially the split in traffic between the Harbour Bridge and Maungatapu Bridge routes.

Test 7 Changing the form of the impedance function used in the gravity models used the same model structure and parameters as Test 5.1, but altered the impedance function from an exponential form to a Gamma function. The parameters of the Gamma function were calibrated against the Base 'with-toll' matrices, then applied in the forecasting models. The exponential form of the cost deterrence function used in the base model is of the following form:

$$F(C_{ij}) = \exp(X_2 C_{ij})$$

The Gamma function used in Test 7 is of the form:

$$F(C_{ij}) = C_{ij}^{X_1} \exp(X_2 C_{ij})$$

where:

$F(C_{ij})$ = cost deterrence for zone i to zone j
C_{ij} = generalised cost for zone i to zone j
X_1 and X_2 = coefficients to be calibrated

The aim of this test was to see if the alternative form of the impedance function would alter the sensitivity of the distribution model to the toll removal.

The tests are summarised in Table 7.5.

7.3.3 Test results

Appendix 1 gives the graphs comparing the observed and modelled traffic volumes for each modelled period and for each direction.

The following conclusions were made from these comparisons:

Tests 1.1 and **1.2** Reducing the weight[9] applied to tolls in the distribution model reduced the sensitivity of the model, but significantly higher changes in the toll weighting would be required to replicate the observed changes. The differences between Test 1.1 and Test 1.2 were not significant.

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9 Reducing the VoT implies a higher weight applied to tolls in the generalised cost function which is specified in units of time.

Table 7.5 Summary of model tests.

Test	Sub-test	Description	Recalibration
Base	–	Run the full existing base models with and without tolls.	No
1	1.1	Reduce toll weighting parameters in generalised costs by 20% in both the assignment and distribution models.	No
	1.2	Reduce toll weighting parameters in generalised costs by 20% in the distribution models, retaining the original values for the assignment model.	No
2	–	As for Test 1.1 but recalibrate the gravity models to match the base model matrices.	Yes
3	–	Use an altered combination of time period costs in the distribution models.	Yes
4	–	Use purpose-specific weightings on toll and distance (TL and D) in the generalised costs used in the distribution models.	Yes
5	5.1	Combination of Test 2, 3 and 4 using a 50% reduction in toll weighting (TL) in the distribution model.	Yes
	5.3	Same as 5.1 but with no reduction in toll weighting.	Yes
6	–	Distribution model as used in Test 5.1 but with adjusted TL and D values in the assignment model to get a better split between the Tauranga Harbour Bridge and Maungatapu Bridge routes.	As for Test 5.1
7	–	Same as Test 5.1 but with a different impedance function in the distribution models. Instead of an exponential curve, a Gamma curve is used for the cost deterrence function.	Yes

Test 2 The effect of recalibrating the distribution model to the revised generalised cost function in the 'before' case meant a marginal increase in model response compared with Test 1.1 and the predicted change in total cross-harbour trips is still significantly higher than that observed.

Test 3 This test, involving use of all three time-period costs in the 24-hour distribution, led to a marginal increase in model response compared to the base model.

Test 4 This test provided similar results to the base model and previous tests.

Tests 5.1 and **5.3** The revised model structure (Test 5.3) showed a reduction in both before and after total cross-harbour flows, but only a marginally reduced model response compared to the base model. Doubling the VoT used in the distribution model (Test 5.1) significantly reduced the response of the model to toll removal, providing a change in total cross-harbour flows similar to the observed response. However, although the total flow is consistent with observed flows, this model predicted too much traffic on the Harbour Bridge post-toll removal.

Test 6 This test was a refinement of Test 5.1, and showed marginal improvement in the match with observed flows.

Test 7 This test is similar to Test 5.1 but using a Gamma impedance function. This test showed little change compared to Test 5.1, with a marginally increased model response.

Overall these tests indicate that minor structural changes to the model make little difference to the model response. The only test which provided results close to the observed response involved the doubling of the VoT. However, this test indicated a fairly poor validation to the un-tolled flows, and over-predicted the traffic on the bridge. This suggests that there are other impedances to use of the Harbour Bridge in the un-tolled network than those indicated in the models.

These tests also demonstrate that the use of a 24-hour distribution did not allow for the different model response between peak and interpeak periods that were apparent in the observed data.

Subsequent to these initial tests, and as part of the general maintenance of the model, the model was re-based to 2001 census data and validated to 2001 flows post-toll removal. Also in that update the model structure was modified to include peak-period rather than 24-hour distribution. This resulted in version 3.0 of the model, which shortly after became version 4.0 following development of new land use forecasts. The testing of that revised model to toll removal is detailed in Chapter 8.

8. Tests using updated model

8.1 Model update

As part of the re-basing of the model to 2001 census data, the model structure was modified to use peak-period rather than 24-hour distribution. This meant that peak period and directional factors were applied to the 24-hour trip-ends before distribution, rather than following a 24-hour distribution as included in the original model.

This allowed calibration of the model to flow patterns post-toll removal. The minor structural and parameter changes tested in the initial work were also incorporated in the model update.

Calibration of the travel patterns required the use of cross-harbour factors in the distribution models to match the observed cross-harbour flows. This process resulted in models which were validated to 2001 counts post-removal.

This updated model (version 4.0) was then also used by Transit New Zealand's National Toll Modelling Consultant as a base to provide patronage and revenue forecasts for the Harbour Link project[10] with a toll applied. That work used more sophisticated toll choice models in the assignment process than in the base TTM. Based on preliminary toll forecasts on Harbour Link and also based on the initial results of this research, it was agreed with Transit's Consultant to apply damping factors to the toll component of the generalised cost used in the distribution model. The toll costs were therefore reduced by 25% before inclusion in the generalised cost for the base year.[11] This has the effect of increasing by a third the VoT applied to tolls in the distribution model.

The base VoT used in the distribution model as well as the implied VoT after the 25% damping is shown in Table 8.1. The base VoT was retained for conversion of the vehicle operating costs from monetary units to units of time.

Table 8.1 VoT applied to tolls in the distribution model.

Trip purpose	Base VoT ($/h)	Dampened weight applied to tolls (minutes/cent)	Implied VoT ($/hour)
HBW	13.6	0.0330	18.1
HBS	10.2	0.0443	13.6
HBO	12.1	0.0375	16.1
NHB	12.1	0.0375	16.1
CV	40.0	0.0113	53.0

[10] This is the project to widen the Tauranga Harbour Bridge and approaches.

[11] This damping was only applied to the skimmed tolls for use in the distribution models. The path-building process used to skim the toll costs included the base VoT. Further damping was applied to future forecasts to represent the effects of fully electronic tolls and increasing VoT over time.

8.2 Model tests using updated model

The updated 2001 model, validated to the no-toll scenario, was run with the $1 toll in place and results are shown in Table 8.2.

Table 8.2 Initial model testing of toll removal in updated model (TTM version 4.0).

Location	AM		Interpeak		PM	
	Obs	Model	Obs	Model	Obs	Model
With Toll	vph	vph	vph	vph	vph	vph
Harbour Bridge	2260	1796	1760	1336	2460	2077
Maungatapu Bridge	1810	1972	1210	1487	1880	2162
Total Cross-Harbour	4070	3768	2970	2823	4340	4239
Without Toll	vph	vph	vph	vph	vph	vpf
Harbour Bridge	2610	2729	2300	2419	2800	2889
Maungatapu Bridge	1760	1638	1200	1091	1960	1876
Total Cross-Harbour	4370	4367	3500	3510	4760	4765
Percentage Change	%	%	%	%	%	%
Harbour Bridge	15	52	31	81	14	39
Maungatapu Bridge	−3	−17	−1	-27	4	−13
Total Cross-Harbour	7	16	18	24	10	12

Obs = observed

These tests indicate a reasonably good match with the change in total cross-harbour traffic, but a poor match with the change on each individual route. The model over-predicts flows on the Harbour Bridge and under-predicts flows on the Maungatapu Bridge.

This suggests that the assignment model was not replicating the observed changes in flows, although it is difficult to distinguish between redistribution and diversion effects from the available data.[12]

8.2.1 Parameter tests undertaken

The model parameters were therefore varied in a series of tests to determine if a better match to the flows on individual routes could be achieved, while retaining the good overall response of the model to total cross-harbour flows. The models run were as follows:

Base model Running the model with the full $1 toll but reducing the skimmed toll costs by 25% in the distribution model.

Test A Running the distribution model with 75% of the toll but the assignment model with 100% of the toll. In this test the separate 25% damping of the toll in the distribution was removed. This differs from the base model in that the 25%

[12] The base version of the model used here uses a typical, single-class path-building and assignment process, whereas the revenue forecasting for Harbour Link used a different approach to modelling the route choice.

reduction in the toll was applied in the path building used to skim the toll costs, rather than to the resulting skim costs themselves. (This means that effectively the same 25% reduction in the toll is applied in the assignment model. However as the reduced toll is used in the skim assignments, there could be a change in paths taken during that skim assignment.)

Test B Running the distribution model with only half the toll but using the full toll in the assignment model. In these tests the 25% damping of toll costs in the distribution was removed.

Test C Running the model with only half the toll both in the distribution model and in the assignment model. In these tests the 25% damping of toll costs in the distribution was removed.

Test D Running the distribution model with a toll discounted by 25% (as per Test A), but using a multi-class assignment model with a 50c toll for the final assignment. The multi-class assignment model segments the demand by trip purpose, and hence by VoT.

8.2.2 Test results

The observed and modelled flows with and without tolls are presented in Appendix 2. The key findings of these tests are as follows:

Test A This test provides results very similar to the base model. This indicates that the model responds the same whether the 25% discounting of tolls is done during or after the tolls are skimmed.

