Improving bus service reliability
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Executive summary

Project overview, objectives and scope

Numerous international market research studies into factors affecting customers' perceptions and usage of urban bus services have found that (un)reliability is at or very close to the top of the list of important attributes to customers, but often very low down the list in terms of actual performance. New Zealand market research has reached similar findings.

In the light of these findings, this research project on improving bus service reliability was commissioned as part of the NZ Transport Agency (NZTA) research programme. The research was undertaken by consultants Ian Wallis Associates Ltd (Wellington, New Zealand) in association with TAS Partnership (Preston, England). The research was undertaken in 2010-2012.

The overall project objective was to:

> *provide urban bus operators and public transport contracting authorities with practical guidance, in the New Zealand context, on: methods for diagnosis of urban bus service (un)reliability; the causes of unreliability; how unreliability is best measured and monitored; and experiences and best practices on measures and methods to improve reliability, through a series of case studies with bus operators and service contracting authorities.*[1]

New Zealand reliability policies, standards and performance

The project included an appraisal of New Zealand bus service reliability policies, standards and actual performance, focusing on the 'big three' metropolitan regions (Auckland, Wellington, Christchurch). The main findings were:

- Reliability (including punctuality) is one of the most important (often **the** most important) attributes of urban bus services in New Zealand, as in other countries, as perceived by users and potential users of the services. It is also one of the attributes for which perceived performance is poorest, relative to its importance. This indicates that improving service reliability warrants very high (or the highest) priority in order to enhance customer satisfaction, and hence increase patronage.
- Current performance standards/targets for reliability (including punctuality) differ between the three regions – in terms of both their structure and their specific standards.
- Historically, the reporting of reliability (including punctuality) performance in the three centres has been based on operator self-reporting, using manual systems, and this currently remains the case in Auckland and Wellington. With the recent availability of electronic-based information systems (using real-time information (RTI) and electronic ticket machine (ETM) data), much more comprehensive and accurate data on reliability performance is now available in the three centres.
- The project has assembled recent reliability data provided by the three regional authorities from RTI/ETM data sources to show the proportions of scheduled services operating within various reliability/punctuality thresholds. This evidence confirms that the reliability problem is indeed very significant, and that the extent of early/late running reported by operators understates the true extent

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[1] This report uses the term reliability to cover the two concepts of 'reliability' (whether or not the service operates) and 'punctuality' (whether the service runs to timetable). Reliability is not concerned with delays *per se*, but with the variability of delays (from trip to trip, and day to day), which prevents the services operating to timetable.

by an order-of-magnitude. We thus consider it as highly desirable that Auckland and Wellington move to monitoring performance through electronic-based systems as soon as any remaining technical difficulties can be overcome.

- The NZTA has recently developed proposals for an improved public transport (PT) performance monitoring regime for all regions. These proposals include monthly data on reliability/punctuality performance at a 'unit' (route group) level, divided into peak/off-peak time periods. In addition the NZTA proposes changes to customer satisfaction surveys undertaken regularly by the regions, so as to ensure the survey results (including on reliability aspects) can be compared between regions and over time.

Causes of unreliability

The causes of unreliability in urban bus services may be classified in various ways. One (four-way) classification (used by London Buses) is: traffic congestion (relates to the extent of bus priority issues); staff shortages (including staff quality issues); bus boarding times (reflecting bus design and ticketing methods); and inadequate route supervision (including deficiencies in vehicle monitoring systems).

From the user perspective, these causes translate into services running late (or early), missing services, bus bunching (with overcrowding issues), and slow and variable speeds (including time spent at stops, at traffic signals or caught in congestion).

No New Zealand studies in the three main centres (or elsewhere) have quantified the various causes of unreliable bus operations. Our British case studies found that the largest single causes of both average delays and the variability of delays were passenger boarding/alighting times, waiting at traffic signals and traffic congestion – together accounting for around 70% to 80% of overall delay variability. We would expect generally similar results would apply in the New Zealand context.

An additional aspect which affects reliability (punctuality) from the passenger perspective, but not day-to-day variability in performance, relates to scheduled running times. Recent analyses of RTI/ETM data (in Auckland and Wellington) indicate that the current scheduled running times are often not consistent with the 'typical' running time performance achieved, and hence the services concerned run either early or late on the majority of occasions. This problem could be ameliorated relatively easily, and should be addressed with priority (and is being addressed in all three centres).

Reliability performance measures and data sources

The project included an international review of literature and practices relating to a preferred 'package' of performance measures (indicators) to reflect the reliability performance of urban bus systems. Any such 'package' should cover service reliability (whether the trip operates), service punctuality and running times, and passenger perceptions (not addressed in detail in this report).

The report sets out a range of performance measures under each of these aspects, examines several review papers comparing the merits of various indicators/packages, and documents the practices of a number of major bus operators internationally.

Current reliability performance measures adopted in the main New Zealand centres are generally consistent with Australian/international practices adopted for timetabled services[2], and these measures are being refined at a regional level as part of the development of new operator contracts.

[2] Different performance indicators are more appropriate for 'headway' services (eg a bus every seven to eight minutes) than for timetabled services (for which a precise timetable is defined): most New Zealand services are of the latter type.

The widespread availability of electronic-based information (drawing on RTI/ETM systems) in recent years has revolutionised the task of monitoring service reliability. In New Zealand as elsewhere, electronic data is becoming the main source of monitoring information, with manual methods being largely limited to situations where detailed understanding of the causes of reliability problems is required.

Approaches to improving reliability

Efforts to improve reliability should start from a 'root cause' analysis of reliability problems, which will provide the evidence base for the development of effective improvement measures.

Actions to address bus service reliability may be taken at three levels, with associated timings, as follows.

Service planning level. The aim here is to develop the 'ideal' timetable, which will minimise the probability of unreliable operation in 'normal' conditions, while being robust enough to allow for the expected variability around 'normal'. Aspects addressed include: i) assessment of total (terminus to terminus) trip times and intermediate section times, taking into account patterns of journey time variability; ii) allowance for layover at termini; iii) coordinating timetables for several services operating over common sections of route; and iv) 'sensitivity testing' of timetables in response to expected variable factors (eg effects of traffic congestion on running times, peaking of passenger demand).

Operational planning level. The task here is to formulate operating plans to optimise the services in response to short/medium-term problems that have arisen or are anticipated. Aspects addressed include: i) the operator's approach to 'control and intervention' actions; ii) adjustment of schedules and/or resources; iii) addressing driver adherence to schedules; and iv) development of route contingency plans.

'On-the-day' level. The focus here is on rapid, effective and efficient responses to unanticipated problems as they arise, so as to minimise any adverse effects on the reliability of the operations. The role of the operations supervisor at the 'coal-face' is critical here, supported by operator 'contingency' guidelines on the procedures and responses appropriate when particular situations arise. Aspects addressed include: i) 'triggers' to initiate 'on-the-day' intervention and improvement actions; ii) roles and deployment of supervisors and communication procedures; iii) options to respond to bus bunching and gaps in services; and iv) deployment of 'spare' resources.

Recommendations

To support and enhance efforts to improve bus service reliability in New Zealand's urban centres, the following main recommendations are made:

- Current efforts (principally in Auckland and Wellington) to derive high-quality information on reliability and punctuality using automated (GPS-based) data sources should be continued as a high priority. Once this approach is sufficiently proven, the current system of operator self-reporting of reliability performance should be replaced with the GPS-based estimates.
- Using the GPS-based information, high priority should be given in the main (and other) regions to deriving and implementing optimum running times (by route section and overall trip), by day/time period, having regard to patterns of running time variability.
- New operator contracts should include and apply incentives/penalties on operators to improve service reliability, while recognising that it is affected by a number of factors beyond the control of operators.
- Tackling reliability problems needs to be very much a joint endeavour between regional authorities and their operators. Some form of 'quality partnership' between the two parties would be appropriate to develop, implement and monitor 'reliability plans' on an ongoing basis. Such a partnership could

also act as a focus for disseminating knowledge on reliability issues across the regions, so as to provide the basis for developing and continuously improving New Zealand 'best practices' on the topic.

Abstract

The objective of this research (undertaken in 2010–12) was to provide urban bus operators and public transport contracting authorities in New Zealand with practical guidance on methods for diagnosis of urban bus service (un)reliability, the causes of unreliability, how unreliability is best measured and monitored, and experience and best practice on measures and methods to improve reliability and punctuality.

The research outputs were intended to assist urban bus operators and planning/contracting/funding authorities in New Zealand to gain a better understanding of bus reliability and punctuality issues and how best to address them. The report addressed the causes of unreliability, reliability standards and measurement, data collection and analysis methods, and the approaches available to tackle reliability problems through planning and timetabling measures (when problems can be anticipated in advance) and/or through operational measures (for problems arising on a day-to-day basis).

Recommendations were made on: the continuing refinement and adoption of outputs from automated (GPS-based) data sources as the primary means of monitoring reliability performance, replacing operator self-reporting methods; on using these data sources to optimise running times; and on the adoption of some form of 'quality partnership' arrangement between regional authorities and their operators to jointly pursue continuous improvements in reliability performance.

1 Introduction

1.1 The project

This research project on improving bus service reliability was commissioned as part of the NZ Transport Agency (NZTA) research programme.

The research was undertaken by consultants Ian Wallis Associates Ltd (IWA, Wellington, New Zealand) in association with The TAS Partnership – (TAS, Preston, England).

1.2 Project background and context

Numerous international (including New Zealand) market research studies relating to customer perceptions and usage of urban bus services have found that (un)reliability is near to or at the top of the list in terms of importance, and often very low down the list in terms of actual performance. For example:

> *Qualitative and attitudinal studies of travel choice behaviour have found that the punctuality, reliability and dependability of a transport system are rated by users as a very important feature, affecting both their perceptions and levels of use for different modes.* (Balcombe et al 2004).

> *Surveys and research show that the most important consideration for public transport users – and potential users – is reliability: a trip leaves on time and arrives at (or very close to) the scheduled time. This is even more important when connections need to be made with other services.* (Auckland Transport 2012).

A review of market research undertaken in recent years relating to public attitudes and perceptions towards Wellington's bus services highlighted that their unreliability was the most important aspect that needed to be addressed to improve customer satisfaction and to increase patronage. There is little doubt that a similar conclusion is true in the Auckland context.

Land Transport NZ research report 339 'Measurement valuation of public transport reliability' (Vincent 2008) addressed user valuations of bus and train service unreliability (both at the stop and on the route), and further highlighted the importance of unreliability to public transport (PT) users.

Despite its importance, the topic of bus service (un)reliability is very under-researched both internationally and in New Zealand. The Balcombe et al (2004) report gives about one page to reliability issues (valuation, demand elasticities, etc), compared with about 50 pages to fares issues. In New Zealand, until very recently the level of resources being applied by regional authorities and/or operators to first monitor the reliability performance of their bus services and then attempt to improve their performance has been very limited, relative to the size and importance of the problem.

The evidence (set out in more detail later in this report) is thus very clear that urban bus service (un)reliability is a major problem that needs to be addressed, and can be addressed very cost effectively, in order to improve customer perceptions of urban bus services in New Zealand and hence increase their usage.

1.3 Project objectives and scope

The overall project objective was to provide urban bus operators and PT contracting authorities with practical guidance, in the New Zealand context, on:

- methods for diagnosis of urban bus service (un)reliability
- the causes of unreliability
- how unreliability is best measured and monitored
- experiences and best practices on measures and methods to improve reliability, through a series of case studies with bus operators and service contracting authorities.

While this report is titled as being about improving the reliability of bus services, it does cover what may be regarded as two different concepts, ie reliability (ie whether the service operates at all) and punctuality (ie whether the service runs to timetable) (refer to further discussion in section 2.1).

The project outputs (as described in this report) are intended to assist both urban bus operators and planning/ contracting/funding authorities (principally regional authorities) in New Zealand. We anticipate that the bus operators, particularly the larger ones operating complex urban networks, will be the primary beneficiaries of the research: they have to tackle reliability issues on a day-to-day basis, and are the party with direct control of the resources involved. However, it is also important for the planning/contracting authorities to gain a better understanding of reliability issues, particularly given their roles in developing timetables and in setting, monitoring and enforcing reliability standards, but also in their role of ensuring best value for money in service provision. They are also the owners, in the three major centres, of the GPS-based real-time information systems which can provide comprehensive data on the reliability performance of all contracted bus services. Improving bus service reliability appears to be an area where an operator/authority partnership approach will provide the best results.

At an early stage in the project, we investigated and reviewed previous research and documentation relating to current practices and advice available on the planning and operation of bus services, particularly to enhance their reliability. These investigations covered a range of sources, including bus operators, local transport authorities, researchers and academics. While we identified many academic papers relating to the measurement of PT reliability, somewhat surprisingly we were unable to find any source document internationally which brings together modern bus operating practices and provides practical advice to the PT operations analyst/planner.

Thus this research report attempts to bring together our current understanding of modern good practice in bus service planning, operations and monitoring, focused on the objective of providing reliable services that are attractive to users.

Within the English-speaking world, as far as we could ascertain, the ‘state-of-the-art’ (and science) in the planning, operations and management of reliable bus services appeared to be more advanced in Great Britain than in most other countries. This in part reflects the prime emphasis since ‘deregulation’ (1986) on the provision of urban bus operations on a commercial basis – requiring a strong focus by operators on both cost efficiency in operations and the provision of services attractive to customers. This research has therefore drawn considerably on the TAS Partnership’s extensive work in Britain on analysing and improving bus service reliability, working with bus operators and contracting/funding authorities. To a considerable degree, the British experience in terms of bus service planning and operational aspects and in reliability measurement and monitoring methods remains applicable in the New Zealand context, although differences in the operating environment in the two countries need to be recognised (eg the roles of the operator vs the funding/contracting authority, the more ‘deregulated’ environment in Great Britain compared with the largely contracted environment in New Zealand, and differences in reliability standards).

1.4 Report structure

Following this introductory chapter, the report is structured as follows:

Chapter 2 provides an overview of reliability concepts, measures of reliability, the importance of reliable services to bus users and usage, and data sources and analysis methods.

Chapter 3 outlines New Zealand policies, standards and performance relating to bus reliability aspects, with a focus on the three main metropolitan areas (Auckland, Wellington, Christchurch). It covers in turn: reliability policies and standards in these centres; monitoring methods adopted and evidence on recent reliability performance; market research evidence on public/user perceptions; and recent/current national developments relating to reliability standards and monitoring.

Chapter 4 addresses the causes of unreliability, methods to analyse these causes, and outlines the ‘tool-kit’ of measures available to improve reliability: these measures are divided into planning/scheduling measures, operational management/control measures, measures to give priority to buses to minimise the impact of traffic congestion, and the role of real-time information in mitigating some of the adverse effects of unreliability from the user perspective.

Chapter 5 summarises the research conclusions and recommendations.

Chapter 6 provides details of references.

Further details on a number of aspects are provided in appendices, as listed on the contents page.

2 Reliability concepts, measures and significance

2.1 'Reliability' concepts

2.1.1 Concepts of service 'reliability'

The term 'reliability', as used in this report, covers what may be regarded as two different concepts, ie reliability and punctuality. Box 2.1 sets out dictionary definitions of these concepts and the way in which they are generally used in the PT sector.

For convenience, we use the word **reliabilit**y throughout this report to cover both concepts:

- From the perspective of the operator and contracting authorities, reliability and punctuality are generally monitored separately, and different approaches are generally required to address deficiencies in one or the other.
- From the perspective of the customers (passengers), they are concerned only with the end result, ie does the bus turn up at the stop at the advertised time: they are not concerned with the distinction between whether the service has failed to operate or is operating late, or even with which particular service arrives at the stop at the advertised time.[3] Thus they have no interest in the distinction between an unreliable service (not operated) and an unpunctual service (operating, but not to timetable).

Box 2.1 Definitions and interpretations – *reliability and punctuality*

Dictionary definitions

- Reliability: property of being able to be depended on with confidence; consistently good in quality or performance.
- Punctuality: property of happening at the appointed time, rather than early or late.

Public transport sector usage[(a)]

- Reliability – property of whether or not the service operates (at all)[(b)]
  - typically measured in terms of the proportion of planned trips (or km) that is operated over any defined period.
- Punctuality - property of whether the service runs to timetable
  - typically measured in terms of the proportion of operated trips (or km) that operate within a defined punctuality 'window' (eg between one minute early and 5 minutes late) at specified points on the route.

[(a)] These interpretations are consistent with those generally used in the New Zealand PT sector.

[(b)] Referred to as 'cancellations' by some PT authorities (particularly in the rail sector).

In most bus systems the primary cause of buses not turning up at their stops on time is poor punctuality rather than poor reliability (using the usual PT terminology). In that sense, this report is about addressing punctuality issues primarily, and reliability issues somewhat secondarily – but we use 'reliability' throughout.

[3] If a service is timetabled to operate, say, every 15 minutes, but every bus trip runs 15 minutes late, this will be a perfectly 'reliable' service from the customer viewpoint. However, its 'punctuality' performance will be judged as very poor by the operator and maybe by the contracting authority.

While there are many causes of unreliable PT services, the unreliability essentially results from travel time variations for services operating over the same route at the same period of the day, either on the same day (due to traffic signals, random traffic fluctuations, etc) or on different days (due to weather effects, demand variations, etc). Variations in running time that have a regular pattern (eg due to recurrent congestion or average loading levels varying through the peak period) may be addressed by appropriate timetabling, and therefore should not be the cause of unreliable services (although, in practice, early or late running is often the result of poor timetabling). Irregular variations in running time cannot readily be accommodated within a fixed timetable, so manifest themselves in services operating late or early relative to the timetable, in an unpredictable way: the result is unreliable services.

2.1.2 Reliability components – operator and user perspectives

From an operator perspective, it can be useful to analyse the 'reliability' (variability) of services into two, more-or-less independent, components – the departure time from the start of the route and the running time along the route[4]. The variability when the service reaches the end of the route is then the sum of these two components (table 2.1).

Table 2.1 Components of 'reliability' of services (operator perspective)

Component	Comment
Departure time from start of route	• Service may not operate at all. • 'Reliability' measured by variation around scheduled departure time.
Route running time (start-end route)	• 'Reliability' measured by variation around scheduled running time.
Arrival time at end of route	• 'Reliability' measured by variation around scheduled arrival time. • Variations are the sum of variations in departure time and route running time.

In similar manner, the passenger is likely to be interested in three perspectives on service reliability[5]:

- departure time variability – pick-up time at boarding bus stop (relative to the timetable)
- running time variability – between boarding and alighting stop
- arrival time variability – drop-off time at alighting stop.

Unreliable services, from any of these three perspectives, are likely to cause adjustments in an individual's trip-making behaviour to account for the service not operating 'as normal':

- Departure time variability may cause:
  - increased waiting times for the traveller. Late services cause travellers to have to wait some time after arriving at their stop or station. Early services also increase waiting times because they cause the traveller to miss the targeted service and have to wait for the next service and/or they require the traveller to arrive earlier at the stop or station
  - increased concern and anxiety caused by fears of arriving late at the destination

[4] These two components are, in practice, not entirely independent: a service that leaves the start point late is likely to be further delayed en route, due to the extra passengers likely to be boarding at bus stops.

[5] As in table 2.1, one of these factors is likely to be dependent on the other two.

- increased concern and anxiety caused purely by uncertainty about when the next service will arrive
- increased likelihood of a late service that, because of its lateness, picks up more people and hence forces additional passengers to ride standing and/or in crowded conditions.

- Running (in-vehicle) time variability may cause:
  - increased concern and anxiety due to fears of arriving late at the destination
  - increased concern and anxiety due to uncertainty about how long they will have to spend on the service
  - increased variability surrounding how long the passenger will have to spend standing and/or in crowded conditions.
- Arrival time variability may cause the traveller to arrive at their destination late and/or force them to take an earlier service. Arrival time variability can also cause the traveller to arrive at their destination too early, hence they have to wait around or make up time.

All of these aspects can be expected to reduce the propensity to travel by bus by people who have experienced them (either first or second-hand).

2.2 Performance measures

2.2.1 Introduction

Internationally, there is no widely accepted 'best practice' in terms of a preferred package of performance measures (indicators) to reflect the reliability performance of urban PT systems (from user, authority or operator viewpoints). This section first sets out those aspects of PT reliability performance that a key performance indicator (KPI) system needs to capture, and then, under each aspect, defines specific performance measures and comments on their features, strengths and weaknesses. It then provides some concluding comments regarding the choice of appropriate packages of performance measures.

2.2.2 Aspects of reliability performance

Table 2.2 summarises those aspects of PT reliability performance that should be covered by any KPI system, under four main headings:

A Cancellations

B Specific service timings (B1) or regularity of service (B2) at stops, relative to advertised timings – of primary interest to users.

C Running times, relative to advertised running times, from trip start to trip end.

D Passenger perceptions – not addressed in detail in this report (but refer to section 3.4 re some New Zealand evidence).

Table 2.2 Performance aspects to be incorporated in KPI systems

Aspect	Coverage	Notes
A Cancellations	• Proportion of scheduled trips cancelled/not operated ('reliability').	• Various definitional issues: – treatment of services operated in part (breakdowns etc) – weighting by trips, km? • Effects of cancellations implicitly feed through to aspects B1/B2 below. • Primarily of relevance to authority/operator, not to user.
B1 Service arrival/ departure times (infrequent services)	• Arrival/departure times, relative to scheduled times, at start of route, intermediate stops, end of route ('punctuality').	• Relevant to situations where a specific timetable is advertised (most New Zealand bus services). • Departure times relevant at start of route, arrival times at end of route, either/both (usually identical) at intermediate points. • Primary interest to most users is time departing from boarding stop – both early and late running are unpopular with users.
B2 Service regularity (frequent services)	• For frequent services, the variation of headways, and hence average waiting times, relative to the schedule, at all stops along the route ('regularity').	• Relevant to situations where services are specified in terms of typical headways (eg every 5–7 mins) rather than in terms of specific timetables. • May also be applied to other high frequency services where users tend to arrive at the boarding stop at random[(a).] • 'Excess waiting time' is the primary measure (see table 2.3).
C Running times	• Bus running time, relative to scheduled time, between departure from start of route to arrival at end of route.	• Of central interest to operators/authority in developing timetables, etc. • Also of considerable interest to bus users, who are likely to have concerns about late arrivals at their destination. • Analogous to the 'travel time' aspect covered by road traffic indicators.
D Passenger perceptions	• Various qualitative/subjective measures of passenger perceptions of reliability performance, including: – passenger ratings, from attitudinal surveys – passenger complaints/ commendations.	• This aspect is not addressed further in this paper.

Note:

[(a)] The 'frequent service; category covers those services that are specified in terms of headways rather than specific timings (eg every 10–12 mins), plus other services for which the specified timings are more frequent than every 10–12 minutes (as users will then typically arrive at the stop more-or-less at random). All other services are in the 'infrequent service' category (this would cover most New Zealand services). (Refer Trompet et al 2011; Currie et al 2012.)

2.2.3 Specific performance measures

Table 2.3 lists 16 separate performance measures, covering the categories A, B1, B2, C above:

- Quite a number of these measures have been developed primarily in the context of road traffic travel times, delays, etc and subsequently adopted in the PT sector.
- Most, but not all, the measures listed, are used by some PT systems internationally (as shown in later sections). Some of these measures are primarily of interest to operators, some to authorities and some to users.
- Most provide some measure of either mean values or the spread of values of distributions (for travel time, waiting time, etc). The 'spread' measures include those that focus on outlying parts of the distribution (eg the slowest X% of trips) rather than the overall distribution.
- Further information on the standard statistical parameters for the mean and spread of distributions is given in box 2.2.

Table 2.3 Specific reliability performance measures

Aspect	Measure	Definitional issues, comments	Reference
A1 Cancellations	Basic definition: % of scheduled trips cancelled.	• How to treat breakdowns, skip-stops etc? • May be expressed in terms of % bus km rather than % trips. • Some authorities group very early or very late services with cancelled trips. • Various practical difficulties in obtaining good estimates from surveys etc (often rely on operator self-reporting).	Currie et al (2012)
B1 Service arrival/ departure times (infrequent services)	Basic definition: Bus arrival/ departure times, relative to scheduled times, at start of route, intermediate stops, end of route:	• Use of arrival times likely to be more appropriate in some circumstances, departure times in others.	Currie et al (2012)
	1 % of trips arriving/departing 'on time' (within defined window, eg 1 min early – 5 mins late).	• Useful basic indicator – relates to standards applied in many systems (incl New Zealand). • Results may be reported against different 'windows'. • Does not discriminate by early vs late, or by degree of earliness/ lateness.	
	2 Average minutes early/late arriving/departing	• Essential to distinguish between early and late trips. • Useful when applied to time of arrival at alighting stop – covers delays at boarding and en route. • Does not discriminate by degree of earliness/lateness, etc.	
B2 Service regularity (frequent services)	Basic definition: For frequent services, the variation of headways relative to the schedule, and hence average waiting times, at all stops on the route:		Mazloumi 2010; Trompet et al 2011; Currie et al 2012

Aspect	Measure	Definitional issues, comments	Reference
	1 Average passenger waiting time (AWT): $E(W) = 0.5\ E(H).(1+C^2_{vh})$, where $E(W)$ = average waiting time $E(H)$ = average headway C_{vh} = coefficient of variation of headways (refer box 2.2)	• Commonly used regularity indicator (assumes uniform passenger arrivals). • Shows that as variance (inconsistency) in headways increases, passengers experience increased average waiting times.	
	2 Standard deviation (SD) of headways (box 2.2): $SD(H_{Dev})$ = SD of headway variations from scheduled headway	• Relatively simple measure to calculate and understand, with results expressed in minutes (eg SD of 2 mins means that 68% of headways would be within 2 mins of the scheduled headway).	
	3 Coefficient of variation of headways (refer box 2.2): $C_{vh} = SD(H_{Dev})/\overline{H}_{Sch}$ C_{vh} = headway regularity index $SD(H_{Dev})$ = SD of headway variations from scheduled headway $\overline{H}_{Sch}$ = mean scheduled headway.	• Known as headway regularity (or headway adherence) index. • Preferred measure in US *Transit capacity and quality of service manual* (Kittelson et al 2003a). • Gives additional weight to long intervals between services. • Does not directly relate to passenger waiting times.	
	4 Excess waiting time (EWT): EWT = AWT – SWT, where AWT = average actual wait time (refer B2.1), SWT = average scheduled wait time, assuming even headways.	• Used by Transport for London and a number of other authorities for frequent/headway services. • EWT represents how much longer, on average, passengers have to wait for buses than if the service operated with even headways (when EWT = 0). • Ratio EWT/SWT also used, indicating the proportionate increase in average waiting time relative to even headway services.	
	5a Wait assessment: % of headways within X minutes of the scheduled interval.	• One of four regularity indicators proposed in TCRP *Guidebook for developing a transit performance measurement system*. (Kittelson et al 2003b).	
	5b Service regularity: % of headways within Y% of the scheduled interval	• Variant of (5a) also covered in the TCRP guidebook.	
	6 'Bunching' index: $R = 1 - \frac{2\Sigma^n(h_r - \overline{H}).r}{n^2.H}$, where R = (normalised) headway regularity index (scaled from 0 to 1)	• R = 1 indicates uniform headways, with increased degree of bunching as R reduces towards zero. • Useful measure of the 'bunchiness' of services, although not widely used.	

Aspect	Measure	Definitional issues, comments	Reference
	h_r is a series of headways, ranked from smallest (1) to largest (n) $\overline{H}$ = mean headway.		
C Running times	Basic definition: Bus running times, relative to scheduled times, between departure from start of route and arrival at end of route:		Mazloumi et al 2010; Currie et al 2012
	1 Mean running time, relative to scheduled time.	• Basic measure, of use in considering running time adjustments, but gives no information on variability in running times.	
	2 Standard deviation of running times, relative to scheduled time (box 2.2)	• More useful measure, showing variability of running times, in minutes.	
	3 Coefficient of variation of running time, relative to scheduled time: $C_{vt} = SD(T_{Dev})/\overline{T}_{Sch}$ where C_{vt} = running time coefficient of variation SD (T_{Dev}) = SD of running times relative to scheduled time $\overline{T}_{Sch}$= scheduled running time.	• A useful, dimensionless, measure of running time variability as proportion of the mean running time.	
	4 Travel time (TT) buffer index: Index = (95% ile TT – ave TT)/ave TT	• Useful, intuitive measure. • Indicates the level of delay expected for the slowest 5% of trips (eg 1 day/ month for commuters). • Could be seen as a possible threshold for commuter expectations of a reasonable level of reliability: the buffer time (ie 95%ile TT – ave TT) represents the extra time needed, over the average, for the commuter to be on time for 19 days out of 20.	
	5 Florida reliability index: Index = 100% - % of trips with TT greater than (mean + specified margin).	• Primarily applied to road traffic travel times. Not often used for bus services. • Reflects the % of trips on route that take longer than the expected (mean) TT plus a defined 'acceptable' additional time (eg 20% of mean TT): this additional time may represent variations in 'normal' congestion.	

Aspect	Measure	Definitional issues, comments	Reference
	6 Misery index: Index = (ave TT slowest 20% trips – ave TT all trips)/ave TT all trips	• Also primarily applied to road traffic travel times. • Represents the average' excess' TT% of the longest 20% of trips relative to the mean TT.	

2.2.4 Travel time variability – statistical measures

Box 2.2 defines the standard statistical formulations referred to in table 2.3.

Box 2.2 Standard statistical measures

Standard deviation (SD)

This is one of the most common measures of variation, which, in essence, shows the dispersion of the values around the average:

$$SD = \sqrt{\frac{\sum_{i=1}^{n}(x_i - \bar{x})^2}{n}}$$

This measure is reasonably easy to compute. Additionally, it is simple to use this measure to find the percentage of data within a particular range of the mean. For instance, in a normal distribution, one SD from the mean implies that about 68% of the data values will be within this range, while two SDs from the mean cover 95% of the data.

Coefficient of variation (CV)

This is the ratio of SD to the mean value:

$$Coefficient\ of\ variation = \frac{SD}{\bar{x}}$$

CV is a 'dimensionless' measure of variation and hence it can be applied to different datasets to represent variation between them in a comparable way. (This could be important when reliability is compared between routes of different lengths or travel times.)

Percentiles

Travel time (TT) percentiles are widely used to measure travel time variability (TTV). Here the difference between a high TT percentile (eg the 90th) and a lower one (eg the 10th) is adopted to measure TTV, eg:

$$TTV = (TT_{90} - TT_{10})$$

In practice, the larger the distance and longer the travel time, the higher TTV tends to be on this definition. Hence, to neutralise the effect of differing trips lengths, the TTV figure is often divided by the median TT value:

$$TTV^* = (TT_{90} - TT_{10}) / TT_{50}$$

Source: Adapted from Mazloumi et al 2008.

2.2.5 Comments on choice of performance measures

As noted at the start of this section, there is no widely accepted 'best practice' in terms of the preferred package of performance measures (indicators) to reflect the reliability/punctuality performance of urban bus systems (from user, operator or authority viewpoints). The choice of the preferred package for any bus system will be influenced by several factors including:

- Whether the primary focus of the package is on the needs of users, operators or regulatory authorities. For instance, the information needs of users ('will the next bus get to my destination in time?') are likely to be quite different from those of operators (eg did the bus operate, did it start the trip on time?)
- The types of services operated. The main distinction here is between services defined (for users) in terms of frequency (eg a service every six to eight minutes) and those defined in terms of specified

timings (eg 8.20, 8.35, 8.52, 9.15). The former are the norm in many larger cities internationally, while the latter are predominant in New Zealand and most smaller cities.

- The availability and accuracy of suitable data and the costs of its collection and analysis. For instance, with manual data collection methods (eg roadside inspector or driver reporting), obtaining good data on headways along a route would be very costly, whereas with real-time information (RTI) systems it can be readily obtained and analysed.

A recent paper (Currie et al 2012) reports on a review of urban bus service reliability indicators, using Sydney as a case study. From a review of the literature and practices, the authors identified 10 indicators of service reliability that have been used in the urban passenger transport sector. They then undertook a comparative assessment of these indicators based on four criteria:

- ease of understanding
- the extent to which the measure has a customer focus
- the accuracy, completeness and objectivity of the measure
- the relative cost/effort in collecting and analysing the data.

It also included a fifth criterion (overall weighting), reflecting the average (more-or-less) of the other four criteria. The results of the authors' assessment against these criteria are shown in table 2.4.

Table 2.4 Summary assessment of reliability measures[(a)]

No.	Description	Ease of understanding	Customer focus	Objectivity and completeness	Cost/effort efficiency	Overall rating
1	% buses cancelled	High	Low	Medium	Low	Medium
2	% departing on time	High	Low	Medium	Medium	Medium
3	% arriving on time	High	Low	Medium	Medium	Medium
4	Excess waiting time	High	High	Medium	Medium	High
5	Average lateness	High	High	High	Medium	Medium
6	Reliability variability	Low	Low	Low	Medium	Low
7	Reliability buffer	Low	Medium	Low	Medium	Low
8	Passenger ratings	Medium	High	Medium	Medium	Medium
9	Customer complaints	High	High	Low	Medium	Medium
10	Customer delay	High	High	High	Low	High

(a) # 2, 3, 5 relevant to services with specified timetables; #4 relevant to frequency-based services

The original (2006) study on which the paper was largely based excluded the customer journey time delay (CJTD) measure (10), as it was considered too difficult to collect the required information at that time. CJTD requires collection of data on times at both boarding and alighting stops relative to the scheduled times. On assessing the remaining nine measures, the original study concluded that:

- *For high frequency bus services, excess waiting time (EWT – measure 4) was the preferred measure.*
- *For low frequency bus services, the percentage of buses running on time was the preferred measure, with little to choose between measuring departure times (measure 2) or arrival times (measure 3).*

Since 2006, the calculation of the new CJTD measure has become feasible for the Sydney rail system, through the introduction of systems that record the times at which each train stops at each station. Given this development, the recent paper undertook a new assessment including the CJTD measure, with the following conclusions and comments:

- *When considered alongside the other nine reliability indicators in the evaluation framework, the new CJTD measure ranked equal top with EWT.*
- *Both measures were considered easy to understand and have a high customer focus. Where they differed was in terms of fidelity/objectivity and cost efficiency. EWT is a partial measure since it excludes on-board delay, whereas CJTD is a total combined measure of 'at stop' and 'on bus' delay. EWT is also only appropriate for high frequency services whereas CJTD is applicable to low and high frequency services.*
- *In terms of data collection, EWT is more feasible since it only requires information at unlinked bus stops whereas CJTD requires stop-to-stop bus times which are far more onerous to collect. However with automatic collection of travel times, CJTD should become a practically feasible measure for bus as has already been demonstrated for rail in Sydney.*

In terms of the authors' assessment and conclusions, we would note the following:

- It is evident that their conclusions are specific to the Sydney situation and in particular to the state of its monitoring systems and capabilities at the time.
- It is important in any assessment to focus on the type of services being considered. As the authors note, the EWT measure is only appropriate for high-frequency services (which are not prevalent in New Zealand).
- While the CJTD measure has considerable attraction as a single indicator of total delays (at stop and on-vehicle), this is also a weakness – in practice, passenger perceptions of at-stop delays and on-vehicle delays are often very different (eg refer table 2.5).
- In the context of bus services in the main New Zealand centres, which now have operational automatic vehicle location (AVL) systems, it should be feasible to calculate CJTD. We see merits in further exploration and trialling of this measure by the regional authorities concerned.

Appendix B summarises practices on the performance measures (indicators) and standards adopted in selected international countries and major cities. Perhaps of greatest relevance, section B2 sets out the measures and standards adopted in the main Australian cities; while section B5 shows the measures and standards adopted by bus operators in 14 major metropolitan areas in a range of countries – but noting that in most cases these cities largely operate frequent (headway-based) services.

Appendix C provides additional information on practices and performance in London, including London Buses' use of the 'excess waiting time' (EWT) performance measure and their associated operator incentive system.

2.3 Importance of service reliability to bus users

Numerous market research studies internationally (and in New Zealand) over the past 30+ years, with either PT users or the population at large, have aimed to rank or rate the importance to users/potential users of the many different attributes of the 'ideal' PT service; and then to assess the extent to which the existing services meet this ideal. Some studies have then attempted to develop mode choice (or ridership) models, based on changes in people's rating of the various attributes.

Interpretation of the way that travellers rate the various attributes suffers from the difficulties of specifying a reference point for the attributes, but the usefulness of this approach lies in identifying the aspects with most potential for increasing ridership, pinpointing particular problem areas, and providing guidance on how best to market the services. Such an approach is more useful when the research into rating attributes by importance is complemented by ratings of current performance on the same attributes: the gaps between performance and importance on the various attributes provide a good guide to priorities for service improvement.

Appendix A summarises a selection of international research findings on the perceived importance of different service attributes, focusing on the ranking of the 'reliability' attribute (however defined) relative to other 'hard' and 'soft' attributes. Findings from New Zealand market research and reports on the perceived importance of reliability include the following:

- Wellington surveys of residents and businesses (GWRC (2007b) *RLTS market research review*). Respondents were asked about the relative importance of various journey attributes in influencing their choice of mode. For the resident sample, 90% said that 'reliability of journey time' was either very important or quite important: this was the highest rating among eight attributes covered. For the business sample, 91% said reliability was very/quite important, the second highest attribute rating (after safety).
- *Draft Auckland regional public transport plan* (Auckland Transport 2012). 'Surveys and research show that the most important consideration for PT users – and potential users – is reliability: a trip leaves on time and arrives at (or very close to) the scheduled time. This is even more important when connections need to be made with other services'.