Tests B and **C** These tests with the 50% damping of tolls costs provide a response much closer to the observed change than tests using only the 25% damping.

Test D The use of this multi-class model made only a negligible change in flows when compared to the equivalent single-class model (Test A).

Test C The model that best matched the observed change is Test C, where the toll was damped by 50% in both the distribution and assignment models.

The correlation between modelled and observed flows was assessed by calculating the R^2 value for each toll model. This value was compared across both routes, in both directions and across all three time periods (providing 12 data points for comparison). The R^2 for the no-toll scenario was common to all tests at 0.98, while those for the with-toll scenario are shown in Table 8.3.

Table 8.3 Correlation (R^2) between modelled and observed toll flows for base and Tests A – D options.

Option	Base	Test A	Test B	Test C	Test D
R^2	0.34	0.30	0.47	0.91	0.35

These results clearly show that effectively doubling the VoT used in both the distribution and assignment models provides the best fit to the observed change in flows, both in terms of the change in total cross-harbour traffic and the split between the competing routes.

8.3 Predictions for Route K

In 2003 a new toll route was opened in Tauranga, known as Route K. This project runs up the Kopurererua Valley connecting SH29 east of Tauriko to the Route PJK junction in Judea (see Figure 1.1). Up to 3 parallel roads provide alternative routes to Route K which results in relatively low usage of Route K with the $1 toll. Because of the low volumes and numerous parallel routes, it is recognised that Route K is not an ideal project for calibrating a toll model.[13] However, it was thought useful to validate the generalised cost functions developed and tested above for the Tauranga Harbour Bridge predictions against the observed screenline[14] flows through the Route K corridor.

The focus of this work was on the potential effect on the total corridor demands rather than the predictions on individual routes within the corridor. This was because of the very subtle time differences between the parallel routes and hence the sensitivity of the models to minor changes in speeds or delays.

The corridor screenline was defined as including Cambridge Road, Route K and Cameron Road, as indicated in Figure 8.1.

Again, a series of tests was undertaken in the model to test the effect of various damping ratios on the tolls. It is important to note that these tests were undertaken using the simple route choice model rather than more sophisticated and purpose-built toll models. As such these results are presented for testing purposes only and do not in any way represent actual patronage forecasts for Route K.

The tests undertaken were as follows:

Base model Running the model with the full $1 toll but reducing the skimmed toll costs by 25% in the distribution model.

Test K1 Running the distribution model with 50% of the toll in both the assignment and distribution models.

Test K2 Running the models with no toll on Route K.

Test K3 Running the distribution model with no tolls in the distribution model but the full toll in the assignment model.

In all the above tests, both the single-class and multi-class models were run.

The results of these tests using both the single-class and multi-class assignment models are detailed in Table 8.4. The results from the multi-class model are shown schematically in Figure 8.2.

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[13] Traffic models often become sensitive and unstable when attempting to predict flows on parallel competing routes with similar travel times.

[14] The 'screenline' is an imaginary east-west line passing through Route K and parallel alternative routes, from which traffic flows are determined.

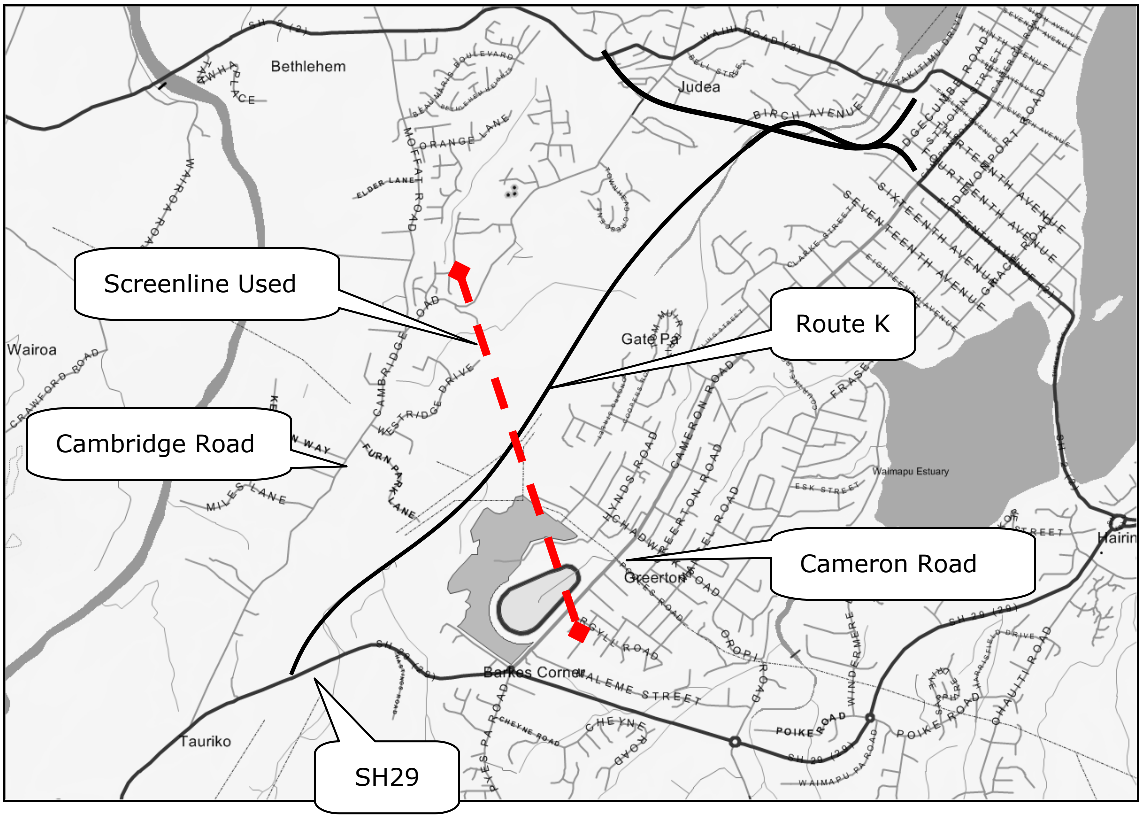

Figure 8.1 Route K screenline.

Table 8.4 Daily flow predictions on Route K.

Site	Observed	Base model	Test K1[1]	Test K2[2]	Test K3[3]
Single-class assignment model					
Cambridge Road	6,509	5,780	4,655	4,047	5,854
Route K	2,226	3,039	7,750	14,905	3,205
Cameron Road	16,000[15]	16,107	13,340	12,308	16,066
Screenline Total	24,735	24,926	25,745	31,260	25,125
Multi-class assignment model					
Cambridge Road	6,509	6,481	4,702	3,993	6,610
Route K	2,226	2,474	7,854	14,967	2,771
Cameron Road	16,000	15,846	13,280	12,014	15,737
Screenline Total	24,735	24,801	25,836	30,974	25,118

[1] 50% damping distribution and assignment
[2] no toll [3] 50% damping distribution only

[15] No 2003 data for Cameron Road were available so, for comparative purposes, this flow was set similar to that predicted in the base model.

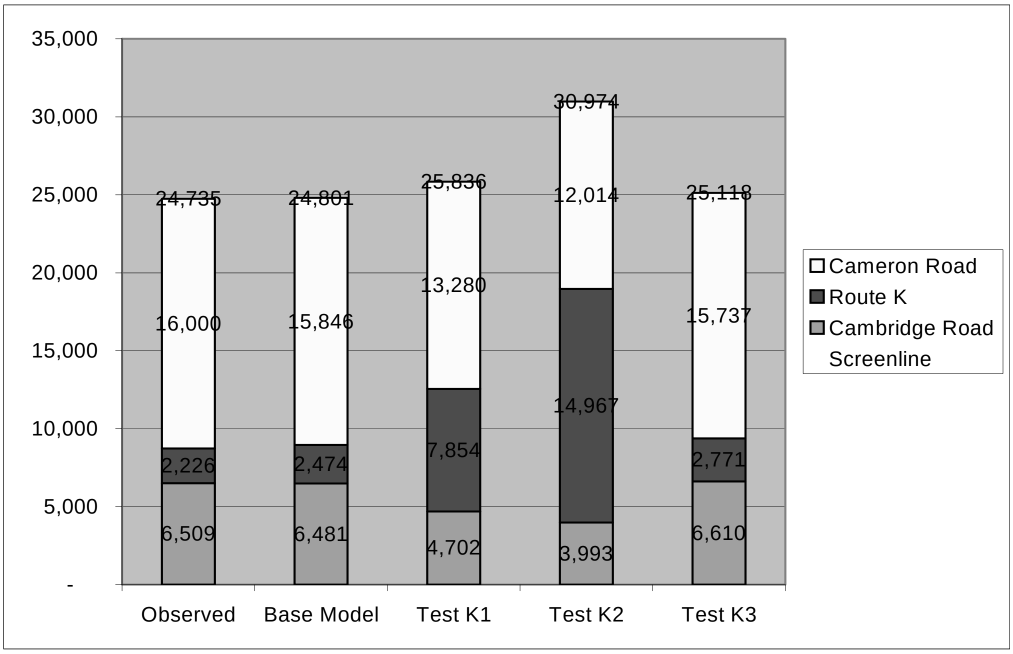

Figure 8.2 Test results on Route K screenline.

The key findings from these tests are as follows:

- The damping on the toll makes little difference to the total screenline flow, with total flows in Tests K1 and K3 showing similar total flows to the base model. This is because of the easy access to alternative routes to Route K, meaning that very few origin-destination pairs have a toll cost applied. Consequently the tolls have limited effect on the distribution patterns, irrespective of the weights applied to the tolls in the models.
- However, the toll damping has a significant effect on the diversion patterns, with the modelled flows on Route K being very sensitive to the toll used in the assignment.
- The multi-class model shows a better match to observed flows than the single-class model. This is believed to be because the different routing parameters for each class provide a better spread of paths, and hence less sensitivity to small cost changes in the competing routes.

These results are somewhat different from those found on the Harbour Bridge toll, where the flows were much more sensitive to the treatment of tolls in the distribution model, and relatively less sensitive to how the tolls are represented in the assignment model. This is not surprising given the nature of the two roads, where land use patterns have developed over a long period since the Harbour Bridge was constructed and the alternative route is significantly longer for some movements. This contrasts with Route K which has a number of parallel alternative routes, only small time savings on Route K, and as yet no land use patterns developed that have direct access to or use Route K.

These tests do not contradict the findings of the Harbour Bridge tests with regard to the distribution model, where doubling of the VoT was required to best match the observed change in cross-harbour traffic.

However, at face value, these results do suggest that doubling the VoT applied to tolls in the assignment model would not be appropriate, which was not the case in the Harbour Bridge tests. Note however that, in the validation of the updated model, initial testing of Route K found the assigned flows highly sensitive to the relative speeds on the competing routes and some adjustment of the relative costs of the two routes was required to match the very low observed flows.

Subsequently, the feasibility of calibrating models or VoT parameters directly to observed flows on Route K is doubtful due to the high level of sensitivity to small time savings. These results do however suggest that differences in the initial response to tolls could occur when applied to a new facility than when applied (or removed) from existing facilities.

8.4 Implied value of time

In the updated traffic model, slightly different VoT were applied to tolls in the distribution and assignment models. This was because the stated preference survey results only became available after calibration of the distribution models. Because the surveyed VoT were found to be highly consistent with the initially adopted values used in the distribution model, the original values were not altered. However, the surveyed VoT were used directly in the assignment models.

8.4.1 Distribution model

In the distribution model, the toll costs were damped by 25% to reduce the responsiveness of the model. While this provided an acceptable overall response, further testing has indicated that a 50% damping would provide a better match to the observed data[16]. These VoT are presented in Table 8.5.

Table 8.5 VoT applied to tolls in the distribution model.

Trip purpose	Base VoT ($/h)	25% damped VoT	50% damped VoT
HBW	13.6	18.1	27.2
HBS	10.2	13.6	20.4
HBO	12.1	16.1	24.2
NHB	12.1	16.1	24.2
CV	40.0	53.0	80.0

The Base VoT values used are consistent with those from various stated preference (SP) surveys, including those undertaken for the Project Evaluation Manual (Transfund NZ 1997) benefit parameters. However those surveys are generally targeted at route choice decisions rather than destination decisions. It is believed that these tests on their own do not provide strong justification to conclude that the VoT applied to tolls for destination choice should be double the base values, as the over-sensitivity of the distribution models

[16] In the model update, further damping was applied in the future year models when testing fully-electronic toll systems on a number of projects in the network.

could conceivably be related to the exclusion of other unquantified attributes, rather than an incorrect weighting on the toll parameter.

However, because most transport models of this type use similar cost attributes, it could be argued that a higher VoT on tolls should be seriously considered in these models, with values as high as double the base values shown in Table 8.5.

8.4.2 Assignment model

The VoT applied to tolls in the assignment models is also based on the SP survey data, and the model testing indicates that the best fit to the observed changes on the Harbour Bridge comes from doubling the VoT used in the assignment. Like the distribution models, the route choice models only consider travel time, operating cost and tolls, when other attributes could be involved in the choice of route. These could include the quality of travel time (congested, free-flowing), trip reliability, perceived safety risks, etc., and many of these attributes are included in the more sophisticated patronage forecasting undertaken for toll roads. Therefore these tests do not in themselves justify adoption of VoT parameters double those used in these base models, but they do indicate a high level of uncertainty in the appropriate values, and the potential that the effective revealed choice values could be up to twice the stated preference values.

For completeness the VoT used in these tests are shown in Table 8.6. The purpose-specific values are those used in the multi-class models while the weighted-average values are those applied to all vehicles in the single-class assignment model.

Table 8.6 VoT applied to tolls in the assignment model.

Trip purpose	Base VoT ($/h)	Doubled VoT ($/h)
HBW	13.11	26.22
HBS	10.22	20.44
HBO	10.22	20.44
NHB	12.12	24.24
LCV	20.00	40.00
HCV	40.00	80.00
Weighted-average: AM	11.98	23.96
Weighted-average: Interpeak	11.90	23.80
Weighted-average: PM	12.13	24.26

9. Conclusions

9.1 Purpose of study

The main purpose of this study was to undertake an analysis of the observed changes in traffic following the removal of the $1 toll on the Tauranga Harbour Bridge in July 2001. From this analysis the research intended to infer parameters and elasticities which could assist in the development and validation of models developed to forecast the effect of new toll projects.

9.2 Available before-and-after data

Detailed monitoring of traffic was undertaken around the time of the toll removal by the Tauranga City Council, but this was limited to the traffic counts obtained on the Harbour and Maungatapu Bridges. No origin-destination data or directly comparable travel time data were available for this study so the detailed analysis of the changes in travel behaviour was not possible.

9.3 Changes in traffic flow following toll removal

In the week immediately following removal of the toll, the daily flows on the Harbour Bridge increased by 18% while the daily flows on the Maungatapu Bridge reduced by only 9%, meaning a net increase of 7% in the combined cross-harbour flows.

Analysis of the data collected following toll removal found that the flows on both routes at first increased, but appeared to stabilise some 14 weeks after the toll was removed. Subsequently a trend analysis of the available data was undertaken with Week 14 used as the reference point for prediction of the short-term stabilised changes in traffic flows.

Although some effects of the toll removal could take longer than 14 weeks to occur, the analysis was constrained to this period to avoid the influence of the high general traffic growth and the opening of the major new Route J expressway in April 2002.

The key findings of this analysis were:

- The daily flows on the Harbour Bridge increased by 26% from 27,600 vpd to 34,900 vpd.
- After the initial reduction, the flows on the Maungatapu bridge returned to their pre-toll-removal level of 20,100 vpd within the 14-week period, i.e. a change of 0%.
- The combined daily flows on both routes increased by 15%, clearly demonstrating that significant traffic was induced into the corridor following toll removal.
- The effect on heavy commercial vehicles was more pronounced than for light vehicles, with an increase of some 1000 trucks per day (74%) on the Harbour Bridge and a reduction of only 150 per day on the alternative route.

- Some evidence of peak spreading exists with a reduction in the proportion of the daily traffic occurring in the peak periods following toll removal. But these effects are believed to be caused mostly by the resulting increase in congestion rather than as a direct response to the removal of the toll.
- Increases in traffic were apparent in the wider Harbour Bridge corridor and feeder routes, and some reductions noted in the wider parts of the alternative route via Maungatapu, but no strong patterns of change were identified in the wider network.

9.4 Capacity assessment

With the Harbour Bridge currently running at capacity, the observed flows are a good indication of the capacity of this type of facility. This analysis indicated that the peak directional capacity was some 1470 vph eastbound and 1520 vph westbound, with the directional differences believed to be caused by the different merge length and environment on each approach to the bridge. These values accord with values of between 1450 and 1500 vph observed at other similar sites and are also consistent with the values derived from the Austroad guide.

9.5 Initial model testing

The traffic model of the Tauranga and Western Bay of Plenty sub-region is a typical, 3-step car-driver model comprising trip generation, trip distribution and trip assignment. The original model was developed and calibrated to 1996 data with the toll in place. The toll is represented in both the distribution model (which matches trip productions and attractions to create an origin-destination matrix), and the assignment model (which predicts the route vehicles will use between each origin and destination). This means that the toll will affect both the demand pattern and the routes taken through the network.

Initial forecasts of the effect of toll removal showed that the model significantly over-predicted the response to the toll, with an increase in the combined total daily traffic on both routes of some 28%, which is significantly higher than the observed 15% increase in combined flow.

Tests of different model structures and parameters indicated that the parameter which most influenced the response of the model was the weight applied to tolls, and that the implied value of time (VoT) had to be doubled in order to replicate the observed flow changes.

9.6 Test of updated model

Following the re-basing of the model to 2001 census data and validation to 2001 post-toll-removal flows, the model was tested by adding back the toll and analysing the predicted changes in flows. This test again showed that the toll costs needed to be damped by between 25% and 50% to match the observed change in traffic flows. This test suggested that the VoT applied to tolls needed to be doubled to match the observed traffic patterns.

Similar tests were undertaken on the Route K toll road opened in 2003. In this case the presence of parallel routes and the small time savings on Route K meant that the flow forecasts were somewhat insensitive to the VoT applied to tolls in the distribution model, but highly sensitive to the VoT applied to tolls in the assignment model. In these tests doubling the VoT significantly over-predicted the flows on Route K, but the high level of sensitivity to small time savings suggests that Route K is not an appropriate project to use to calibrate revealed VoT.

9.7 Implications for forecasting studies

The key implications for forecasting studies derived from this analysis are as follows:

- The effect of tolling can have greater effects than simple diversion to the alternative route, with significant potential for travel demand management including trip suppression or redistribution. Such effects will be most prominent in projects within dense urban areas which provide a more direct route and hence significant time and distance savings over the alternative route. Conversely, for projects providing limited time or distance savings in semi-rural areas, small trip suppression or redistribution effects from tolling are likely, but a high level of sensitivity to the VoT used in the diversion modelling may be present.