This evidence shows that the reliability attribute is almost invariably the most important or one of the most important service attributes to PT users (all PT modes), in influencing their perceptions of PT and their decisions as to use of the services. One other 'soft' (quality) attribute often ranked of similar, or greater, importance to reliability is safety (from accident and assault): this tends to be a 'passive' attribute, which people often take for granted except where major safety problems are perceived (refer TRRL 1980). A 'hard' (quantity) attribute that is often ranked of similar or greater importance than reliability is service frequency.

For bus services in many developed-world cities, the high importance rating given to service reliability is accompanied by a relatively poor performance rating, resulting in a large shortfall between performance and importance, suggesting that service reliability should be given a very high (or the highest) priority for improvement in order to increase customer satisfaction and attract additional passengers. The New Zealand evidence, as noted in the following sources, tends to be consistent with the wider international evidence on this point:

- **Wellington PT attribute importance v performance research** (GWRC (2007a) *Public transport customer satisfaction monitor*). Respondents who had used bus services within the previous three months were asked about: i) the importance of various attributes in encouraging their bus use; and ii) their rating of the bus service performance on these attributes. Of 26 service-related attributes, the two that were given the greatest importance were 'reliability of the service' and 'buses arrive/leave on time'. These two attributes also showed the greatest shortfalls between performance and importance, indicating that they should be given high priority for improvement to enhance customer satisfaction and to increase patronage.

- *Wellington public transport satisfaction monitor 2011* (Premium Research 2011). 'We know from previous surveys that reliability is consistently regarded as the most important service attribute'. 'Satisfaction with reliability is still at mediocre levels, and has dropped for all modes in 2010: among recent users, 59% were satisfied with the reliability of bus services, 29% with train services, 78% with ferry services'.

While there is a strong consistency between most international market research studies in their findings on the importance of different service attributes, the results of such attitudinal studies need to be interpreted with considerable caution. People's rating of attribute importance will be influenced by:

- what they have become used to
- the perceived performance of the current system (eg if the system is perceived to be relatively 'safe', people will tend to rate the importance of safety lower than if the system was considered unsafe)
- whether they believe there is scope for improvement against the attributes
- particular recent (but maybe atypical) experiences.

In addition, there is wide scope for errors in measurement, analysis and interpretation of the outputs of any attitudinal surveys, and even wider scope for interpretation in any attempts to compare findings from different surveys (in the same or different cities).

One further, important, point should be made relating to the high importance of the reliability attribute in market surveys. Most of the surveys from which this conclusion is drawn (as in table A.1) are based on surveys of PT/bus users[6], rather than of the population at large. Such surveys clearly focus on those people who have reasonable PT services available to cater for (some or all of) their travel needs. However, surveys of the population at large will typically (as in New Zealand) include a substantial proportion of the population for which current PT services meet very few if any of their travel needs: such people are likely to give greater importance to attributes relating to the availability of services (eg walking distances, service frequencies) than the quality of services (eg reliability). Market research in (for example) Auckland has shown marked differences between PT 'users' and 'non-users' in their priorities between different attributes – with the 'users' giving priority to quality factors, the 'non-users' giving priority to availability factors (Booz Allen Hamilton 2005).

2.4 User valuations of reliability improvements

2.4.1 Overview

An understanding of the behavioural valuations that bus users (and potential users) place on changes in the (un)reliability of services in different situations is very relevant to the development of strategies and tactics to improve service reliability. It was outside the scope of this project to undertake a comprehensive review of New Zealand and international evidence on user valuations of reliability. However, such a review, along with primary market research in New Zealand, was included in an earlier NZTA research project (Vincent 2008). The market research findings from that project have, in effect, now been incorporated into NZTA's (2010) *Economic evaluation manual* (EEM) (vol 2).

[6] Some of these surveys cover a random sample of PT users (eg as obtained from a household-based survey); others cover a random sample of PT trips (as obtained from an on-board survey), with an inherent bias in favour of frequent users.

This section therefore:

- summarises the key findings from the literature review on the user valuations of reliability relating to PT services (in Vincent 2008)
- summarises the findings from the New Zealand-based market research undertaken in Vincent (2008)
- provides brief commentary on the implications of these findings for investigations and measures to improve bus service reliability in New Zealand.

2.4.2 Literature review on reliability valuations

Vincent (2008) compiled a comprehensive international literature review of evidence on user valuations of (changes in) the reliability features of PT services. Most of the literature findings were derived from stated preference (SP) based market research with PT users.

It is noted that:

- The research in this area is not very extensive – the area is relatively under-researched compared with other aspects of PT evaluation.
- Most of the evidence is drawn from urban (often metropolitan) situations, involving relatively short-distance travel.
- Most of the research studies are not explicit about the sources of delay (eg whether when waiting at the stop or when travelling in the vehicle).
- Most studies derive values for either the mean delay or the variance (standard deviation) of delays, averaged over all travel by the person concerned over a period of one week or longer.
- For comparative purposes, one minute's mean delay or a one minute standard deviation in delay are usually expressed in terms of the equivalent in-vehicle time (IVT) increase.

Given this context, the key findings on reliability valuations from Vincent (2008) were as follows:

- The range of values found across the available studies is relatively large: this probably reflects both different survey/analysis methodologies as well as 'real' differences between the various situations surveyed.
- Typically, one minute's mean lateness is valued at around four minutes IVT (or around 2.5 minutes expected waiting time at the stop).
- Similarly, a one minute change in the standard deviation of lateness is valued at around one minute change in IVT.
- Valuations for delays for passengers waiting at the stop are generally higher than those for passengers travelling on the service.
- There is insufficient evidence to identify consistent differences in valuations by PT mode, trip purpose or time of day.

2.4.3 RR339 market research findings

The research project involved primary market research among PT users in Auckland and Wellington. The survey was administered on-line, based on SP methods, and provided results from some 750 respondents (c. 13,500 SP trade-off results).

Respondents were presented with a series of choices between two trip scenarios, differing in terms of:

- in-vehicle time
- fare
- probability of a specified delay at either the pick-up point or on arrival at the final destination.

Two main models were applied to analysing the survey results:

- a disaggregate model, providing separate valuations for services being five minutes early, five minutes late and 10 minutes late
- an aggregate mean model, providing valuations for an 'average minutes lateness'.

Table 2.5 presents the research results for bus passenger values of early/late time (disaggregate and aggregate), expressed relative to the equivalent values of IVT (similar tabulations were also derived for rail users). Key findings included:

- The average valuation per minute of mean delay for bus users is equivalent to 4.8 minutes IVT.
- This overall result is very consistent with the weight of evidence from international research (a factor of around 4.0 from Vincent 2008, as above).
- The values for delays while travelling in the vehicle are in most cases considerably lower than those for delays while waiting at the stop. This would reflect the typically better environment in the vehicle (weather protection, seating) than at the stop.
- The disaggregate unit values for 10 minutes late are significantly higher than those for five minutes late. These are likely to reflect the increased anxiety and disruption when services are exceptionally late (passengers may well expect and plan for a modest level of lateness).
- The unit values for services running early (at the stop) are considerably higher than all the values for late services. These probably reflect the passengers' perceptions of having missed the service and having to wait for the next one.
- By contrast, the values for services running early (on the vehicle) are much lower than all the other values. These reflect passengers' relatively low disutility from arriving a few minutes early at their destination.

Table 2.5 Reliability parameter (mean delay) summary (Vincent 2008)

Mode	Item	Value of early/late time relative to in-vehicle time[(a)]		Average[(b)]
		Waiting at stop	Travelling in vehicle	
Bus	Early – 5 mins	11.1	2.0	6.6
	Late – 5 mins	3.5	4.5	4.0
	Late - 10 mins	8.0	5.2	6.6
	All variations	6.4	3.2	4.8

Source: Vincent 2008, table 8.5.

Notes:

(a) All valuations expressed in terms of equivalent in-vehicle minutes.

(b) Average is the simple average of the two previous columns (assumes a 50:50 split between departure delays and in-vehicle delays).

The table 2.5 values (and the equivalent values for rail services) have been incorporated into the EEM (January 2009 update), although EEM only gives values for average minutes late, not distinguishing between early and late occurrences.

2.4.4 Comments and implications

In the New Zealand context, we consider that the values in table 2.5 provide a good guide to user valuations of (changes in) reliability in New Zealand urban situations. This set of values has the merits of:

- being generally consistent with the weight of international evidence
- providing useful distinctions between modes and (as required) journey purposes
- providing useful distinctions between delays in waiting at the stop and delays while travelling in the vehicle
- emphasising the particularly high disutility that passengers place on services running early; and also the increasing (unit) value for services operating more than five minutes late (these distinctions are lost in the more averaged values given in EEM).

In general, the high reliability values, relative to standard values for IVT, emphasise the importance of addressing reliability issues; and the matrix of reliability values (as in table 2.5) provides good guidance to operators and planners on priorities for improving service reliability (eg reinforcing the importance of avoiding any early running).

2.5 Impacts of (un)reliability on patronage

2.5.1 Introduction

This section provides an overview/commentary of evidence on the impacts of (un)reliability on local PT patronage, focusing on urban bus services. It does not attempt a comprehensive review, as the topic is covered in previous NZTA research reports (Wallis 2004) and other sources (Balcombe et al 2004; TRRL 1980; Evans et al 2004).

2.5.2 Attitudinal and stated preference (willingness-to-pay) evidence

It was shown earlier (section 2.3) that based on attitudinal surveys, PT users and potential users place high priority on services operating reliably – reliability is seen as one of the most important ‘qualitative’ attributes of PT services.

This attitudinal evidence is supported by willingness-to-pay evidence, mainly from stated preference surveys. The previous NZTA research described in section 2.4 found that, on average, bus users valued one minute’s average lateness at around five times one minute of IVT. Lateness in departure from the boarding stop was valued higher than this average, at around 6.5 times IVT, and even higher than this in cases of services operating early or very late; while delays when travelling on the vehicle were valued rather less, at around three times IVT. The values of reliability from this research are generally consistent with those from other studies internationally, and they are now incorporated in the EEM (vol 2).

Consistent with these relative valuations, the demand effects of a one minute change in average lateness would be equivalent to those of a four to five minute change in IVT, which in turn could be expected to result in a patronage change of around 5%–10%. The implications of this evidence in terms of demand elasticities are discussed further in Wallis (2004).

2.5.3 Revealed preference data

Despite the importance of reliability to passengers, very limited revealed preference (RP) evidence is available internationally on how changes in in-service reliability have affected patronage levels on urban PT services. As noted in Balcombe et al (2004): 'Public transport demand elasticities (or other quantitative estimates) with respect to service reliability are limited and often only qualitative estimates of passenger response to reliability have been made'.

Limited RP evidence is given in Wallis (2004) and Evans et al (2004), but this relates largely to urban rail services.

2.5.4 New Zealand evidence

We investigated whether any useful New Zealand-based evidence was available on the effects of changes in (un)reliability on PT patronage, first for bus services and, failing that, for rail services. Our investigations focused on evidence for Wellington, since it has experienced significant disruptions of both its bus and rail services over the last five to six years.

The impact of (un)reliability changes on both bus and rail services in Wellington was examined in recent work for the NZTA (Kennedy 2013). However, in neither case has the work turned out to be useful:

- In the case of bus services, the work analysed the effects of the Go Wellington rescheduling and associated driver shortages in early 2007. While the study report suggested that this event had a negative effect on patronage over a six-month period, its econometric analyses only found marginally significant (negative) impacts on weekend patronage, with estimated impacts on weekday patronage appearing to be implausible (positive).
- In the case of rail services, the econometric analyses did not include a reliability variable, as the available time series of reliability data was judged to be of insufficient length (covering only about two years of the five-year analysis period).

Given the deficiencies in the evidence available, we conclude that no useful New Zealand-based evidence is available at this time on the impacts of changes in reliability on patronage for either bus or rail services.

2.6 Reliability data collection and analysis aspects

2.6.1 Overview

This section following describes and compares the merits of the various means of collecting bus service reliability data. These essentially are of three main types:

- 'manual' monitoring (usually on-street but may be on-bus)[7]
- use of data from electronic ticket machine (ETM) systems
- use of data from AVL/GPS systems (often installed as the base for real-time information delivery).

Each of these methods has its own strengths and weaknesses, primarily related to the cost and efficiency of collecting data, the quality and quantity of data obtained and the purposes for which it can be used.

The two latter methods, which may be collectively referred to as 'electronic' methods, are set apart from 'manual' methods inasmuch as i) they are dependent on high-technology systems, which are relatively

[7] Driver reports can also provide useful data on reliability issues and may be considered under this heading.

costly to install and maintain (but are usually justified for purposes other than reliability data collection), and once operational can provide extensive data at low marginal costs; ii) whereas manual methods involve minimal up-front costs but high marginal costs, and thus the extent of data collected is inevitably constrained.

We note that the over-riding consideration behind any decision to use a particular method of data collection over any other should be – 'is the data collection appropriate for the use intended?' The various purposes of data collection are therefore outlined in the next sub-section. This is followed by an outline of some data collection issues, and then by an assessment of the merits of the different methods for the various potential data applications.

2.6.2 Purposes of data collection

Data collection is likely to be directed towards measurement for one of two main purposes:

- data for reporting performance to stakeholders ('performance reporting')
- data for implementing improvement actions ('diagnostic and improvement analysis').

2.6.2.1 Performance reporting

Data for reporting to stakeholders is likely to be 'pure' performance data. It may be required to support measurement of performance against a number of different standards including:

- excess wait time or actual wait time for headway mode services
- departures within a 'window of timeliness' for scheduled mode services
- journey time analysis – for both headway mode and scheduled mode services.

Data for reporting performance to stakeholders does not need to include great detail as it is essentially 'summary' information. In terms of achieving improvement, its contribution is likely to be at a high, strategic level, assisting to highlight particular poor-performing areas, as a prelude to developing strategies and action plans to address these areas.

2.6.2.2 Diagnostic and improvement analysis

Data that is to provide the basis for developing and implementing improvement actions will be at a far more detailed level: accurate planning and scheduling of a bus service requires a significant volume of information on section-by-section journey times. Effective improvement actions will only be possible if data is available in sufficient detail to identify where and when a timing problem exists and the type and extent of change required to correct it. Decisions will be required on where along the route data is collected (in terms of distance from start of the route and location relative to any 'pinch-points'), and what times of day/week it should cover.

At a further detailed level, monitoring and measurement of individual driver issues (if those are identified as a root cause of punctuality problems) would require its own reporting.

2.6.3 Some data collection and monitoring issues

2.6.3.1 Covert versus overt (the 'Hawthorne effect')

Put simply, the 'Hawthorne effect' is when people improve an aspect of their performance or behaviour in response to the fact that they are being observed or studied.

For whatever purpose data is collected, it is relevant to consider the effect of the act of collecting data upon the performance measured. One way of introducing a 'control' for this variable is to collect data both overtly and covertly and establish the difference between the two results.

At its most obvious, the significance of the 'Hawthorne effect' when monitoring bus service reliability can be measured by comparing the results achieved through:

- inspectors or monitors standing obviously and clearly at timing points, and
- the same inspectors or monitors standing covertly at the next stop down the route after a timing point.

In the case of the overt observations at timing points, any drivers tempted to 'run early' are likely to amend their behaviour. In the case of covert observations at the subsequent bus stop, drivers running early have already 'passed the point of no return' by the time they are observed. The decision for the observer is then whether to intervene (and advise the driver there and then that they have been caught running early – and potentially then breaching the observer's cover in the process), or whether to carry on making observations.

For the electronic methods of collecting data, although these methods (eg using GPS and/or ETM sources) are apparently overt and obvious to drivers, in reality driver performance will depend on how likely they are to be 'brought to task', as a result of analysis of data from such sources. In short, although most operators in the developed world use ETM and/or GPS systems, unless an operator is in the habit of analysing the data and bringing concerns to the attention of drivers, drivers' timekeeping performance is unlikely to be influenced.

2.6.3.2 Data quality issues

Data collection based on ETM systems tends to suffer from several deficiencies affecting data quality (and quantity). In particular, 'first generation' ETM records of time-keeping at the start of routes are usually compromised by the fact that drivers will start to issue tickets prior to their departure from the terminus. Also there can be points on a route where data is 'thin' – depending on the sample size (or date range selected), there may be no passengers boarding at particular points. Again, this may also be noted towards the terminus point of a route, where more passengers will usually be alighting than boarding. Where low-quality ETM data exists it will often be necessary to interpret the overall data and in-fill gaps. Good practice will usually involve confirmation that ETM data is in line with actual observed times[8].

GPS-based systems, including RTI and modern ETM systems, can still suffer from low-quality or dirty data unless resources are put into maintaining the whole system. Maintenance includes not only checking that contact continues with each 'live' vehicle but also that, as routes and schedules are changed, this is recognised and updated in the software systems to compare actual times with scheduled times. Maintaining each 'live' vehicle requires contingency planned into the system as operators go through fleet renewal and replacement.

Essentially, for both ETM and AVL/GPS systems, resources need to be provided to ensure that reliability data remains meaningful and accurate on a continuing basis.

2.6.3.3 A comparative case study

The UK Department for Transport (DfT) has undertaken case studies to compare bus reliability data collected using electronic methods with that from manual observations, with the particular objective of assessing whether the electronic data was of satisfactory quality to be used in assessing bus reliability performance against the stipulated standards. DfT recognised that in principle the electronic systems should provide data that is cheaper to obtain than manual observations and is free of human error, but it is known that electronic systems can fail to work on occasions.

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[8] These problems do not arise with the current ('second generation') ETM systems in Wellington and Christchurch, and will not be expected with the new system shortly to be introduced in Auckland. In these cases, the ETM system incorporates GPS-based location equipment.

For some 1400 trips for the services of eight operators, departure times were matched between roadside observers and electronic data. It was found that the error rate of the observers was very low (three occasions of incorrect recording), while the proportion of trips 'missed' in the electronic system varied between 7% and 29%. These missing values were potentially because:

- the bus was not fitted with a device
- the device was switched off or not working
- the 'on-street' monitor had recorded a bus which had not, in fact, run at all.

From the gaps in the data it was concluded that it was probably not yet possible to use electronic devices to measure the excess waiting time (EWT) on 'headway mode' services, where it is essential to record every departure. However, the punctuality of buses within the 'window of timeliness' was found to be almost identical where there was a working GPS system (73% on time) compared with observations made only by roadside monitors (72% on time). This suggested that there was no bias in relying on data from roadside observations or from buses with working GPS.