- Typical gravity distribution models, where trip distribution is a function of travel time and toll costs, could be overly sensitive to toll costs when typical VoT parameters of between $10 and $14 are used. Damping the toll costs should be considered in such models to reduce over-sensitivity. Models with lower VoT are likely to be even more sensitive to tolls, with implied VoT potentially as much as twice these values. The resulting changes in trip patterns should be verified using simple elasticity calculations.

- The use of single-24-hour distribution models may not be appropriate for forecasting infrastructure or policy scenarios which have a differential effect throughout the day (including congestion relief). In such cases period-specific distribution models may provide more appropriate forecasts. However neither structure is likely to adequately deal with trip-chaining/tours.

- A high level of uncertainty surrounds the appropriate VoT to apply tolls in the route-choice model. Although more sophisticated toll-choice models should be used for detailed patronage forecasts on specific toll projects, for general planning purposes the sensitivity to the VoT should be considered and tested.

10. References

Austroads. 1988. *Guide to traffic engineering practice Part 2: Roadway capacity. AP-11.2/88*. Austroads: Sydney, Australia.

Transfund New Zealand. 1997. *Project evaluation manual.* Transfund New Zealand: Wellington, New Zealand.

Transfund New Zealand. 1999. *Research strategy*. Transfund New Zealand: Wellington, New Zealand.

Appendix 1 Observed and modelled traffic volumes for each modelled period and for each direction.

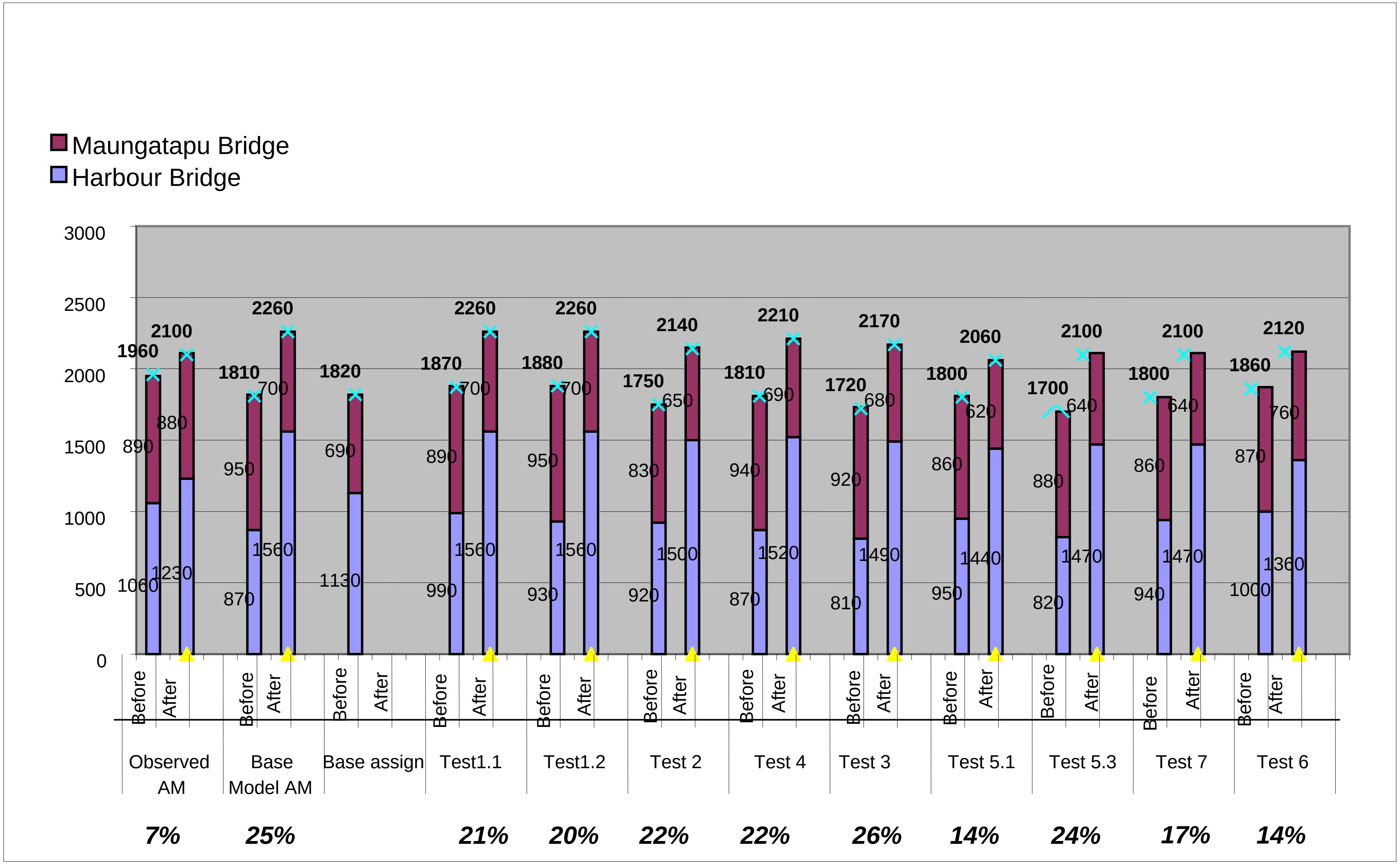

Figure A1.1 Comparison of results for eastbound morning traffic.

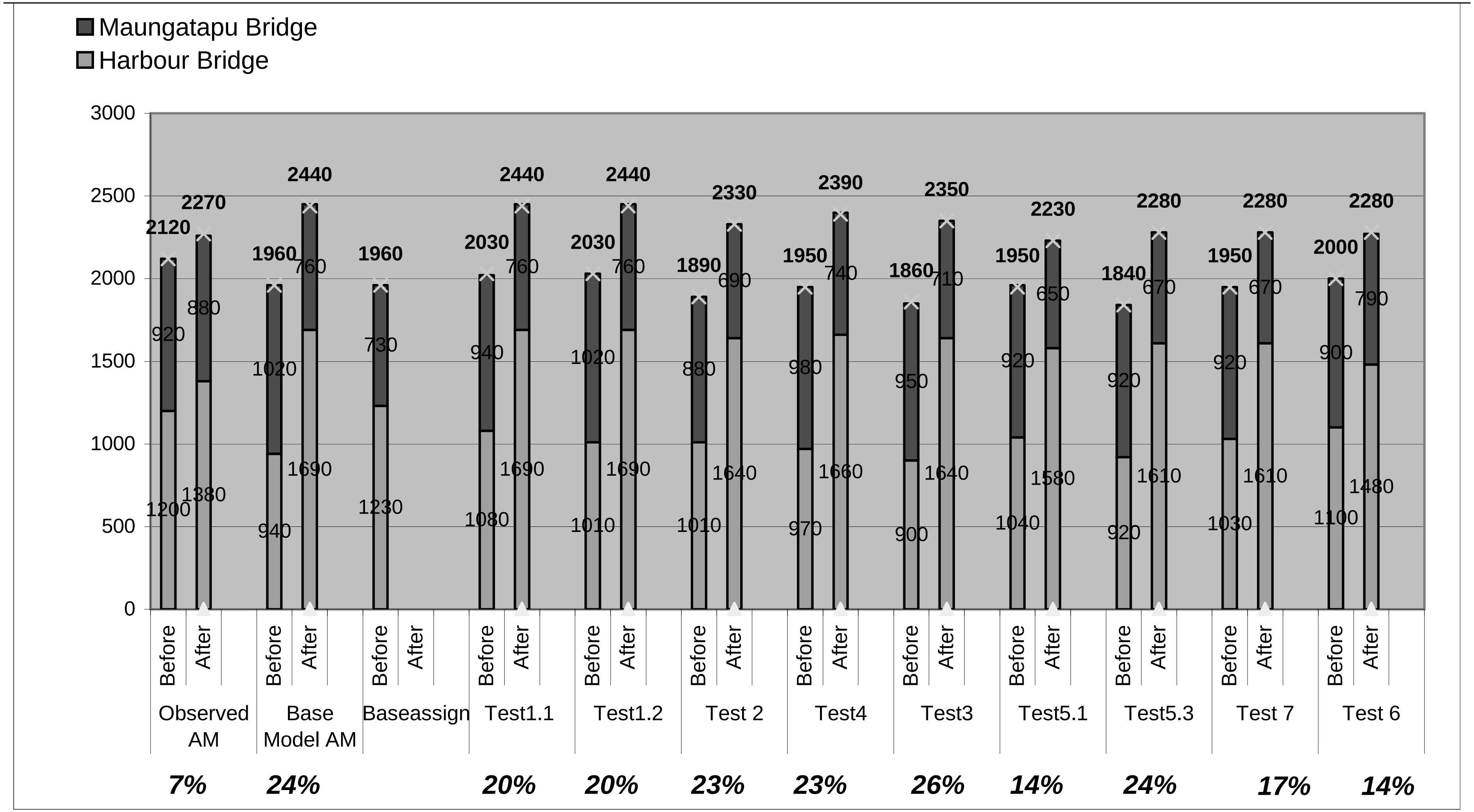

Figure A1.2 Comparison of results for westbound morning traffic.

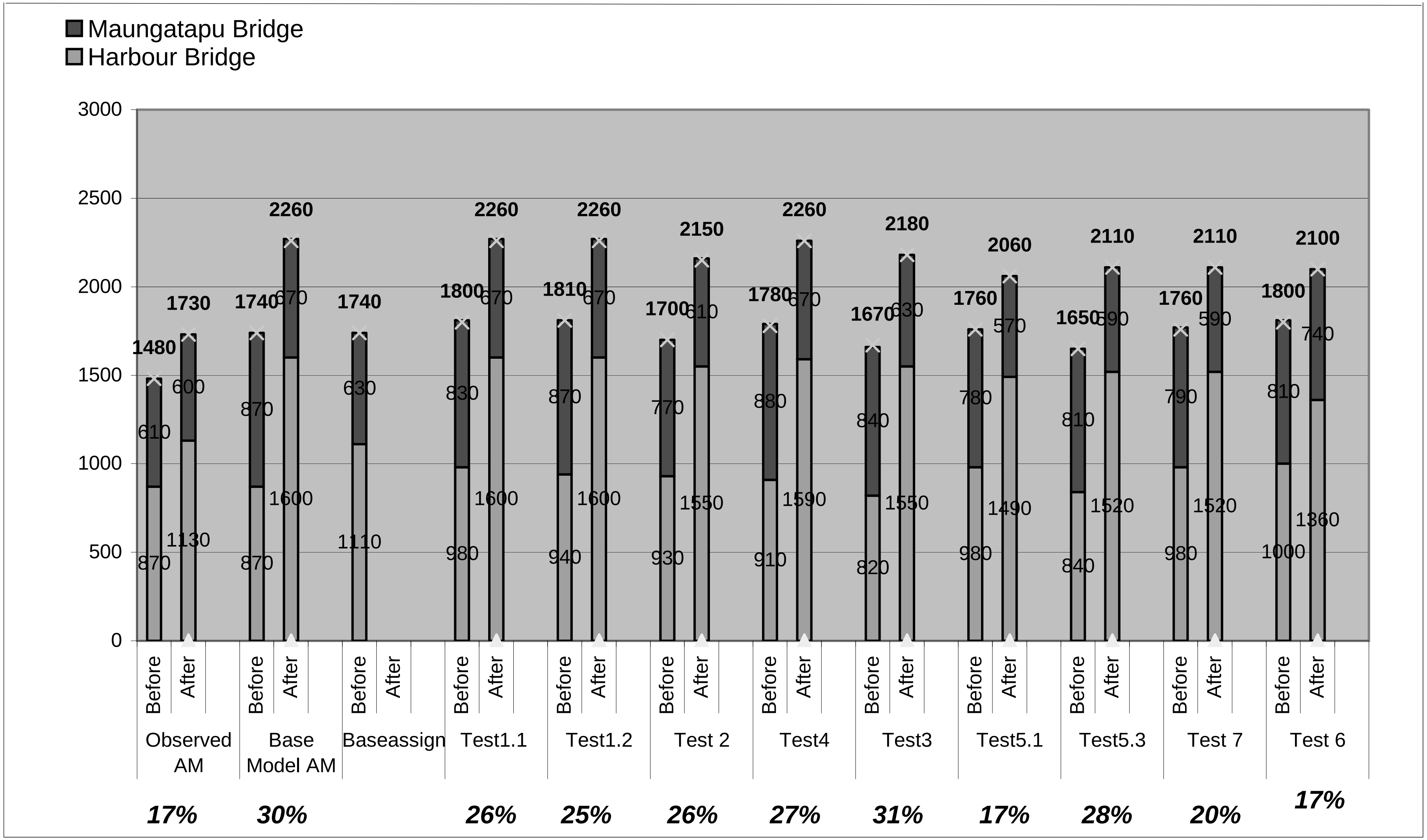

Figure A1.3 Comparison of results for eastbound interpeak traffic.

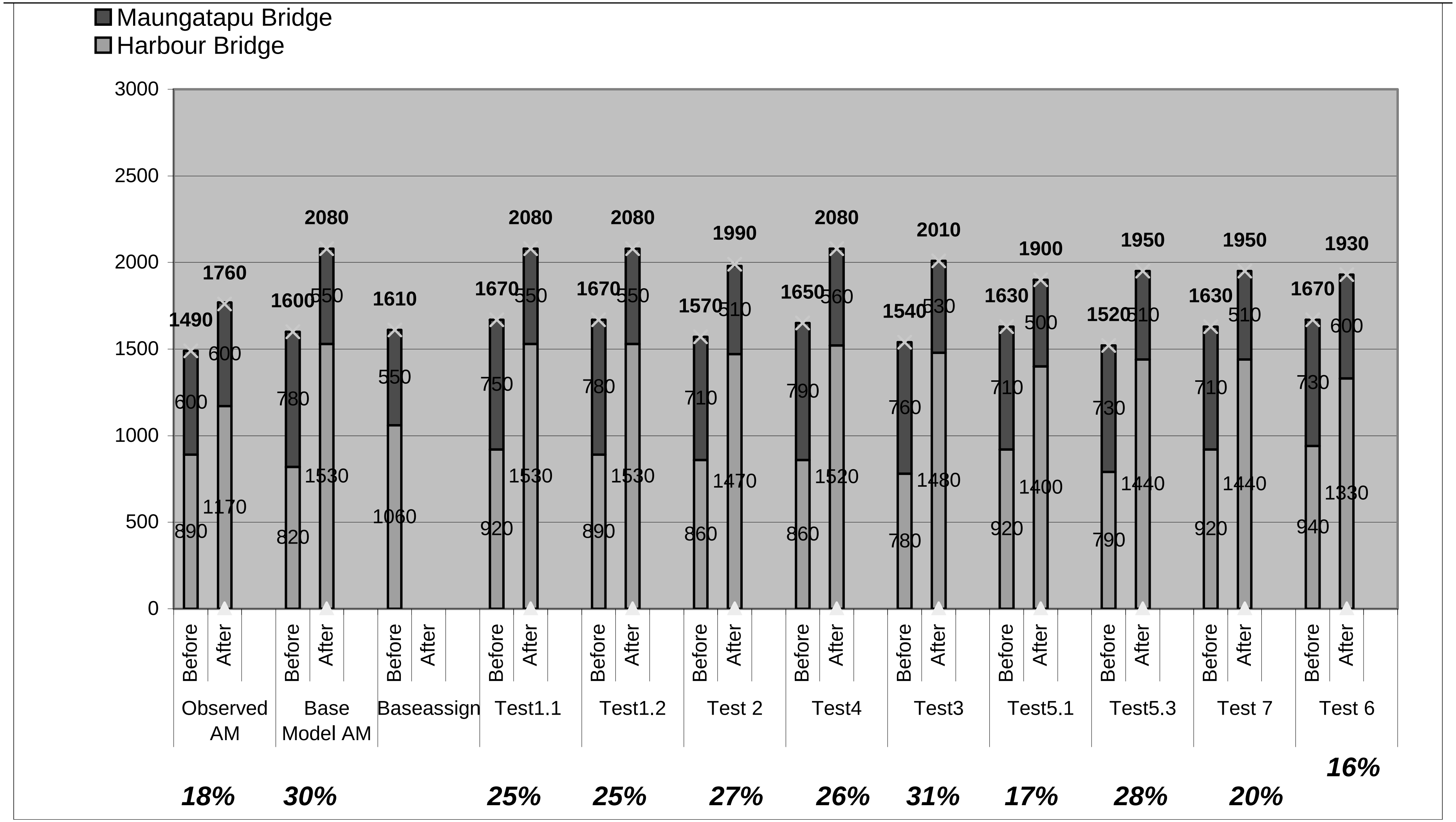

Figure A1.4 Comparison of results for westbound interpeak traffic.

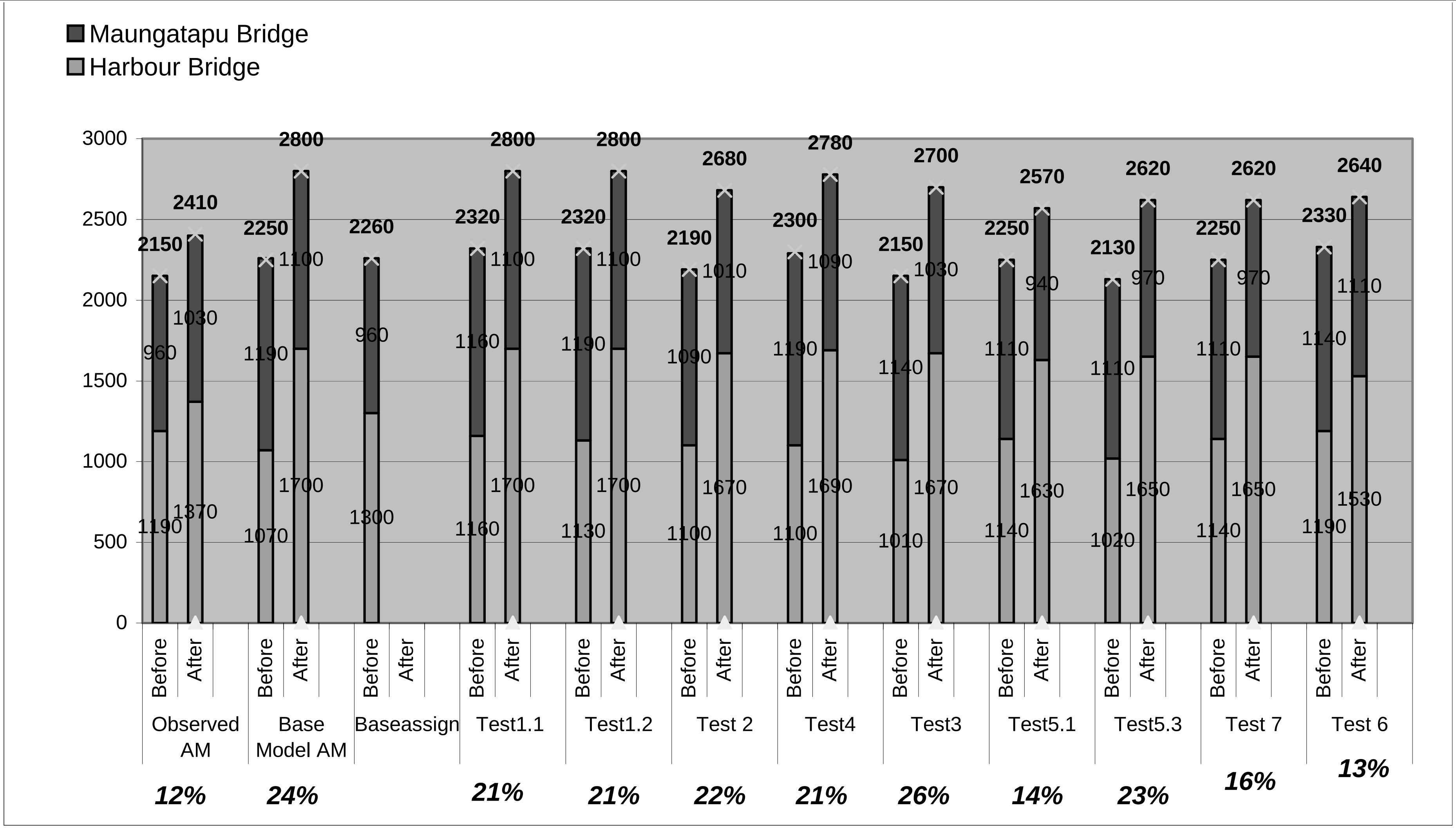

Figure A1.5 Comparison of results for eastbound evening traffic.