Although the overall proportions of punctual buses recorded by GPS or by roadside observation did not appear to be biased, perhaps surprisingly there was only a 53% exact matching between the visual observations and the electronic estimates of times of departure. However, once allowance was made for minor timing differences of ±1 minute, this matching proportion increased to 90%.

2.6.4 Data collection methods – assessment and conclusions

Table 2.6 provides a summary of the strengths and weaknesses of the three different data collection methods. It confirms that the different methods have their own attributes in terms of cost, efficiency and quality, while underlining the importance of considering the purpose for which the data is required.

If there is a desire to understand the reasons behind journey time variability, it is likely that some degree of 'boots on the ground' – either through 'on street' or 'on vehicle' monitoring – will deliver the best results. There may well be a reduction in the volume of data collected in this way – and it may be more costly to collect – but it will most likely help to provide more detailed analysis of the problems and hence almost certainly provide clearer direction about the actions to be taken.

Analysis of ETM data and/or AVL/GPS data may well assist in directing the 'on the ground' research to the 'hot-spots', and is usually seen as 'objective' data (subject to adequate maintenance of equipment etc). Human interaction with drivers may produce similar findings and, at the same time, let bus drivers know that other people involved such as supervisors and managers are interested in producing improvement. Often both electronic and human information can have complementary roles in identifying and addressing problems.

2.6.5 Data collection methods – New Zealand developments

In recent years, there have been major developments in New Zealand's three main centres in relation to the measurement/monitoring of bus service reliability performance – particularly for the purpose of reporting performance against reliability/punctuality standards.

Historically, the main basis of regular performance monitoring has been through operator self-reporting using 'manual' methods, ie manual logs filled in by drivers or depot operations staff, usually focusing on 'missed' trips and departure time from the start of the route. A small sample of services might then be monitored by regional authority staff, to check the veracity and completeness of the operator returns.

However, all the evidence now indicates that the operator returns have understated the extent of unreliability by an order of magnitude (refer section 3.3).

Electronic-based data, through AVL/GPS and/or ETM systems, has more recently become available, first in Christchurch (using its RTI system) and subsequently in Auckland and Wellington (using RTI and ETM systems). Christchurch has completely replaced its operator self-reporting system by the use of electronic data for both service reliability and punctuality (at the start of trip and at timing points en route). Auckland and Wellington are still in the process of refining their electronic data collection/analysis methods for assessing reliability and punctuality, with a view to these replacing the operator self-reporting methods once they are proven to be of sufficient accuracy.

Table 2.6 Strengths and weaknesses of alternative data collection methods[(a)]

	Strengths	Weaknesses
Purpose 1: *Background/ performance monitoring*	*High level, strategic: assists in highlighting hot-spot routes. Easy production of 'good' and 'bad' performer league table.*	
A On-street monitoring	• May be overt or covert.	• Data collection costly.
B ETM data analysis	• Quantity of basic data is not a limit (but note weakness): time to analyse and interpret is the limit. • Can allow journey time variability to be shown (see section 4.16).	• With 'first generation' systems, dependent on driver performance in updating stages and gives poor information where few tickets are purchased. (These deficiencies overcome in 'second generation' systems, which include GPS equipment.)
C Remote sensing/tracking (GPS/AVL)	• Provide detailed information by individual services/trips as required. • Data collection not reliant on drivers	• Resource intensive to maintain the system, schedules and connections from vehicles to the system (but may be maintained for other purposes).
Purpose 2: *Reliability improvement and root cause analysis*	*Requires detail, allows action – but only after analysis. Realistically, each route has to be analysed in isolation: this is likely to lead to a 'route by route' approach over time*	
A On street monitoring	• Because it can be overt or covert, it is possible to measure the difference (ie the effect of 'on street' supervision). • Allows discussion with drivers and verbatim reporting of hot-spots and root causes.	• As on-street data collection is costly, it is likely to be limited (though it may well align with the requirement for detailed analysis). • Sampling framework unlikely to dovetail with background monitoring requirements.
B ETM data analysis	• Quick identification of key locations.	• Does not identify solutions for hot-spots.
C Remote sensing/tracking (GPS/AVL)	• Quick identification of regularly failing drivers or journeys.	• Does not identify solutions for hot-spots.

In terms of the 'diagnostic/improvement analysis' purpose for data collection, all three centres are making use of the electronic data to monitor and then adjust running times and hence timetables/schedules. Such electronic monitoring is still being supplemented by manual monitoring methods where it is necessary to examine specific issues in detail.

Further information on the developments in the three main New Zealand centres is provided in chapter 3.

3 New Zealand reliability policies, standards and performance

3.1 Overview

This chapter outlines reliability standards and performance for urban bus services in the three main New Zealand centres (Auckland, Wellington, Christchurch), which together account for over 90% of total urban PT patronage and funding in New Zealand.

This chapter covers, in turn:

- the policies and standards adopted towards bus service reliability and punctuality in each of the three centres
- statistics on the reliability/punctuality performance of bus services in each centre
- evidence on customer attitudes and perceptions relating to reliability/punctuality in these centres
- policies and procedures relating to bus service reliability performance (including standards, incentives and monitoring) at a national level, through the NZTA.

3.2 Regional policies and standards

Tables 3.1 (Auckland), 3.2 (Wellington) and 3.3 (Christchurch) provide summary information in regard to reliability and punctuality in the three main centres, under the following headings:

- objectives and policies
- standards and targets
- monitoring methods
- operator incentives
- actual performance
- causes of poor performance
- measures taken/proposed/being considered to improve performance
- approach to setting running times and layover times.

This section (3.2) comments on the first three of these headings in regard to each of the three centres: commentary on the other headings is provided in the subsequent sections of this chapter.

3.2.1 Objectives and policies

All three centres set out their objectives and policies relating to reliability and punctuality aspects in their regional public transport plan (RPTP). While the objectives and policies in each centre appear to be arranged and expressed quite differently, in reality there is a considerable degree of commonality in the themes covered.

At the highest level, the overall reliability and punctuality objective adopted is along the lines of 'A high quality reliable PT system that customers choose to use' (refer Auckland/Wellington). At the next level (sub-objectives/policies), common themes include:

- providing realistic, achievable timetables that can be delivered reliably (eg Auckland)
- ensuring that connections between services maximise transfer reliability (eg Wellington)
- providing improved (particularly real-time) information to users on reliability/punctuality performance (eg Wellington)
- promoting the provision of bus priority measures to increase service reliability and reduce travel times (eg Auckland)
- undertaking regular monitoring of operator reliability/punctuality performance and to pursue continuous performance improvement (all three centres).

3.2.2 Standards and targets

All three centres have performance standards and targets (thresholds) relating to:

- reliability – in terms of the minimum proportion of the scheduled services required to be operated
- punctuality – in terms of the minimum percentage of services required to operate within a defined 'window' of the scheduled time, at the start of the trip and (in some cases) at intermediate timing points along the route.

Beyond this, there is little uniformity in the way that standards/thresholds are defined in the three centres. For example:

- The reliability standard refers to 99.9% of scheduled trips in Auckland, 99.5% in Christchurch and 99.0% in Wellington.
- The punctuality 'window' appears to be 0 mins early to 5 mins late in Auckland (95% threshold), 0 mins early to 10 mins late in Wellington (90% threshold at start of trip), 0 mins early to 3 mins late (90% threshold at timing points) or 5 mins late (95% threshold) in Christchurch.

It is thus extremely difficult to compare standards and performance across the three centres.

We note that the reliability/punctuality standards are not well specified in all cases (eg whether they apply just to the departure time at the start of the route or also intermediate timing points). In the Wellington case, the current RPTP has moved away from any quantified targets and replaced these by a target specified as 'continual improvement to bus...services running to time'.

3.2.3 Operator incentives

All three centres include some system of financial rewards/penalties in operator contracts, as an incentive to operators to maintain/improve reliability and punctuality performance. Again, the systems appear to differ between the three centres, and full details are not publicly available in all cases (only being specified in operator contracts):

- For Auckland, few details appear to be publicly available.
- For Wellington, there are provisions for deductions in all cases where services either do not operate or operate outside the standard window (0 minutes early to 10 minutes late). Some contracts also include a provision for liquidated damages where these services are not reported by the operator. However, any deductions are dependent on the fault lying with the operator. In the case of the trolley bus contract, reliability and punctuality performance are also to be taken into account in the decision on contract renewal.

- For Christchurch, Environment Canterbury's (ECan's) 'balanced scorecard' system of operator incentives includes a component relating to late running (>5 minutes) from the terminus or intermediate timing points. Non-compliance penalties may be levied for missed trips and early running, with (much) higher penalty rates if the incidents are not reported to ECan.

As far as we are aware, no information is available publicly on the extent of payments/deductions made to operators under the various incentive arrangements. Nor are we aware of any appraisals being undertaken on the effectiveness of these arrangements in improving reliability/punctuality.

We note that the current systems of performance standards/targets and incentives outlined above are likely to be varied in the near future with the introduction of new unit agreements under the proposed public transport operating model (PTOM) contracting regime. However, the new PTOM proposals for each region are still under development and are not yet generally available.

Table 3.1 Bus reliability/punctuality policies, standards and achievements – Auckland

Aspect	Description	Notes, sources
Objectives and policies	**Objective 3:** A convenient and reliable PT system using modern vehicles. *Policies*: • 3.1: Develop realistic, achievable timetables that are reliable and dependable. • 3.3: Provide a reliable, punctual, customer-focused network of services. • 3.5: Ensure that service agreements encourage good operator performance. • 3.6: Monitor and continuously improve service delivery.	Source: Auckland Transport 2012a
Standards (actions) and targets	**Proposed actions to achieve policies:** *Policy 3.1* 1 Develop new timetable using actual monitored travel times and test reliability before service implementation. 2 Work with operators to monitor actual travel times using GPS real-time tracking and performance measurement systems, and modify timetables as required to provide customers with a high standard of service reliability. 3 Provide priority measures to increase service reliability and reduce travel times, particularly on parts of the network that have high-frequency services. *Policy 3.3* 1 Specify whole network standards for reliability and punctuality, and incentivise good service performance through the PTOM service agreements. 2 Use real-time passenger information or other information for service performance management and make this available to operators for performance monitoring and fleet management. 3 Work in partnership with operators to continually improve reliability, punctuality, and all aspects of customer service. 4 Effectively and efficiently monitor services and manage performance through appropriate contractual methods, as required. 5 Identify failures in performance across the network and work in partner-ship with operators to rectify any identified problems in a timely manner. *Policy 3.5* 1 Incorporate specifications and a KPI regime including service reliability and punctuality, quality, compliance, customer service, and safety in PTOM service agreements. *Policy 3.6* 1 Work with operators to access operational information in a timely fashion, and include conditions for timely operational reporting in PTOM contracts.	Source: Auckland Transport 2012a; Auckland Transport 2012c.

Aspect	Description	Notes, sources
	2 Require contracted service operators to provide operational information, as required, including: a reliability (early running) b reliability (cancellations) c punctuality (late running). 3 Ensure that suppliers have sufficient information about service performance across the whole network, so that they can continually improve services offered to customer. 4 Utilise shared, centrally accessed service specifications, service performance, and service measurement data between Auckland Transport (AT) and operators to improve service performance. 5 Use real-time passenger information (or other systems for monitoring service delivery and managing service performance) including through PTOM contracts.	
	Standards/targets – current • Reliability: 99.9% of all service trips to operate. **Punctuality:** • *Early:* No services to leave early. • *Late*: 95% of services to operate within 5 mins of schedule[(a).] **Standards/targets – proposed** Under the proposed PTOM contracting regime, standards/ targets are proposed on the following reliability/punctuality aspects (draft unit agreement): • *Reliability* (missed trips – threshold figures to be defined. • *Punctuality* (start route): within window 60 secs early – 5 mins late (threshold figures to be defined). • *Punctuality* (end route): within window up to 5 mins late (threshold figures to be defined, depending on route characteristics).	
Monitoring methods	**Historic** Reliability and punctuality monitoring has historically been dependent on operator self-reporting to AT, on a monthly basis, against the standards set out above. Operator reports have been drawn from depot/driver logs, rather than (it appears) any electronic monitoring systems. AT has been working to develop improved systems by which to check the operator self-reporting. **Systems under development.** *AT is in the process of developing an automated tracking and monitoring system to report bus reliability and punctuality and provide enhanced data to improve service delivery across all bus services (contracted and commercial).* A review of the reliability and punctuality of all bus timetables is underway to ensure timetables continuously reflect operating conditions. This system will draw data from the RTI (RAPID) and ETM systems (currently principally NZ Bus's Snapper system). It will be able to report punctuality data at a detailed level, both at the start of the route (already possible) and at timing points along the route (likely in future).	Sources: Auckland Transport 2012b
Operator incentives	**Current** Currently, operators are liable to deductions from their funding where performance (based on operator self-reporting) against reliability and punctuality standards is below the defined threshold levels (further details not known.) **Proposed unit agreements (PTOM)** Under AT's proposed unit agreements, for the reliability and punctuality (start route) KPIs, there will be a fixed deduction per event when performance is worse than the	Sources: Auckland Transport 2012c.

Aspect	Description	Notes, sources
	'deductibility threshold' (see above). In the event of performance worse than the 'KPI failure threshold', a cure plan will be initiated. For the punctuality (end of route) KPI, an incentive scale for service level credits/incentive payments will apply for performance significantly above or below the specified standards (details still under development.)	
Actual performance	Historic methods (operator self-reporting) Reliability and punctuality performance is reported in the AT statistics report, which gives monthly statistics by operator on reliability (% scheduled services that were operated and reached their destination) and punctuality (% services which commenced within 5 mins of the scheduled start time and reached their destination). Typical reported results (average all operators) are: • *Reliability:* 99.4% to 99.9%. • *Punctuality:* 99.2% to 99.7%. Methods under development (AVL data) All performance data relating to reliability and punctuality is generated by AT, sourced from RTI and ETM systems. Based on this data, AT is developing analysis methods to report on reliability and punctuality based on all scheduled services (and which can potentially replace the previous system of operator self-reporting).	Sources: Auckland Transport 2012b
Causes of poor performance	Major factors behind services departing significantly from their scheduled timings are understood to be: • Schedules often do not reflect the running times (overall or by section) that a 'typical' driver will require to run the route (on an 'average' day or any defined %ile day). • Limited bus priority measures that would protect buses from the vagaries of traffic congestion. • In the absence of adequate priority measures, the variable effects of congestion on bus running times (by day/time period, season, school term v holidays, weather conditions, etc). • The failure of drivers/operators to take action to ensure that services do not operate early along the route.	AT advice
Measures taken/ proposed/being considered to improve performance	Measures include the following: • *Adjustment of timetables (running times)* where appropriate, in order to minimise running time variations from timetables (refer below). • *Bus priority measures* on links and at intersections (using RTI data). • *Improved (real-time) information for passengers*, including at stops/stations. • *Improved (real-time) information to assist operators*, in monitoring/ managing services and ensuring that specified standards are being met (assisted by incentives).	Auckland Transport 2010
Approach to setting running times and layover times	Based on the AVL data now available, AT is currently (in conjunction with the region's bus operators) reviewing running times and layover allowances, with a view to specifying draft times for the proposed new (PTOM-based) contracts. **Running times:** • Running time data is extracted from RTI data for each route variant. • This running time data is then allocated to days of the week and time periods during the day. • The travel times are then split into individual links (bus stop to bus stop). • The travel times are then averaged and stretched to cover the longest running trip in the selected time period for travel in the area where the links are. • An experienced human eye then analyses complete trips and routes to ensure	AT advice.

Aspect	Description	Notes, sources
	that the running times are realistic. • A lot of tinkering has to take place here, as multiple routes often use the same links. • In general running time is stretched out to accommodate a certain level of running times outliers. **Layover times:** • AT does not have a specific policy on setting layover times. • In practice, reasonable layover times vary considerably, depending on factors such as length of trip, time of day and location of service. • All trips/routes are assessed using Austrics (scheduling package) but there is no set way of calculating the layover time required. • In addition to this any layover time that is built into a timetable is not guaranteed to be used by an operator: they can add or subtract layover time depending on how they scheduled their vehicles.	

Notes: [(a)] This appears to be defined as 'the percentage of services which commence their journey within five minutes of the timetabled start time and reach their destination' (refer Auckland Transport 2012b).

Table 3.2 Bus reliability/punctuality standards and achievements – Wellington

Aspect	Description	Notes, sources
Objectives and policies	**Strategic issues (regional land transport strategy)** include: Improved reliability of PT services and network resilience. **Objectives, policies and methods (regional public transport plan)** *Objective 2:* an integrated network of services that makes it easy and safe to change between and within modes. *Policy 2.2:* Ensure that connections between services minimise transfer times and maximise transfer reliability. Methods: refer to policy 3.1/3.2. *Objective 3*: A high quality, reliable PT system that customers choose to use. *Policy 3.1:* Develop and maintain PT timetables that are easy to understand and can be reliably delivered and depended on for all services. Methods: 1 Work with transport operators to continually refine timetables to achieve greater reliability of service. 2 When carrying out service reviews, develop timetables that balance operational needs and customer needs. 3 When carrying out service reviews, develop timetables based, where possible, on regular clock-face intervals. *Policy 3.2*: Ensure the provision of reliable information on the arrival and departure times of PT services. *Policy 3.3:* Ensure that PT services deliver a high-quality customer service experience. *Policy 3.4:* Carry out regular monitoring to enable continuous improvement in service delivery. *Policy 3.5:* Advocate for PT priority measures on the rapid transit network and quality transit network in support of the future network plan.	Sources: GWRC 2010; GWRC 2011.
Standards (actions) and targets	**General target – reliability (2015/2020)** Performance measure/target for 'continual improvement to bus...services running to time'.	Sources: GWRC 2011; GWRC 2009; GWRC nd

<table>
<tr><th>Aspect</th><th>Description</th><th>Notes, sources</th></tr>
<tr><td></td><td>(Previously, a bus service was defined as being ‘on time’ when it ran within 10 minutes of scheduled time at departure and at its destination.)

Trolley bus contract
Reliability: No more than 1% of all scheduled service trips (monthly basis) to:
• not operate
• operate >10 mins late from origin terminus
• operate early from origin terminus or any timing point.
Punctuality: 98% of trips operated (monthly basis) to depart origin terminus within 9:59 mins of scheduled departure time.
Notes:
• Distinction between reliability and punctuality requirements is unclear.
• Standards appear only to be applied when operator is deemed ‘at fault’ – contract defines ‘at fault’ situations.
• Contract notes that punctuality standards will be changed to adopt time bands when improved data available.