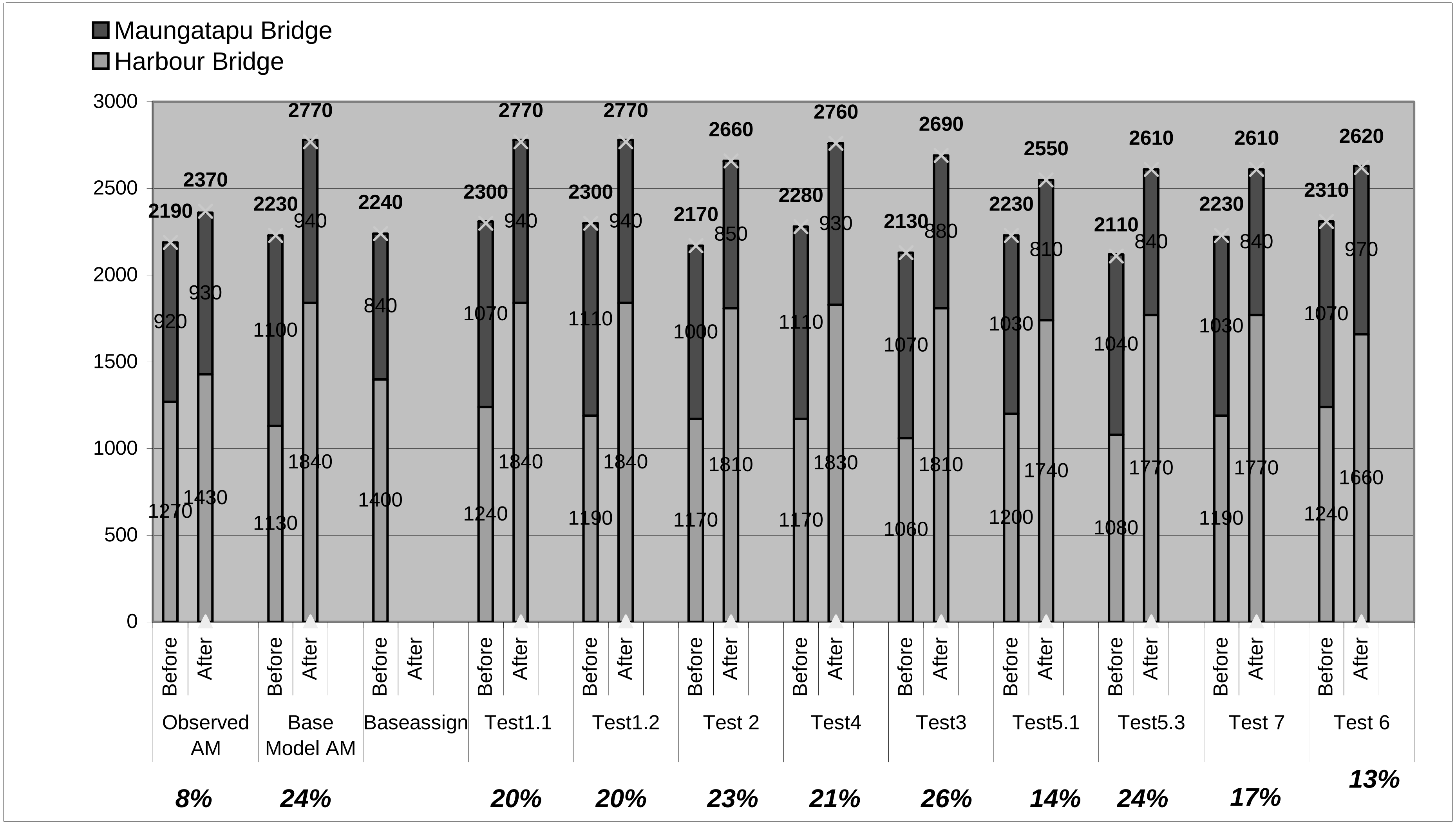

Figure A1.6 Comparison of results for westbound evening traffic.

Appendix 2 Observed and modelled flows with and without tolls.

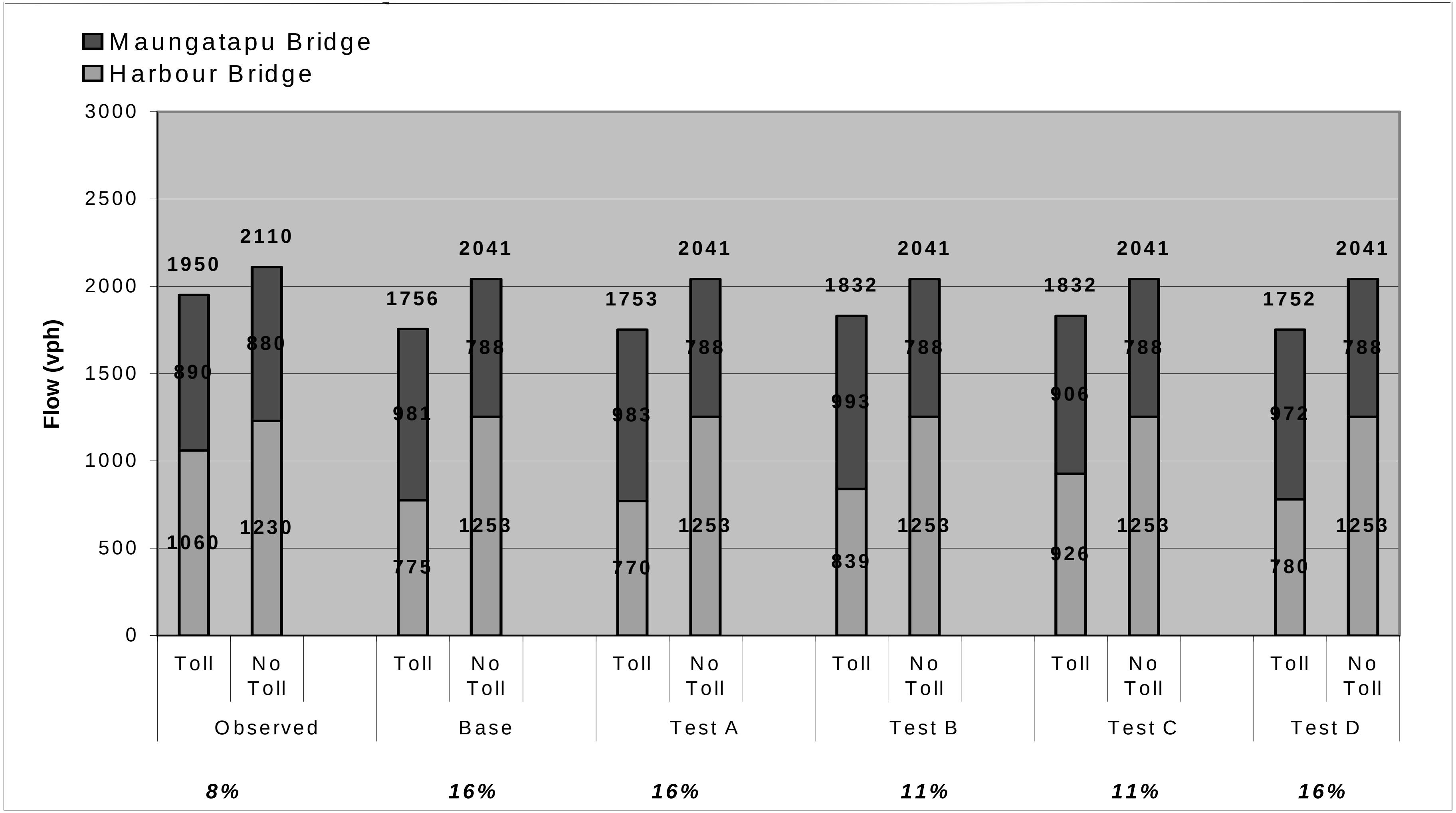

Figure A2.1 Comparisons of test results for eastbound morning traffic.

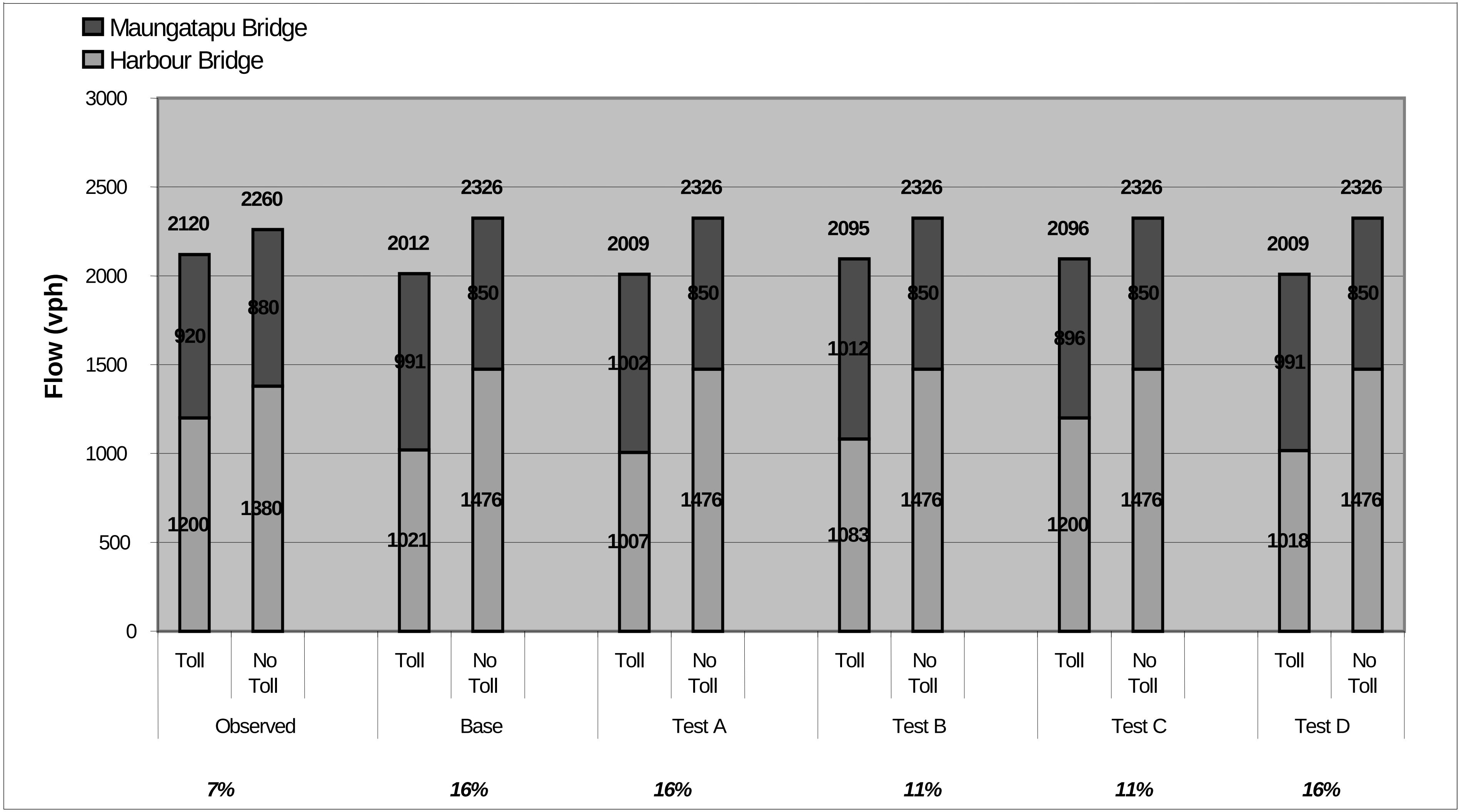

Figure A2.2 Comparisons of test results for westbound morning traffic.

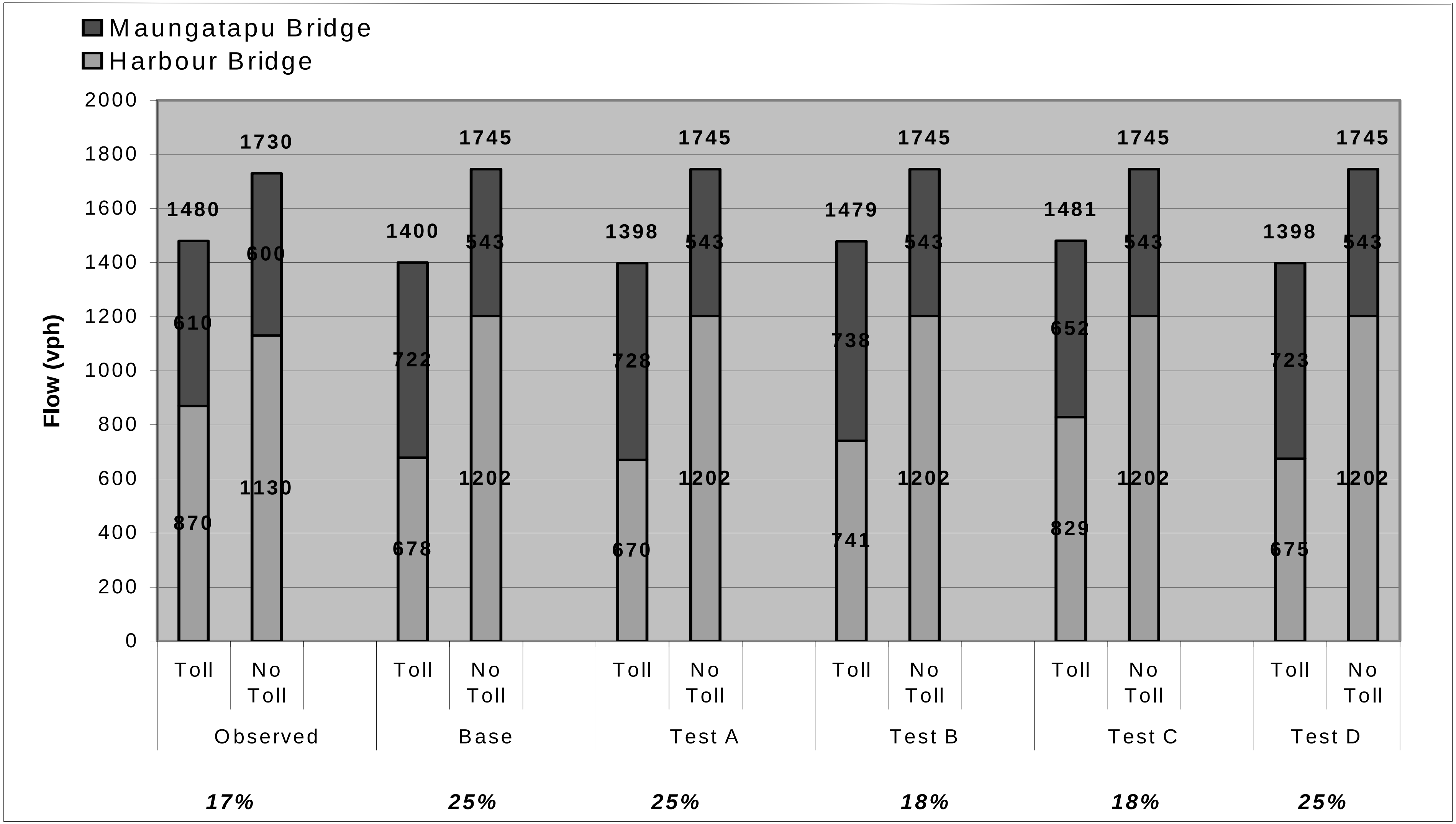

Figure A2.3 Comparisons of test results for eastbound interpeak traffic.