Other bus services. Generally similar standards/targets to those above for the trolley bus contract.</td><td></td></tr>
<tr><td>Monitoring methods</td><td>General
• Data is obtained from both operator self-reporting and GWRC’s quality monitoring. Quality monitoring is conducted across a region-wide programme in order to obtain a statistically meaningful number of services. This is done manually and with the aid of movable cameras that are fixed to the top of bus-stop poles.
• GWRC also has the ability to audit the records that operator reports are derived from.
• Monitoring and reporting forms the basis for a regular quality report which also includes progress on all matters being addressed in order to improve network performance.
• With the introduction of RTI in 2010, GWRC ‘looks forward’ to being able to spend more time looking at quality assurance matters rather than just quality control.
Trolley bus contract
• Trolley bus contract notes that monitoring is to be based on:
– reporting by Wellington City Transport Ltd (WCTL) based on driver and controller reports
– surveys conducted from time to time by WCTL and GWRC
– new data sources – including RTI systems.</td><td>Sources: GWRC 2009; GWRC nd.</td></tr>
<tr><td>Actual performance</td><td>Operator self-reporting
• Reliability: scheduled bus services operate at least 99% of the time.
• Punctuality: nearly all (99.9%+) bus services operated on-time in 2008/09. 2008 calendar year: 99.7% of bus services operated within contractual limits.
AVL/RTI monitoring
The following table provides a summary of RTI analyses for Go Wellington services over 11 months July 11 – May 12. This indicates that approx 94% of services were ‘within specification’ at the start of the route and 76% over all route timing points, using GWRC’s ‘within specification’ definition of one minute early to 10 minutes late.</td><td>Sources: GWRC 2010; GWRC 2009; GWRC 2012</td></tr>
</table>

<table>
<tr><th>Aspect</th><th>Description</th><th>Notes, sources</th></tr>
<tr><td></td><td>
<table>
<tr><th rowspan="2">Timing</th><th colspan="2">% scheduled services</th></tr>
<tr><th>Departure from terminus</th><th>Overall route (timing points)</th></tr>
<tr><td>Early 15+ mins (anomalies)</td><td>0.27%</td><td>0.37%</td></tr>
<tr><td>Early 14.99 mins to 1.00 mins</td><td>4.05%</td><td>19.78%</td></tr>
<tr><td>Early 1 mins to late 9.99 mins (within specification)</td><td>94.12%</td><td>76.32%</td></tr>
<tr><td>Late 10 mins to 19.99 mins</td><td>1.17%</td><td>2.98%</td></tr>
<tr><td>Late 20+ mins (anomalies)</td><td>0.36%</td><td>0.54%</td></tr>
<tr><td>Totals</td><td>100.00%</td><td>100.00%</td></tr>
</table>
</td><td></td></tr>
<tr><td>Operator incentives</td><td>Diesel bus contracts:
• Payments are deducted for all services not operated, and that operated early or >10 mins late, where the fault lies with the operator.
• Some diesel bus contracts include an additional provision for $200 liquidated damages where a missed service goes unreported by the operator, but recorded by GWRC. This reflects the cost of monitoring, investigation and reporting of said trip.
Trolley bus contract:
• Contains similar provisions to the above. Any deductions are also indexed.
• A ‘stable or improving trend over the contract term’ in terms of reliability (calculated) and punctuality (reported) also constitute contract renewal benchmarks.</td><td>Sources: GWRC nd</td></tr>
<tr><td>Causes of poor performance</td><td>These include:
• general traffic congestion, particularly in Wellington city CBD and approaches
• bus congestion, particularly at stops in Wellington CBD (peak periods)
• driver shortages (occasional/periodically)
• unrealistic scheduled running times that do not reflect traffic conditions etc (too long or too short) – see below.</td><td>GWRC advice</td></tr>
<tr><td>Measures taken/ proposed/being considered to improve performance</td><td>• Review/adjustment of scheduled running times based, on RTI data being collected/analysed by Go Wellington (see below).
• Extension of bus priority measures.
• PT Spine Study (current), to provide high-quality PT infrastructure and services through Wellington CBD (medium/long term).</td><td>GWRC advice</td></tr>
<tr><td>Approach to setting running times and layover times</td><td>Running times:
GWRC is adopting a general approach, to be progressively implemented, for ‘standard’ running times to be based on 40%ile running time (ie 40% of trips could operate earlier/faster than this standard, majority would be slower/later, as recorded by RTI). Policy is to be applied to ‘time bands’ having similar running conditions.
To date, GWRC has assessed appropriate ‘standard’ running times on a number of routes. These have to date been implemented on one route (#10) only, with some success as summarised in the following table.</td><td>Go Wellington advice</td></tr>
</table>

<table>
<tr><th>Aspect</th><th>Description</th><th>Notes, sources</th></tr>
<tr><td></td><td>
<table>
<tr><th>Measure</th><th>Inbound (before/after)</th><th>Outbound (before/after)</th></tr>
<tr><td>Mean running time relative to TT (mins)</td><td>-1.39/+1.11</td><td>+4.09/+2.22</td></tr>
<tr><td>Running time spread for 99.7% of services (mins)</td><td>25.2/22.1</td><td>21.4/18.5</td></tr>
<tr><td>% services within contractual limits (-0:59 mins to + 9:59 mins)</td><td>45.9%/70.7%</td><td>87.0%/84.0%</td></tr>
<tr><td>% services within window -0.59 mins to +4.59 mins</td><td>n/a</td><td>51.9%/65.8%</td></tr>
</table>
The methodology on the application of ‘time bands’ to timetables has yet to be finalised: for the route 10 timetable trial, a general application of ‘best fit’ running times was used, along with exceptions for greater running times during peak period.
Layover times:
GWRC is developing a general policy, to be progressively implemented, for a min layover time of three minutes, after allowing for the 95%ile running time (ie exceeded on only 5% of occasions). At this stage, this policy has not been tested in practice (for the route 10 timetable trial, the timetable had to be developed constrained by no changes to the trips start times).
GWRC’s work in formulating and implementing improved approaches to setting running times and layover times is being undertaken in close conjunction with the region’s major operators, particularly NZ Bus. Indeed, NZ Bus has taken the leading role in some aspects of this work (refer section 4.4.4/box 4.2 for details of NZ Bus’ work on these aspects).
</td><td></td></tr>
</table>

Table 3.3 Bus reliability/punctuality standards and achievements – Christchurch

Aspect	Description	Notes, sources
Objectives and policies	*Policy 2.4*: Maintain high standards of reliability and punctuality on all contracted services. *Policy 8.1*: Undertake regular monitoring of operator performance. *Policy 8.2*: Regularly monitor progress towards system targets.	Source: ECan 2012
Standards (actions) and targets	*Policy 2.4*. ECan to include reliability/punctuality requirements in service contracts to ensure the following: Reliability: • At least 99.5% of (scheduled) trips in any day on each service are to be operated in full. • Where necessary, alternative transport is to be provided by the contracted operator to maintain all services, to avoid any passenger being stranded through the unreliability of the service.	Source: ECan 2012 Alternative transport is to be provided, where practicable, within 15 mins of the originally scheduled service, in cases where passengers would otherwise have to wait >15 mins for an alternative service.
	Punctuality • At least 90% of trips in any day on each service shall arrive within	

Aspect	Description	Notes, sources
	3 mins of scheduled arrival times at timetable timing points. • At least 95% of trips in any day on each service shall arrive within 5 mins of scheduled arrival times at timetable timing points. • No trips shall depart a timetable timing point before the scheduled departure time under any circumstances. *Policy 8.1*. ECan requires operators of contracted services to report regularly (monthly/quarterly) on operational performance on reliability and punctuality (against the above standards). Operator performance is to be assessed through a 'balanced scorecard' system (refer below). *Policy 8.2*. ECan to prepare annual reports on system performance, including the following KPIs: • service reliability – % of scheduled trips are operated in full • service punctuality – % of scheduled trips depart on time.	• Appears consistent with reliability standards above. • Not clearly consistent with punctuality standards above.
Monitoring methods	All reliability/punctuality monitoring is based on information derived from the ECan RTI system, operated/managed by Connexionz. RTI data is available, in real time, to ECan and (for their own services) to the operators. ECan is therefore in a position to raise any queries about missed/late trips etc with the operator, either at the time or subsequently. Operators are required to report to ECan on causes of missed/late trips etc on an ongoing basis. Summarising/reporting on key performance statistics and trends is largely undertaken by ECan, with support from Connexionz as required. ECan produces summary performance reports on a monthly basis, to assist in performance monitoring, diagnosis of problem areas, adjustment of running times etc.	Source: ECan – Sam Wilkes discussion (27 Aug 2012).
Actual performance	Reliability: Over period Oct 11 – June 12, 96% of scheduled services were recorded as operating, through the RTI system. The remaining 4% were either not operated or were operated but not recorded through the RTI system. Hence the level of 'not operated' trips will be somewhat less than 4% (further information not readily available). Punctuality: Preliminary information for period Nov 11 – June 12 (weekdays) indicates that: • on average, over all routes, bus departure times from timing points were 3.6 mins late • these averages varied by route between 1.4 mins and 5.6 mins. • these averages were greater in the peak periods (0800–0900 4.2 mins, 1700–1800 5.3 mins) than off-peak.	Source: ECan – Sam Wilkes (email 27 Aug 2012).
Operator incentives	'Balanced scorecard' system of operator incentives applies to all contracts let since Nov 2009. This involves quarterly bonus/penalty adjustments of operator contract payments, reflecting the extent to which their 'weighted sum' performance is above/below the defined standards. System includes i) late running (>5 mins) from terminus or intermediate timing point; ii) breakdown rate in service. Together these account for 14% of total scorecard weightings.	Source: ECan 2010.

Aspect	Description	Notes, sources
	For late running, targets (thresholds) are set by route, specified in terms of % change from route performance in previous 12 months. Non-compliance penalties may be levied in the event of: • missed trip (whole or part) $300 • missed connection $300 • early running $200. These penalties apply in cases of operator reporting: if not reported by the operator, penalties are multiplied by factor 10.	
Causes of poor performance	N/A	
Measures taken/ proposed/being considered to improve performance	N/A	
Approach to setting running times and layover times	**Running times:** • Process involves judgemental assessment based on AVL/RTI data reports over extended (6–12 months) period. • Constant running times are generally set for specified service periods, usually of at least one hour duration (but some flexibility, particularly in peaks). • Service periods are generally: – weekday <0700, 0700–0900, 0900–1430, 1430–1800, >1800 – weekend: <1000 (same as weekday < 0700), 1000–1700, >1700 (same as weekday >1800). **Layover times:** • Minimum layover times specified in contracts. • Generally: – 5 mins for running time <30 mins – 7 mins for running time 30–60 mins – 10 mins for running time >60 mins.	Source: ECan - Sam Wilkes (discussion 27 Aug 2012).

3.3 Monitoring methods and performance

3.3.1 Auckland – historic/current methods

Reliability and punctuality monitoring in Auckland has hitherto (and currently) been largely based on operator self-reporting to AT, on a monthly basis, based on depot/driver logs. Very limited checking/auditing has been undertaken by AT of the operator reports.

AT reports service reliability and punctuality performance, by operator, in its monthly statistics report. Table 3.4 summarises typical performance at the aggregate level based on recent months' statistics, and shows the current AT standards/targets for comparison. We note that, based on these performance statistics:

- The reliability standard is generally not achieved.
- The late running standard is exceeded on average and by a considerable margin.

- AT statistics report does not report performance against the early running standard (it would seem most unlikely that this is achieved in all cases – see below).

Table 3.4 Auckland current reliability/punctuality standards and recent performance (operator self-reporting)

Aspect	Standard[a]	Recent performance[b]	Notes
Reliability	• 99.9% of all scheduled trips to operate and reach their destination	• 99.4% to 99.9%	
Punctuality			
• Early running	• No services to operate early	• n/a	Not included in Auckland Transport 2012b
• Late running	• 95% of services to start their trip within 5 mins of scheduled start time and reach their destination	• 99.2% to 99.7%	

[a] Definitions as used in Auckland Transport 2012b.
[b] Based on reported performance over 12 months to July 2012.

3.3.2 Auckland – methods under development

Recently, following the introduction of real-time information systems (RAPID) and electronic ticketing systems (to date, principally NZ Bus' Snapper system), AT has been in a position to obtain comprehensive reliability/punctuality data from these systems. Based on this data, AT is currently developing analysis methods to report on reliability and punctuality for all scheduled services[9] (at the start of the trip) – which will provide much more comprehensive and reliable statistics than were possible under its operator self-reporting approach.

For this research project, AT provided comprehensive statistics from its data base on reliability and punctuality for the period January – August 2012. These are summarised in table 3.5 and re-presented in table 3.6 in a more readily interpretable form.

The following comments should be made on the basis for these statistics:

- The AT analyses start from the total number of scheduled bus trips in the analysis period (about 200,000/month).
- From these are subtracted 'non-trusted' trips (ie those for which AT considers the data unreliable or incomplete). These currently account for c.25% of total trips[10].
- For the remaining ('trusted') trips, AT then analyses the number of these which were reported in either the RAPID system or the ETM systems (principally Snapper). Approximately 7.5% of all 'trusted' trips were not recorded in this way. At present, it is not possible to divide these between i) trips that did not operate; and ii) trips that did operate but were not recorded through any of the RTI/ ETM systems. Hence estimates of 'unreliability' (eg % of all scheduled trips that were not operated) cannot be made.
- For the remaining (approx 92.5%) of 'trusted' trips that were recorded, their punctuality performance at the start of the trip is then categorised as shown in tables 3.5 and 3.6. Note that the figures

[9] Includes contracted and commercial services.

[10] A large proportion of these 'non-trusted' trips are those starting in specific locations in the CBD, where it appears that the RTI monitoring is affected by interference from traffic signals and/or tall buildings.

represent the proportions of all trips that were recorded through the RTI/ETM systems, ie in effect the proportions of all trips that were known to have operated.

Table 3.5 Auckland bus service punctuality performance statistics (January – August 2012) – indicative only[(a)]

Reference[(b)]	Measure	Definition	% of trips operated	Notes
Punctuality at start of trip[(c)]				
1 J/G(7)	Early trips	% scheduled trips > 1:00 mins early	6.3%	
2 K/G(8)	Late trips	% scheduled trips > 5:00 mins late	8.7%	
3 I/G(6)	'On-time' trips	% scheduled trips within window 1:00 mins early to 5:00 mins late	85.0%	100.0% less item (1) less item (2). PTOM KPI 3
4 L/G(5)	'Missed' trips	% scheduled trips outside window 1:00 mins early to 10:00 mins late	9.1%	
5	'Very late' trips	% scheduled trips > 10:00 mins late	2.8%	Item (4) less item (1)

(a) Data provided by AT (operator and network performance report) – indicative only.

(b) Reference A/B (n) etc represents: A/B – ratios used in AT operator and network performance report; n – chart numbers in AT operator and network performance report.

(c) All punctuality statistics are based on the proportions of all trips sighted in RAPID at the start of trip.

Table 3.6 Summary of Auckland bus service punctuality performance (January – August 2012) indicative only[(a)]

Item	% of operated trips[(b)]
All operated trips	100.0
'Missed' >10 mins late	2.8
'Missed' > 1 min early	6.3
Within window 1 min early – 10 mins late	90.9
5–10 mins late	5.9
Within window 1 min early – 5 mins late	85.0

(a) Data provided by AT – indicative only (punctuality data under review).

(b) Based on all trips sighted in AT RAPID system at start of trip.

Comparing the table 3.5/3.6 results with AT's own standards and with operator self-reporting figures (table 3.4), the following might be noted:

- Punctuality – early running. The > one minute early proportion of 6.3% (at start of trip) may be compared with the AT standard of no trips to operate early.
- Punctuality – late running. The >five minutes late proportion of 8.7% (at start of trip) may be compared with the AT standard of 5% and the self-reported estimates of 0.3% to 0.8%.

It is not possible at this stage to draw any conclusions on service reliability (% of services operated) from the RTI/ETM data available.

While AT is continuing with work (in conjunction with the operators) to refine its analyses of RTI and ETM data, there would seem little doubt that the estimates given in tables 3.5, 3.6 are more accurate than those provided through the operator self-reporting approach[11]. However, significant further work will be

[11] Controlled tests undertaken by AT indicated that in 'normal' circumstances (ie excluding 'non-trusted' data not included in the statistics), the RTI system time recordings are accurate to within 15 seconds of the true time.

required (and is ongoing) before the RTI/ETM data can be used with confidence to provide accurate reporting of punctuality (and reliability) performance.

3.3.3 Wellington – historic/current methods

Similar to the situation in Auckland (section 3.3.1), reliability and punctuality monitoring in Wellington has hitherto (and currently) been largely based on operator self-reporting to GWRC. GWRC also carries out checks/audits of operator information through its quality monitoring programme (refer table 3.2).

Monitoring results are incorporated into a monthly network performance report (for each operator). Unlike in Auckland, these results are not currently published.

3.3.4 Wellington –methods under development

Again, similar to the Auckland situation, following the implementation of RTI on buses (now operating on the great majority of bus services in the region),GWRC is currently (in conjunction with its operators) working towards analysing reliability and punctuality performance based on RTI system data. Performance statistics provided by GWRC for this research project are summarised in table 3.7.

Comparing these results with GWRC's own standards (eg as in the trolley bus contract), the following might be noted:

- **Reliability – % of scheduled trips operated.** Based on the GWRC standard definition (refer table 3.2), approximately 5.2% of services either did not operate or started the trip outside the window between one minute early and 10 minutes late. GWRC's standard for this is 1% of scheduled trips (in the trolley bus contract), and the earlier operator self-reporting statistics are broadly consistent with this standard figure (refer table 3.2).
- **Punctuality – late running.** Conversely, some 94.1% of services started their trip within the allowed window, compared with the GWRC standard of 98.0% (for the trolley bus contract); while 76.3% were within the window when averaged over timing points along the route. By contrast, the available operator self-reporting statistics state that 99.9% of all bus services operated 'on-time' (on the GWRC definition) in 2008/09 (table 3.2).

The deterioration of punctuality performance at intermediate timing points, relative to at the start of the trips, is also evident in table 3.7: the proportion of trips operating within their allowed time window falls from 94.1% at the start of the trip to an average of 76.3% at on-route timing points.

Table 3.7 Summary of Wellington bus service reliability performance (July 11 – May 12) – Go Wellington services based on RTI data – figures approximate only[(a)]

Timing	% scheduled services	
	Departure from terminus	**Overall route (timing points)**
Early 15:00+ mins (anomalies)	0.27%	0.37%
Early 14:59 mins to 1:00 mins	4.05%	19.78%
Early 1:00 mins to late 9:59 mins (within specification)	94.12%	76.32%
Late 10:00 mins to 19:59 mins	1.17%	2.98%
Late 20:00+ mins (anomalies)	0.36%	0.54%
Totals	**100.00%**	**100.00%**

[(a)] Advice from GWRC is that the RTI system timings are highly accurate (with errors of <15 secs) and that no particular difficulties (eg interference) have been encountered.

3.3.5 Christchurch

For some years now, Christchurch has had an RTI system, owned by ECan and operated/managed on its behalf by Connexionz. This RTI system is used as the primary basis of reliability and punctuality performance monitoring: the operators are required to report to ECan on causes of any missed or early/late trips (as incentives/penalties relate only to trips where the operator is at fault).

Summarising/reporting on key performance statistics and trends is largely undertaken by ECan, with support from Connexionz as required. ECan produces summary performance reports on a monthly basis, to assist in performance monitoring, diagnosis of problem areas, adjustment of running times, etc.

For this research project, ECan provided reliability and punctuality data from its RTI records for:

- all CHC route services (in aggregate)
- period 1 Nov 11 to 31 Aug 12
- weekday school term days only
- split between AM peak, PM peak and remainder of weekday periods
  - variation between actual and scheduled departure time from i) start of route, and ii) intermediate timing points (excluding route end point), categorised to the nearest (integer) minute.

The summary analyses of this data are given in:

- figure 3.1: on-time performance (actual – scheduled differences, in minutes) at start of route and intermediate timing points, for three periods of the day
- figure 3.2: on-time performance summary by time window relevant to ECan standards, ie:
  - 5.30+ mins late ('late')
  - 3.30 to 5.30 mins late ('on time')
  - 0.30 to 3.30 mins late ('on time')
  - 0.30 mins early to 0.30 mins late ('on time')
  - 0.30+ mins early ('early').

Points of note from these summaries include:

- The proportion of trips operating 'early' is low, about 1.5% at the start of the trip, 2.7% from subsequent timing points. These figures are similar in the two peak periods and off-peak. The ECan target is that no trips should depart early from any timing point.
- The proportion of trips operating 'late' (>5 mins) is about 7.6% at the start of the trip: this overall figure comprises 6.4% of AM peak trips, 5.7% of off-peak trips and 11.9% of PM peak trips. The proportions are much higher at intermediate timing points – 29.4% in AM peak, 19.8% in off-peak and 36.2% in PM peak (overall 26.4%). The ECan standard is that no more than 5% of trips should arrive at any timing point more than five minutes behind schedule.

Figure 3.1 Christchurch bus on-time performance statistics

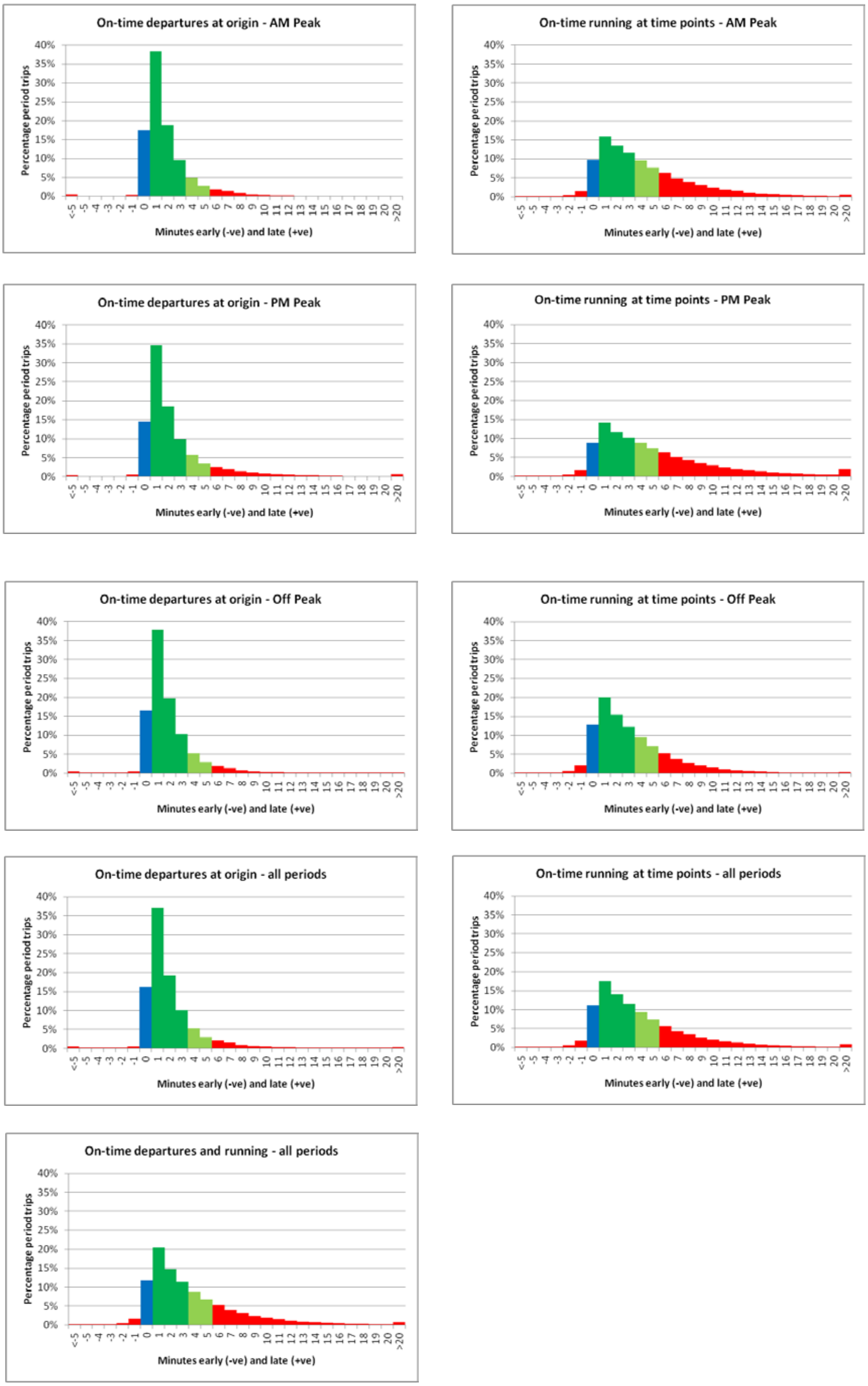
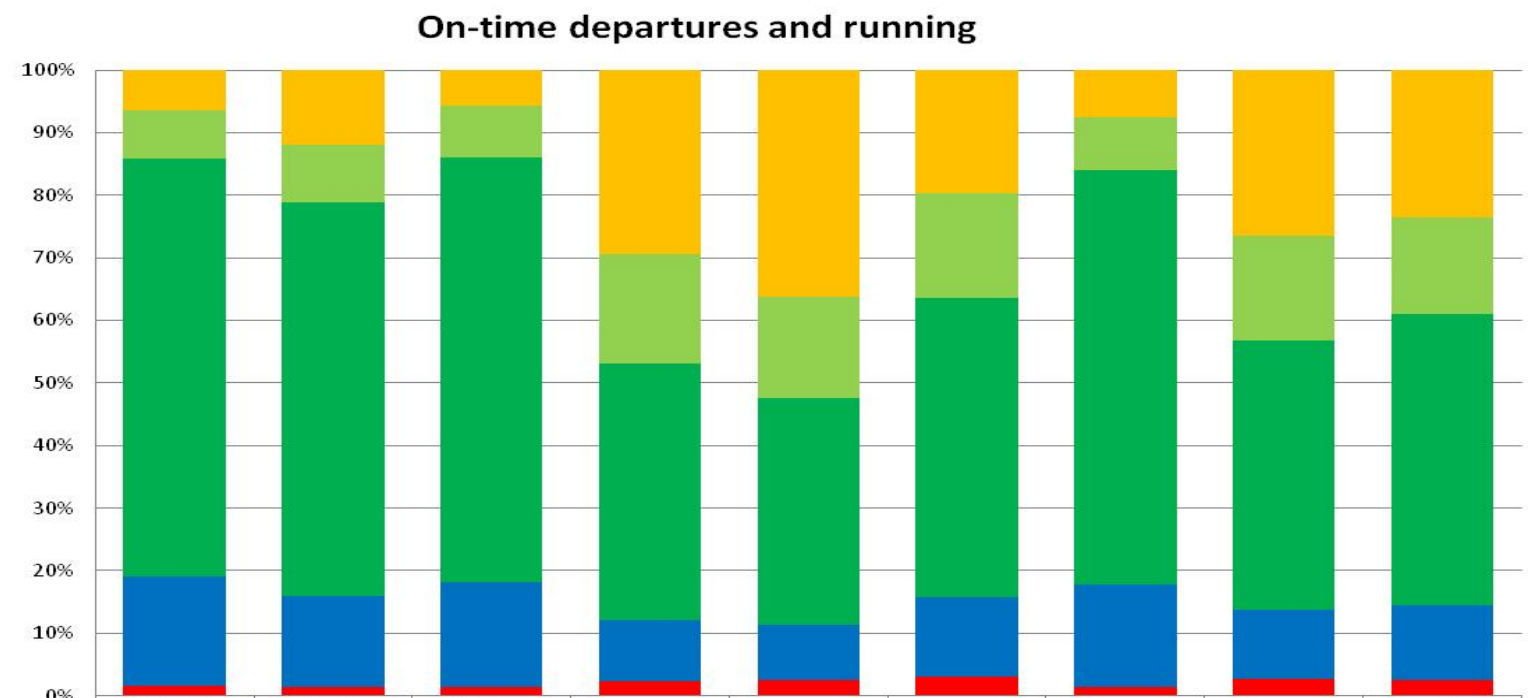


Figure 3.2 Christchurch bus 'on-time', 'late' and 'early' summary statistics



	AM origin points	PM origin points	OP origin points	AM time points	PM time points	OP time points	All origin points	All time points	All origin and time points
Late (>5 mins)	6.42%	11.92%	5.74%	29.41%	36.15%	19.75%	7.57%	26.44%	23.59%
On time (4-5 mins)	7.72%	9.18%	8.14%	17.46%	16.34%	16.67%	8.33%	16.74%	15.47%
On time (1-3 mins)	66.79%	63.00%	67.97%	40.97%	36.16%	47.74%	66.37%	43.03%	46.55%
On time	17.49%	14.48%	16.66%	9.80%	8.86%	12.84%	16.24%	11.07%	11.85%
Early (<0 mins)	1.59%	1.43%	1.49%	2.36%	2.49%	3.00%	1.49%	2.72%	2.54%

3.3.6 Some comparative performance statistics

Drawing on the AVL/RTI punctuality statistics presented for the three centres (tables 3.5/3.6, table 3.7, figure 3.2), table 3.8 attempts some summary comparisons of punctuality performance across the centres. Given that the data collection/analysis systems in Auckland and Wellington are still in a state of development, considerable caution is needed in interpreting these results and they should be treated as indicative only[12]. Also, it should be noted that there are some detailed definitional differences between the categorisations in each centre (eg the Christchurch categories refer to 0.5 minute variations from the scheduled times, whereas the other centres are based on integer minutes).

Table 3.8 Comparative summary of punctuality performance[(a)]

Category	Definition	Auckland	Wellington		Christchurch	
		Start trip	**Start trip**	**Timing points**	**Start trip**	**Timing points**
'Early'	Early >1.00 mins	6.3%	4.1%	19.8%	1.5%	2.7%
'Late'	Late > 10.00 mins	2.8%	1.2%	3.0%		
	Late 5.00–10.00 mins	5.9%	n/a	n/a		
	Late > 5.00 mins total	8.7%			7.6%	26.4%
'On-time'	Window 1.00 min early to 5.00 mins late	85.0%			90.9%	70.9%
	Window 1.00 min early to 10.00 mins late		94.1%	76.3%		

[(a)] All figures represent the proportions of total trips operated.

3.4 Customer attitudes and perceptions

3.4.1 Overview

Surveys of user attitudes and perceptions can be an important source of information on the more qualitative aspects of performance of PT services, particularly those aspects of performance that are not amenable to 'objective' measurement or quantification. They have both advantages and disadvantages in this regard:

- Their main disadvantage is that they do not necessarily correlate very well with more 'objective' measures. In particular, they are likely to be unduly influenced by what people are used to, by recent service aberrations and also by recent external factors (the state of the weather, whether New Zealand has just won or lost the Rugby World Cup, etc). If users are accustomed to a high standard of service but then it deteriorates, they are likely to give it a lower rating than exactly the same service where this shows a recent improvement over previous standards.
- However, their advantage is that they do reflect the actual attitudes of users (and potential users) of services, and it is these attitudes that are a major factor in people's decisions whether or not (and how often) to use the services.

[12] Some investigations and enquiries undertaken recently, prompted by this project, suggested that the RTI data being collected is generally accurate (to within 30 seconds or better), with the exception of limited locations in Auckland city, where the observations appear to be affected by interference problems (from traffic signals, high buildings, etc.

Such perceptions of service quality may be based on either direct surveys of users themselves or 'mystery shopper' surveys by market researchers. Again, there are advantages and disadvantages of both approaches: mystery shoppers are likely to provide more consistent results over time, but their ratings may be subject to bias to the extent that they may not be truly representative of the range of users.

In the context of the current research, a major difficulty in using attitude surveys (whether by users or mystery shoppers) of service reliability aspects is the difficulty of obtaining comparable evidence (identical questions, identical rating scales, identical sampling methods, etc) from such surveys from different cities, and often even for the same city over different years.

Since the early 2000s, regional organisations receiving central government funding for PT services have been required to supply use satisfaction data to the NZTA as part of its monitoring requirements. In recent years, user ratings on nine attributes of PT services and one question about the main reason for using PT have been required for the NZTA's reporting system (formerly LTP online, recently replaced by Transport Investment Online). One of the attributes subject to rating was service reliability, with the question specified by NZTA being 'Are the arrivals and departures of services on time (punctual)?' [13]

While the NZTA's objectives behind its requirements for user satisfaction information are not well articulated, it can be surmised that a major interest is in obtaining user satisfaction ratings that are consistent between regions (and over time), and so can be combined into national values (eg for use in the NZTA's annual report). However, a recent review for the NZTA of the PT customer satisfaction surveys carried out periodically in all regions (in part to meet NZTA requirements) has concluded that they are not effective (or efficient) in providing consistent rating results between regions (Martin Jenkins 2011). Thus any attempt to draw conclusions from the surveys to date on the relative perceived reliability performance of bus services in the different regions is liable to be misleading.

In the light of this conclusion, we do not attempt here any inter-regional comparisons of perceptions of bus service reliability. Rather, in the following sub-section, we present a summary of evidence from Wellington (as a sample case study) on the perceived importance of bus service reliability to actual/ potential users and on the perceived performance of services against this attribute.

3.4.2 Wellington reliability attitudes and perceptions evidence

3.4.2.1 Performance (satisfaction) with bus service reliability

GWRC's recent annual survey of satisfaction with PT services in the region covered 750 households, through a combination of telephone (90%) and online (10%) survey methods (Premium Research 2012).

The survey included a series of questions on 'How do you rate the bus services in Wellington region in terms of these aspects (using a scale 1 to 5 where 1 is poor and 5 is excellent)'. The question was asked in relation to 'the reliability of the bus service' and 16 other attributes, as well as an overall rating of the services.

The most relevant results were:

- the overall service rating (in terms of the proportion of respondents who were satisfied) was 65%
- the service reliability rating was 53%
- this rating was the 10th highest out of the 17 aspects

[13] The question posed in the regional surveys was often worded differently from this.

- comparing the equivalent surveys over the last four years (2009–2012), the reliability rating has declined somewhat, although it is unclear whether this decline is statistically significant.

3.4.2.2 Relative importance of specific travel attributes

An earlier random survey of 800 residents and 100 businesses in the Wellington region asked them to rate the importance of a number of specific journey attributes/considerations in influencing their choice of travel mode. The results are set out in table 3.8.

Table 3.8 Relative importance of specific travel attributes (Wellington)

Consideration	% of respondents					
	Very important	Quite important	Neither important nor unimportant	Not very important	Not at all important	Total
Residential sample (800)						
Reliability of journey time	56	34	7	2	1	100
Convenience	53	33	6	6	2	100
Safety	56	27	10	3	4	100
Total journey time	36	37	13	7	7	100
Health benefits from physical activity	43	24	14	11	8	100
Air quality	33	25	22	12	8	100
Environmental impacts	17	38	23	12	10	100
Cost of the trip	17	32	17	20	14	100
Business sample (100)						
Safety	61	33	1	5	-	100
Reliability of journey time	64	27	6	3	-	100
Convenience	57	28	12	3	-	100
Total journey time	40	27	12	9	12	100
Cost of the trip	24	25	12	13	26	100
Health benefits from physical activity	23	14	13	11	39	100
Environmental impacts	21	15	34	3	27	100
Air quality	18	18	22	6	36	100

Source: GWRC 2007b.

It is seen that 'reliability of journey time' was rated as the most important attribute in the residential survey (90% rating it as 'very important' or 'quite important'), and as second most important, after safety, in the business survey (91% rating it as 'very important, or 'quite important').

3.4.2.3 Ratings of bus service attributes – importance and performance

A random survey of regional residents who had used Wellington's bus services in the previous three months asked their views on 26 service-related attributes (GWRC 2007a):

- their importance rating of each attribute in encouraging their bus use
- their rating of bus service performance against each attribute.

These performance and importance ratings are compared in table 3.9 and the comparisons are shown graphically in figure 3.3. Relevant features of these results include the following:

The four most important attributes (rating 4.2 or better) are:

- reliability of services (eg not breaking down)

- frequency of services
- buses arrive/leave on time (ie punctuality)
- feeling safe on the bus.

It is seen that two of these attributes relate to reliability/punctuality.

As highlighted in table 3.9, large (negative) disparities between importance and performance occur for six attributes: all these attributes are rated as relatively important, but have performance significantly below average. For these six attributes, it is notable that:

- two of these attributes (which rank among the highest in importance) relate to service reliability
- one relates to service frequency
- three relate to responses to service perturbations, in terms of providing additional services in cases of overcrowding and in terms of providing real-time information on delays.

3.4.2.4 Some conclusions in the Wellington context

This review of the Wellington market research evidence highlights that, if overall customer satisfaction and patronage of bus services are to be improved, one of the highest priority areas (if not **the** highest priority) needing to be addressed is the (un)reliability of bus services[14].

This indicates the need for:

- ongoing data collection and analyses to identify the extent and causes of unreliability and to develop and implement remedial actions (eg running time adjustments)
- developing a consensus view among key players (operators, regional authorities, local authorities) about the importance of tackling (un)reliability, accompanied by a partnership approach to develop and implement measures to address the situation
- ensuring reliability standards are included in contracts, and that these are accompanied by an appropriate incentive/penalty system
- improving the monitoring of reliability, by GWRC and/or the bus operators (with suitable auditing): this will be possible given the technology developments which have been largely implemented recently (eg the RTI system in Wellington)
- publishing reliability performance data (once the monitoring systems/procedures are adequate)
- enforcing appropriate incentives/penalties (once the monitoring systems are adequate)
- ensuring past reliability performance is taken into account in the evaluation of any future tenders (or contract extensions).