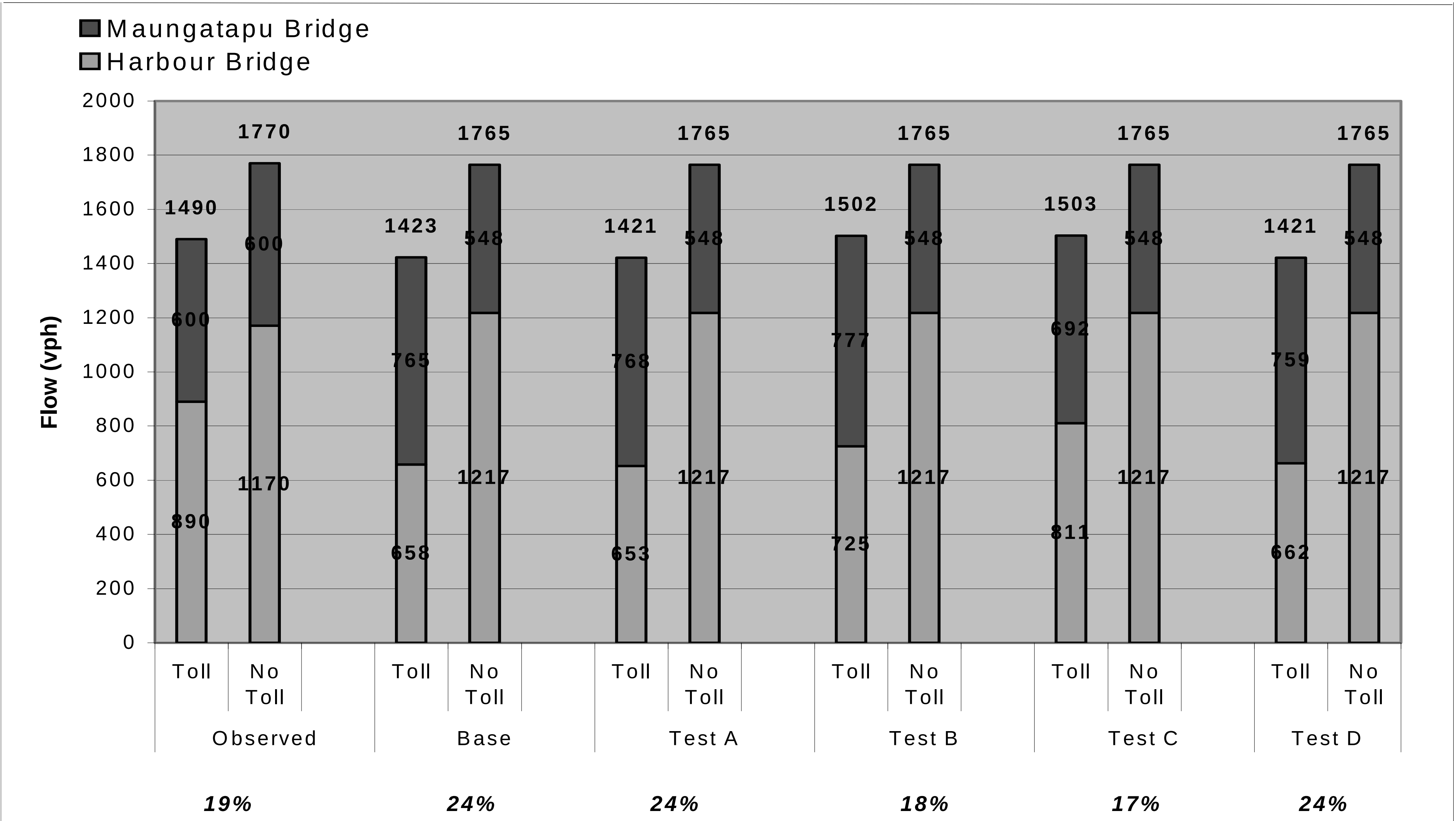

Figure A2.4 Comparisons of test results for westbound interpeak traffic.

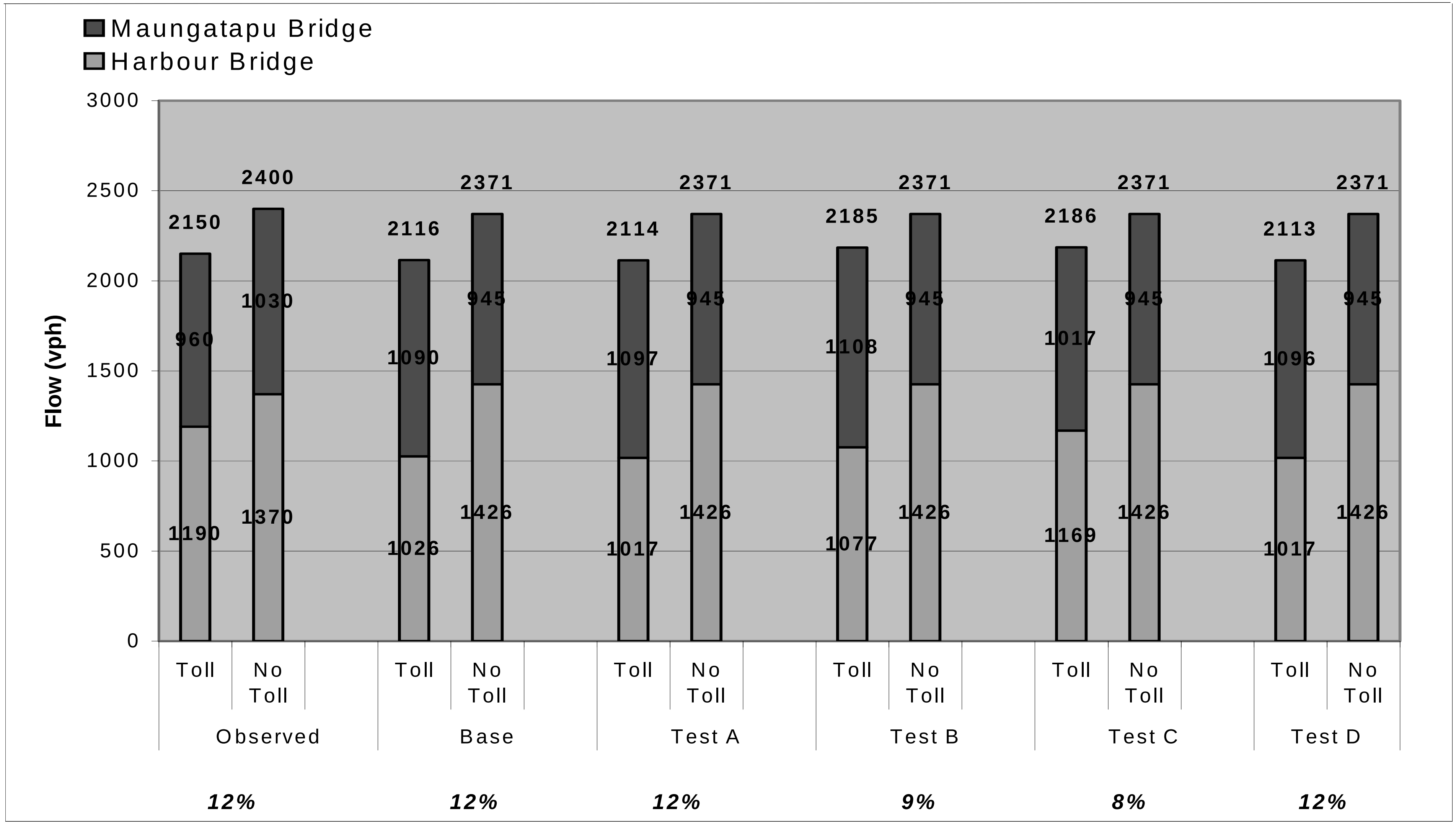

Figure A2.5 Comparisons of test results for eastbound evening traffic.

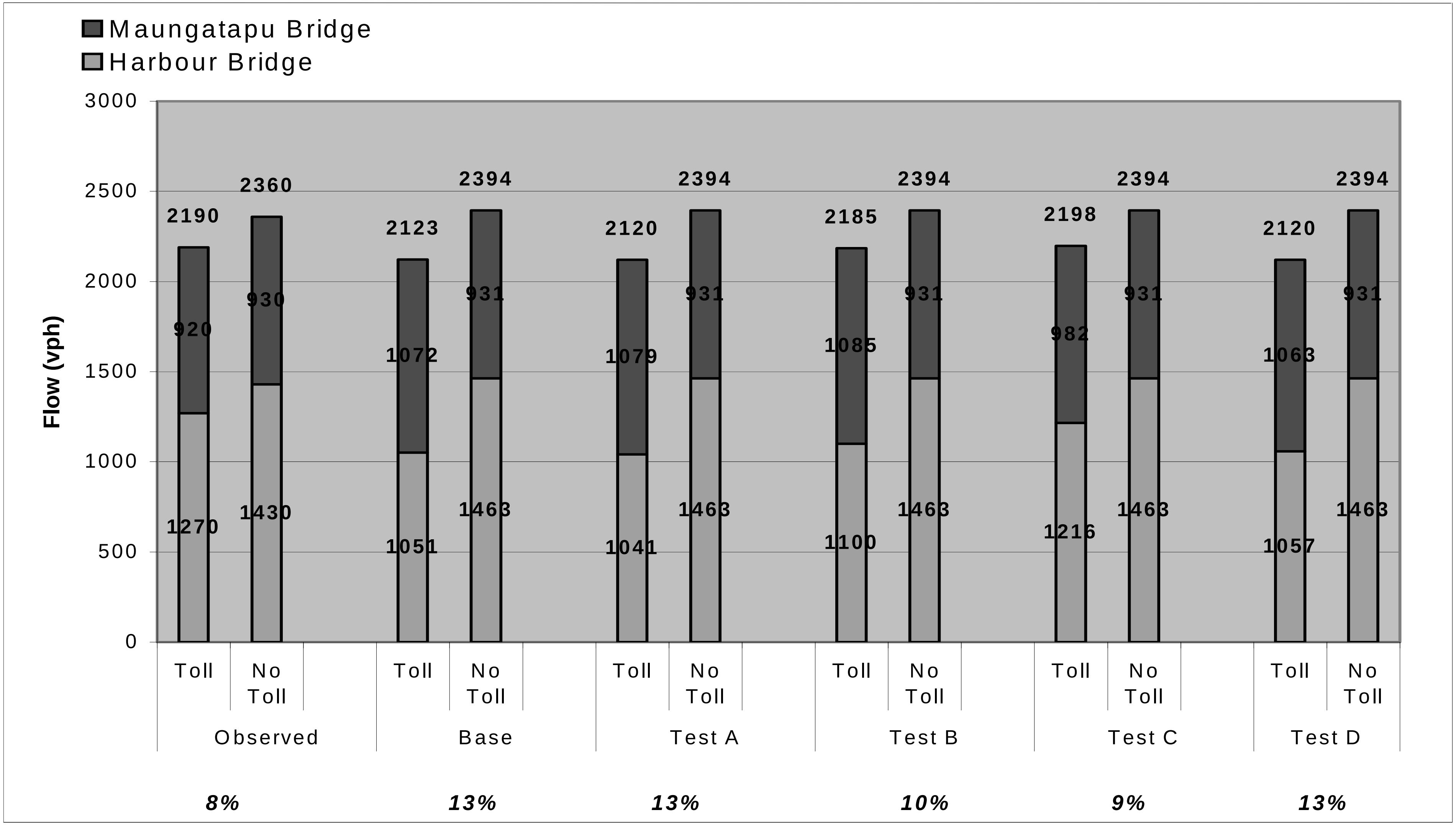

Figure A2.6 Comparisons of test results for westbound evening traffic.

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