[14] This conclusion is supported by data on complaints to the Metlink service centre: for the Wellington city services; rather more than half of all complaints over the period July 11 – May 12 were related to service reliability deficiencies (advice from GWRC). It also has some support from recent work undertaken for the NZTA (Kennedy 2013) that commented in relation to NZ Bus rescheduling of the Go Wellington services in February 2007 that 'There is some evidence that a combination of all these factors had a (temporary) negative impact on patronage over a six-month period, but that patronage recovered soon after that'. However, the evidence is somewhat conflicting on these impacts (refer also section 2.5.4).

Table 3.9 Factors encouraging bus use that significantly under-perform relative to their importance[a]

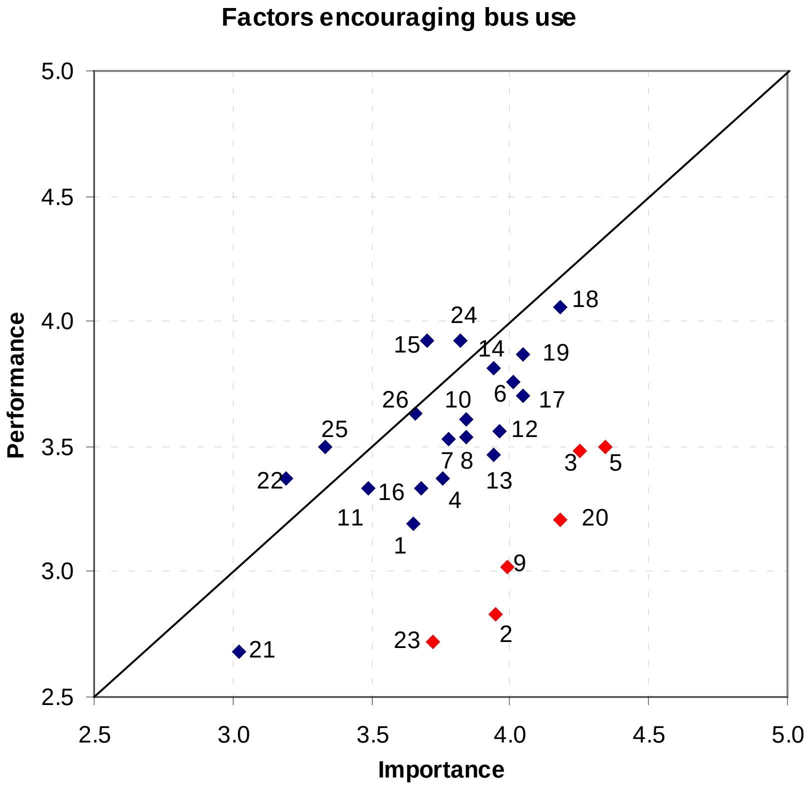
	Importance[b]	Performance[c]	Importance less performance
Q2. Having real time electronic information at bus stops/stations to tell you exactly when your next bus/train is due	4.0	2.8	1.1
Q9. That extra services are put on quickly when buses are crowded	4.0	3.0	1.0
Q20. That buses arrive and leave on time	4.2	3.2	1.0
Q23. That it's easy to get information about delays	3.7	2.7	1.0
Q3. The frequency of the bus service	4.3	3.5	0.8
Q5. The reliability of the bus service (eg not breaking down)	4.3	3.5	0.8
Q1. Having the same ticket for all modes of public transport (buses, trains, ferries, cable car)	3.7	3.2	0.5
Q13. The friendliness and helpfulness of the bus driver	3.9	3.5	0.5
Q4. Having bus services connect with trains	3.8	3.4	0.4
Q12. The ease of accessing timetable information	4.0	3.6	0.4
Q16. That buses get priority over other traffic	3.7	3.3	0.4
Q17. Having bus shelters	4.1	3.7	0.4
Q6. The service goes directly where I want	4.0	3.8	0.3
Q7. The speed of the bus journey times	3.8	3.5	0.3
Q8. How much bus fares cost	3.8	3.5	0.3
Q21.That there are email updates about changes to bus services	3.0	2.7	0.3
Q10. How clean the bus is inside	3.8	3.6	0.2
Q11. That seats are always available	3.5	3.3	0.2
Q19. That bus information is simple and easy to use	4.1	3.9	0.2
Q14. Feeling safe at the bus stop	3.9	3.8	0.1
Q18. Feeling safe on the bus	4.2	4.1	0.1
Q26. The behaviour of other patrons on the bus	3.7	3.6	0.0
Q24. The ease of buying a ticket	3.8	3.9	-0.1
Q15. The ease of access getting on and off the bus	3.7	3.9	-0.2
Q22. How modern the buses are	3.2	3.4	-0.2
Q25. The temperature inside bus	3.3	3.5	-0.2

[a] Relates to respondents (351) who had used bus services in the region in the last three months.

[b] Question asked was 'How important are each of the following factors in encouraging you to use the bus (to use it more or start using it)? Rating scale was Extremely important/Very important/Important/Less Important/Not important at all. Mean rating is the weighted average of all responses, with Extremely important = 5, Not important at all = 1.

[c] Question asked was 'How would you rate using the buses in Wellington in terms of these aspects? Rating scale was Excellent/Very Good/Good/Fair/Poor. Mean rating is the weighted average of all responses, with Excellent = 5, Poor = 1.

Figure 3.3 Specific bus service attributes – performance vs importance ratings



3.5 National (NZTA) reliability monitoring developments

3.5.1 Overview

This section reports on policies and procedures relating to bus service reliability performance (including standards, incentives and monitoring) at a national level, through the NZTA. It covers in turn:

- current NZTA monitoring/reporting requirements
- proposed NZTA monitoring/reporting requirements
- some comments on these aspects.

3.5.2 NZTA performance monitoring/reporting requirements - current

The NZTA currently specifies a number of KPIs that are to 'form the basis of mandatory performance monitoring agreements between approved organisations (typically regional councils) and suppliers of PT services (operators)'. It specifies that 'approved organisations must monitor and record contract performance against (these KPIs)' (NZTA 2009).

The specified service reliability and punctuality attributes and KPIs are set out in table 3.10. The NZTA notes that these KPIs are to be based on data that i) *is available and reliable;* and ii) *can be collected efficiently.*

At the time of preparing this report, the NZTA advised that decisions had not yet been taken on:

- the frequency of reporting required from approved organisations (AOs) (annually or quarterly)
- the reporting unit (region, each main centre within the region, or more detailed, eg by mode).

However, it is clear that, in order to meet the final requirements, the AOs will need to collect data (either directly or from operators) on an ongoing basis, at minimum at an operator/contract level.

Table 3.10 Current NZTA monitoring requirements – service reliability and punctuality

Performance attribute	Key performance indicator
1 Service reliability (scheduled trips completed in full).	Percentage of scheduled trips operated in full. (A trip leaving the origin stop >0.59 mins early or >9.59 mins late is deemed not to have operated.)
2 Service punctuality: a trip start b en route and at destination	a Percentage of scheduled trips leaving origin stop between 0.59 mins before and 4.59 mins after the scheduled departure time. b Percentage of scheduled trips between 0.59 mins before and 4.59 mins after the scheduled departure time at the selected points.

Source: NZTA 2009.

Related to the above requirements, the NZTA requires approved organisations to submit an annual achievement (statistics) report on its PT activities and outputs. For bus services, this is to include reporting on policies on service reliability, where these cover:

- service cancellations
- arrival/departure times when compared with schedules.

Hitherto, the NZTA procedures have not required regional authorities to report on service reliability performance, only to report on their policies relating to reliability.

In addition to the above, the NZTA specifies a question on service reliability for inclusion in the annual customer satisfaction surveys carried out by the regional authorities. However, several difficulties have been identified with these surveys, as discussed below (section 3.5.3).

3.5.3 NZTA performance monitoring/reporting requirements - proposed

The NZTA has recently released its proposed regime for monitoring PT service provision, and is currently seeking feedback on this (NZTA 2012).

The document states that performance data will be required under five performance categories:

- contract monitoring (contestability, competitiveness, conformance, value for money)
- service delivery (by mode)
- fleet characteristics (by mode)
- network and service configuration
- customer satisfaction.

Under the service delivery category, the document specifies that performance on bus service reliability aspect is to be monitored against the 'core' KPIs listed in table 3.11: we note that these are essentially unchanged from the NZTA's current monitoring requirements (as in table 3.10).

Table 3.11 NZTA proposed performance monitoring regime – bus service reliability and punctuality[(a)(b)]

Key performance measure	Specification (all disaggregated peak vs off-peak)
Reliability	
A1 Cancelled/operated part only	• % of scheduled services that were cancelled or not operated in full.
A2 Operated, but outside time window	• % of scheduled services leaving the origin stop outside the time window 0.59 mins early to 4.59 mins late.
Punctuality – start trip	
B1 Operated within time window	• % of scheduled services leaving the origin stop within the time window 0.59 mins early to 4.59 mins late.
Punctuality – en route	
C.1 Operated within time window	• % of scheduled service trips within the time window 0.59 mins early to 4.59 mins late at selected intermediate (timing) points.

Source: NZTA 2012.

(a) Discussion document only – not yet policy. Understood that setting of standards (thresholds) and any operator incentives are to be specified by each RA.

(b) Monitoring is proposed to be on a monthly basis.

The document states that monitoring information is to be collected/reported:

- on a monthly basis (this constitutes a major change from previous practice, which has involved quarterly and/or annual reporting)
- by PTOM units (but excluding 'exempt' services)[15]
- disaggregated between peak and off-peak periods (no definitions given at this stage, unclear how weekends are to be treated).

The NZTA proposes to require regional authorities etc to collect this information on a monthly basis, and to provide it to the NZTA on a quarterly basis. The document states that:

> *Monthly reporting is standard business practice, and ideally both regional authorities and the NZTA should be reviewing key service performance data and indicators on a monthly basis. The NZTA will monitor a similar core set of data, but with a view to inter-regional and national trends rather than an operational focus.*

Under the customer satisfaction category, the document sets out questions that are to be covered in PT customer satisfaction surveys to be undertaken by each regional authority, on an annual basis for the larger regions, probably less frequently (maybe three-yearly) for other regions. The surveys are to include two questions relevant to reliability, ie customer satisfaction regarding:

- the service being on time (keeping to the timetable) – for the surveyed trip
- information provided about service delays/disruptions – from experience over the last three months.

[15] Under PTOM exempt services are ones that do not form part of a region's urban PT network, and do not have exclusive operating rights.

In addition, authorities will be required to report on i) number of complaints received; and ii) percentage of complaints responded to within 10 working days, in both cases disaggregated by service attributes (reliability, comfort, etc).

The target timetable set for the implementation of the new monitoring regime is as follows:

- FY 12/13 – introduction of new regime (starting with larger regions)
- 1 July 2013 – all regions to establish core data baselines
- FY 15/16 – fully-functional monthly reporting regime for all regions.

3.5.4 Some comments

Based on the material available to us (as outlined in the earlier parts of this section), we provide the following brief comments on NZTA proposals to introduce an enhanced performance monitoring and incentive regime relating to bus services throughout New Zealand (some of these comments are relevant to PT performance monitoring more widely).

The NZTA document suggests that the NZTA is to be provided with (or have access to) reliability and other monitoring data from each region on a monthly basis (by unit and peak/off-peak), 'with a view to inter-regional and national trends rather than an operational focus'. We would have some reservations whether this level of 'routine' monitoring at a national level is necessary, or at least is premature:

- To date, the NZTA has not monitored bus reliability at all (even on an annual basis).
- A number of regions are still some way from being able to provide reliability data on an accurate and consistent basis within the region, never mind consistently between regions.
- Our past experience is that the NZTA has hitherto not made full use of the data it has collected from the regions (eg on patronage, service levels, etc): often the data has not been adequately checked/audited, so as to provide confidence of consistency within a region (year-to-year) or between regions. Hence any detailed cross-sectional or trend analyses may not be based on sound foundations.
- Even assuming all (or all major) regions are able to provide good-quality reliability data on a monthly basis, we suggest this would be of limited use to the NZTA for monitoring 'inter-regional and national trends'. It is highly likely that any month-by-month performance variations would reflect seasonal factors, equipment problems, analysis issues etc rather than significant medium-term trends.

Rather than attempting regular monthly monitoring in the short-term, we suggest that the NZTA's PT monitoring resources would be better deployed by focusing on improving the accuracy and consistency of the data that it does obtain, say on an annual basis, and then use this data to analyse medium-term trends between regions and over time.

4 Unreliability causes and approaches to address

4.1 Overview

This chapter addresses evidence on the causes of unreliability in urban bus services and approaches to addressing these causes and hence providing more reliable services.

As a prelude to this appraisal, it is important to distinguish three different concepts which are sometimes used under the heading of 'reliability':

A **Reliability** (including punctuality) of the services as compared against the published timetable (refer section 2.1).

B **Variability** of bus running times, on a day-to-day, trip-to-trip basis. This variability may be only one component of unreliability, as defined here. For instance, a particular trip (or trips) may operate three minutes late on every occasion, because the timetabled running time is three minutes too low. The trip is thus unreliable from the passenger perspective, relative to the timetable, even though it may operate with the same timings every day.

C **'Delay'** to the service, for whatever reasons, relative to some idealised ('free-flow') state. The delays may result from traffic congestion, waiting at traffic signals, time to open/close doors, passengers boarding/alighting etc.

The primary focus in this project (including this chapter) is not on delays as such, but on the variability of delays. But it is also concerned with components of reliability other than the variability of delays (or running times): the main component in this category will be where scheduled running times differ significantly from realistic running times.

4.2 Factors contributing to bus service (un)reliability

4.2.1 Contributing factors – international literature

Various international publications provide listings of factors contributing to urban bus service unreliability, but with somewhat differing emphases. The relevant USA Transportation Research Board publication Kittelson & Associates et al (2003a) states that the following factors influence the reliability of transit services:

- traffic conditions (for on-street, mixed traffic operations), including traffic congestion, traffic signal delays, parking manoeuvres, incidents, etc
- road construction and track maintenance, which create delays and may force a detour from the normal route
- vehicle and maintenance quality, which influence the probability that a vehicle will break down while in service
- vehicle and staff availability, reflecting whether there are sufficient vehicles available to operate the scheduled trips (some vehicles will be undergoing maintenance and others may be out of service for various reasons) and whether sufficient staff are available on a given day to operate those vehicles.

- transit preferential treatments, such as exclusive bus lanes or conditional traffic signal priority that operates only when a bus is behind schedule, that at least partially offset traffic effects on transit operations
- schedule achievability, reflecting whether the route can be operated under usual traffic conditions and passenger loads, with sufficient running time provided for operations, and sufficient recovery time to allow most trips to depart on time even when they arrive at the end of the route late
- evenness of passenger demand, both between successive vehicles and from day to day for a given vehicle and run
- differences in operator driving skills, route familiarity, and adherence to the schedule – particularly in terms of early running
- wheelchair lift and ramp usage, including the frequency of deployment and the amount of time required to secure wheelchairs
- route length and the number of stops, which increase a vehicle's exposure to events that may delay it – delays occurring earlier along a route result in longer overall trip times than similar delays occurring later along a route
- operations control strategies used to react to reliability problems as they develop, thus minimising the impact of the problems.

Ceder (2007) provides a longer list of indicators that are likely to be symptomatic of or contribute to unreliability problems, including factors relating to service design. This list is set out in table 4.1. The primary (but not sole) focus of this report is on the problems listed under the 'operational indicators' heading. Ceder notes the benefits of treating the various indicators as a regular check-list to be addressed, so as to help to pre-empt potential unreliability problems arising, thus reducing the need for subsequent detailed diagnoses and remedial actions to enhance reliability.

4.2.2 Causes of unreliability – some empirical evidence

TAS undertook a study (TAS 2005) on behalf of the Greater Manchester Passenger Transport Executive (GMPTE) which included in-depth analyses of the extent and causes of delays (including their variability) to bus services. The study focused on measuring the causes of delay to individual buses in service (ie punctuality), largely through detailed on-bus (covert) observations.

All delays were recorded (to the nearest second) under one of seven analysis categories, as set out in table 4.2. For each of these seven causal factors, figure 4.1 shows both the extent of delays, as a proportion of the scheduled journey time, on average and the variation (5%ile, 95%ile) around these averages. It is evident that:

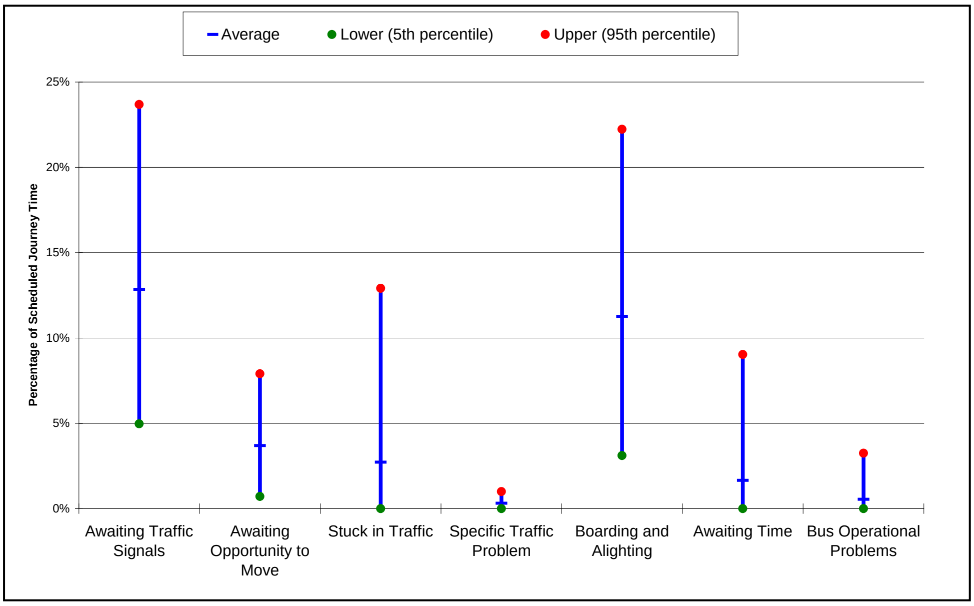
- 'awaiting traffic signals' and 'boarding and alighting' were the largest contributors to both the average delay and its variability
- 'stuck in traffic' was also a major contributor to the variability of delays
- the next highest variability related to 'awaiting time' which refers to time spent waiting so as to avoid running early.

Table 4.1 Indicators of potential/developing reliability problems

Planning (diagnostic) indicators	Operational indicators
• Long urban route • Network of routes requiring many individual (O-D) transfers • Lack of feeder services • Short spacing between stops • Problematic stop location • Single daily average running (travel) time • Sticking, in principle, to even headways • Different forms of fare payment • Poor in- and off-vehicle amenities • Poor security	• Missed trips • Late pullouts • Poor on-time dispatching • Significantly late/early trips • Bunching • Uneven loads • Overloaded vehicles • Unpredictable passenger demand • Missed transfers • High variance of scheduled headway and/or running (travel) time • Insufficient/extended layover time • Absenteeism • Road calls • Breakdowns • Passenger complaints • Dispatcher complaints • Driver complaints • Bad press • Road and other accidents
Maintenance indicators	
• Lack of vehicles available for service • Long hours/kilometres between preventive maintenance activities • Large number of vehicles overdue for inspection • Large percentage of old vehicles • Inadequate replacement policies and contingency plans • Poor quality level of spare parts • Intensive vehicle use • Poor vehicle design • Inadequacy of maintenance facilities • Lack of data on vehicle histories and maintenance effectiveness • Improper maintenance-engineering staff	

Source: Ceder 2007.

Figure 4.1 Delay variability by type of delay



Source: TAS 2005, On-bus delay analysis surveys May–July 2004.

Table 4.2 GMPTE study – delay analysis categories

Description/explanation
Awaiting opportunity to move • Waiting time at junctions, points of traffic priority, waiting to pull out into main traffic flow or any other points where the bus is not able to proceed due to other traffic flows (such as restricted carriageway width or car turning right in front of bus) except for traffic signals.
Awaiting time • Time standing for no other purpose than waiting so as to avoid leaving the point ahead of the timetable.
Awaiting traffic signal • Time spent awaiting traffic signal green light to proceed from 10-15 car lengths away from signals. Include time at both pelican crossings and signalled controlled junctions. If in doubt use the SIT category below.
Boarding and alighting • Time when bus is stationary and passengers are boarding or alighting. Do not include out of course delays such as changing ticket rolls, drivers talking to friends/relatives or standing at stops when no passengers are boarding or alighting.
Bus operational problems • Relates to any delay that is not attributable to 'external' factors but due to problems with the vehicle or its operation by the driver. Surveyors to record problem or incident, eg changing drivers, mechanical problem with bus, problem with passenger.
Stuck In traffic • Delay time stuck in traffic attributable to the volume of traffic flow. Surveyor to record specific problem. • Note that if the bus is delayed in advance of traffic signals then delay is to be recorded as 'stuck in traffic' until 10-15 cars away from traffic signals when delay should then be recorded as 'awaiting traffic signal' – this is related to the length of traffic queue that can reasonably be expected to pass through the junction during the following green phase of the signals. • Surveyor to record specific problem or incident.
Specific traffic problem • Time lost through a specific traffic problem (state what) including roadworks, breakdowns, illegal parking, accidents and other exceptional behaviour by road users. • Surveyor to record specific problem or incident.

Source: TAS 2005

Further analyses of the survey showed that the scale and causes of delays and their variability were influenced by:

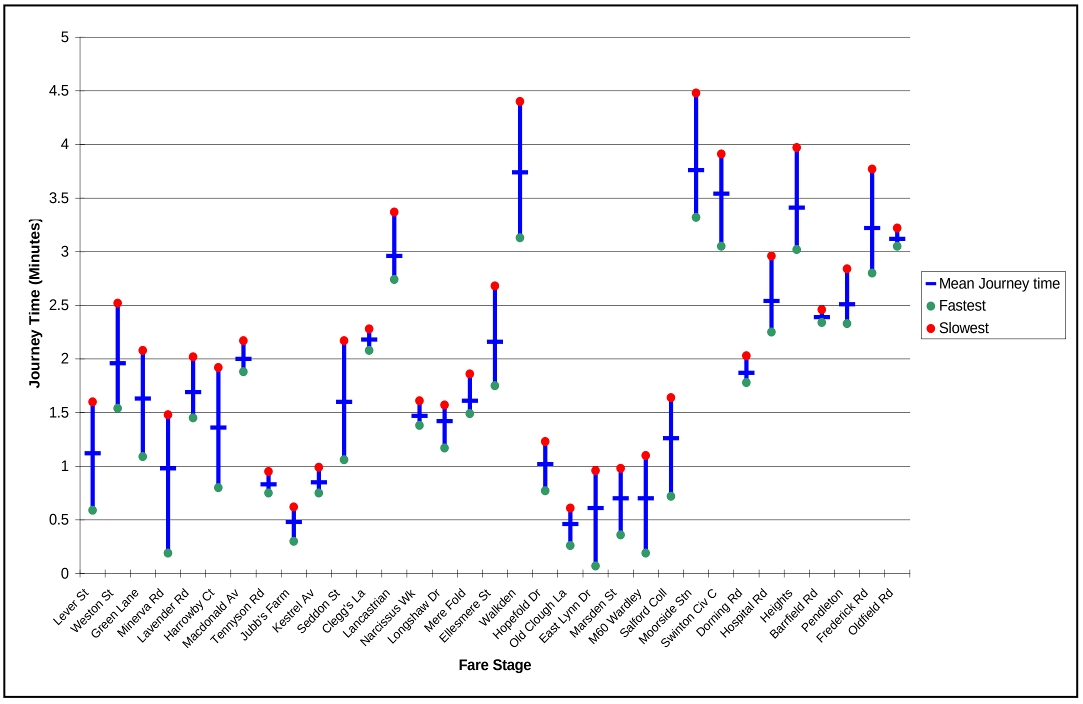
- time period (time of day, day of week)
- direction of travel relative to 'peak' flows
- 'type' of service (radial service, orbital service or other)
- extent of bus priority on route section
- operator
- type of bus being used.

Figure 4.2 shows (for the AM peak period) the average journey time and its variability along the route (by fare stage). For some of the shorter sections in particular, it shows that the variation in journey time is very large relative to the mean time, illustrating the difficulties for operators in running on time in such situations. It also emphasises the need for close examination of the root causes of delays at those points on the route with highly variable journey times.

At a less detailed level, a summary of London Buses' investigations of the main causal factors behind the unreliability of their services is given in appendix C (table C.4). The four key factors were (in no particular order):

- staff shortages
- traffic congestion
- bus boarding times
- inadequate supervision of route performance (including poor performance of AVL/RTI systems).

Figure 4.2 Variability in journey time between stages (morning peak 0700–1000)



Source: TAS 2005

4.2.3 Causes of unreliability – New Zealand evidence

From enquiries made for this research, we have not identified any detailed investigations into the causes of bus service unreliability in the three largest New Zealand centres –although ad hoc studies for particular routes and problem locations may well have been carried out by regional councils and/or individual operators.

At a more general level, Auckland Transport (AT) advised that the main factors behind services departing significantly from their scheduled timings are understood to be (refer table 3.1):

- Schedules often do not reflect the running times (overall or by section) that a 'typical' driver will require to run the route (on an 'average' day or any defined %ile day).
- The failure of drivers/operators to take action to ensure that services do not operate early along the route.
- The limited extent of bus priority measures that would protect buses from the vagaries of traffic congestion.

- In the absence of adequate priority measures, the variable effects of congestion on bus running times (by day/time period, season, school term vs holidays, weather conditions, etc).

However, AT was not in a position to quantify the contributions of the various factors to unreliability at this stage.

In relation to the first factor above, we note that the regional councils in all three of the main centres are currently using their AVL/GPS data to revise their scheduled running times for each route (in part as a prelude to new PTOM-based contracts).

4.3 Approach to diagnostic ('root cause') appraisal of unreliability problems

4.3.1 Diagnosis of problems

A systematic approach is highly desirable to identify the root causes of unreliability or time-keeping problems areas and 'hot spots', and then to address these causes in the most cost-effective way. The alternative is likely to be inefficient schedules, poor and deteriorating reliability performance, loss in patronage and (to the extent that the problems are within the operator's responsibility) the danger of early termination or non-renewal of the contracts concerned.

Figure 4.3 provides an appropriate framework within which a 'root cause' appraisal of unreliability problems can take place. Particular features of this framework include:

- Background monitoring is used, on an ongoing basis, as the 'trigger' for identifying any areas of poor performance.
- Where clear evidence of poor performance is identified, a 'root cause' appraisal of the route in question is initiated.
- Such an appraisal requires a number of background inputs, including collection of more information on operational/driver performance.
- Using these background inputs, key steps in the appraisal include:
  - data analysis and problem definition (step 3)
  - identify and analyse potential solutions (step 4) and determine preferred solutions (step 5)
  - implement proposed solutions, following appropriate (internal and external) consultations and approvals (steps 6/7)
  - post-implementation review of effectiveness of solutions – is there still a problem? (step 8).

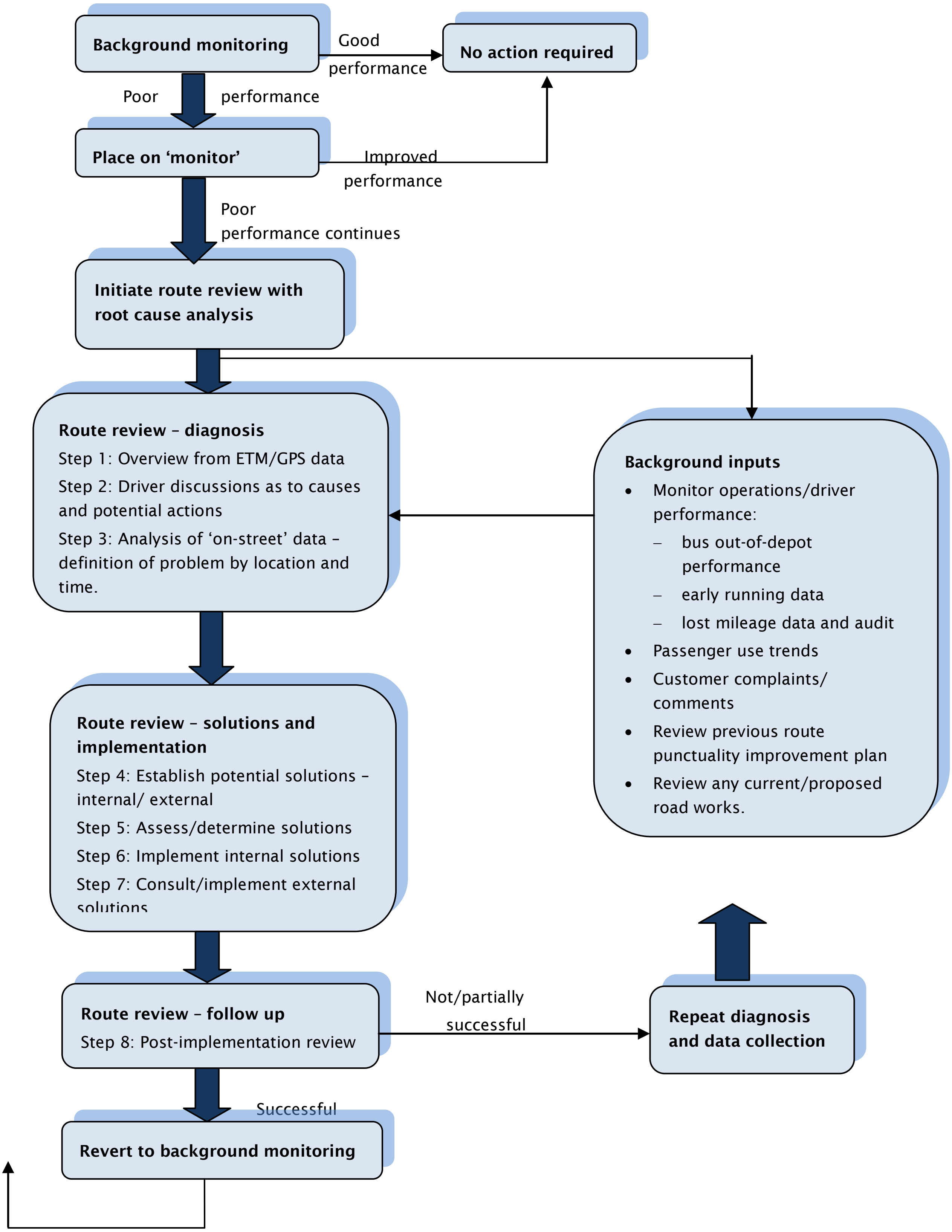
4.3.2 Development of potential solutions – overview

Once the full diagnosis of reliability problems has been undertaken, the bus service operations planner/analyst can then proceed to develop and assess potential solutions. These may be considered under three main headings, which are the topics of the remainder of this chapter:

- Planning and scheduling measures (section 4.4).
- Bus priority measures – to reduce the adverse effects of congestion on bus running times (section 4.5).
- Operational management and control measures (section 4.6).

The chapter concludes by commenting on the role of real-time information for passengers on influencing attitudes to unreliable bus services.

Figure 4.3 Approach to root cause appraisal and delivery of improvements



4.4 Potential measures to address unreliability – planning and scheduling

4.4.1 Overview

A major consideration throughout the planning and design of bus systems should be to ensure or maximise the chances that they will operate with a high level of reliability. Thus reliability considerations should be built into the planning/design process at the system planning stage, the route structuring stage and the timetabling/scheduling stage.

Table 4.3 lists specific actions for consideration at all these planning/scheduling stages to address reliability issues. The material in the remainder of this section focuses primarily on actions under section C in the table, ie it assumes that the route for the bus service has already been established (network design aspects are outside the scope of this project).[16]

Table 4.3 Planning and scheduling – specific actions to address reliability problems

A: Area coverage actions • Increased route coverage; new routes • Old set of routes replaced by a new set • Service expansion, new local circulators/shuttles • New/improved feeder services • New/improved timed transfers, improved route coordination • New/improved transit centres	**C: Timetabling/scheduling actions** • Increased span of service, longer late night and weekend service hours • Increased service frequency • Average even-load headways introduced • Adjusted departure times to suit new connections • Modified running (travel) times by time of day • Increased layover time • Deadheading trips introduced for necessary reinforcement • Shifts in departure times introduced as a corrective strategy
B: Route restructuring actions • Interlinings introduced • Route shortening, extension, realignment and removal • Revised operating strategies • Route splitting • Joining routes to form a single route • New/improved zonal, express and local services • Reduced number of stops	**D: General system's organisation actions** • New/improved geographic, origin-destination, route, stop and transfer-point database • New/improved frequency, timetable and transfer-time database • New/improved stop, station, transit centre and park-and-ride amenities • New/improved passenger amenities • New/improved real-time service information • New/improved vehicles • Increased security

Once the route of the service has been established (sections A, B), the next planning stage involves timetabling and scheduling. This stage needs to address a number of factors which lead to the design of an ‘ideal’ or ‘pure’ timetable, followed by a number of other factors which can introduce compromises.

[16] An appraisal by London Buses of proposed policies to improve their service reliability is given in appendix C (table C.4).

The factors which together produce an 'ideal' timetable are:

- Determination of frequency – influencing the total vehicle resources to be deployed, having regard to the demand and supporting the financial justification for those resources (see section 4.4.2).
- The predicted journey time – at the level of section-by-section times between timing points and also at the level of the total round trip journey time, with the latter allowing for 'layover' time at termini points (see sections 4.4.3 and 4.4.4).
- Design of a simple and attractive timetable (see section 4.4.5).

Factors which may compromise the 'ideal' timetable (sections 4.4.6 – 4.4.7) include:

- variations in journey times throughout the day
- specific passenger demand peaks
- space available at particular control points (for example, bus stations and termini)
- operational issues, including:
  - where the vehicles will be garaged
  - where and when 'driver reliefs' will take place
  - how any driver hours requirements are to be accommodated.

4.4.2 An 'ideal' timetable and schedule – demand forecasting

While determination of the ideal frequency of a bus service based upon demand may sound straightforward, in reality decision making will involve a significant degree of informed judgement.

In the case of existing routes (with maybe changes in service frequencies, running times, reliability and fares), the preferred approach is for any demand forecasts to be 'pivoted' around the existing patronage levels. In this regard, we note that:

- The patronage effects of the changes can generally be best represented by demand elasticities – such elasticity estimates are generally well established (refer Wallis 2004).
- In estimating the effects of patronage changes on a given route, allowance needs to be made for potential 'abstraction' of passengers from routes in the same or competing corridors: a large proportion of additional passengers on the route may just switch from other routes.
- The primary focus of demand forecasting, particularly for peak periods, should be to establish the likely patronage at the maximum load point on the route: this determines the service capacity/ frequency required.

In the case of new routes and/or restructured networks, demand forecasting is more complex. It is likely that demand will best be estimated through some combination of i) a regional/sub-regional multi-modal or PT model (eg in the Wellington region, the GWRC Wellington Transport Strategy Model or the Wellington Public Transport Model) and/or ii) comparisons with passenger numbers and PT trip rates (per person) on other corridors serving areas with similar demographic/economic characteristics. Numerous textbooks /manuals are available on forecasting the demand for overall travel and PT travel in urban areas: the topic is not addressed further here.

The demand forecasts will provide the demand side information required to produce a business case for route development. The other side of the equation will be the supply side: and for this it will be necessary to consider the level of operating resources to be deployed, which may be estimated from consideration of predicted journey times and their associated costs.

4.4.3 An 'ideal' timetable and schedule – timing points and sectional running times

Good practice design of a bus timetable will require careful assessment of realistic journey times not only for the route as a whole, but also between each timing point: timing points act as route 'control points' from the operator viewpoint, being points along the route where drivers may need to wait if the bus is running ahead of schedule.

Considerations relating to the choice of timing point locations include:

- Ideally, from the operator perspective, they should be located at peak boarding points on the route, so passengers have the opportunity to board the bus while it is waiting.
- However, such locations may be undesirable from the local authority viewpoint, as they may be in locations close to prime commercial land and may not be the best use of such land.
- Timing points need to be located where sufficient space is available for the bus to wait (eg in bus lay-bys).
- Timing points may also be unpopular in residential areas, especially if buses wait with engines running.

Once timing points are identified, data is required on the expected journey times (mean and distribution) between each pair of points:

- On an existing route, this is best obtained through analysis of AVL/GPS data for the relevant route section. This should be analysed in detail to understand the pattern of variability in running times (eg day of week, school term vs school holidays, time of day, especially through the peak periods, etc).
- For new/altered routes, the traditional method is to conduct 'timing tests', involving running a bus along the proposed route at a 'typical' bus operating speed, and allowing say 20 seconds per bus stop to replicate boarding/alighting times. Such timing tests should desirably be undertaken in a range of traffic conditions to best replicate likely operating situations.

4.4.4 An 'ideal' timetable and schedule – estimating the total running time and layover time

Once data on observed sectional running times has been collected, a view needs to be taken as to what sectional running times to allow in the schedule. It is unlikely to be appropriate to use the mean (or median) time, or else services will be late on approximately half of all occasions, and unlikely to be able to make up time on subsequent sections; while if the maximum observed time is chosen, then excessive standing time will result, with annoyance to passengers and an inefficient operation. A similar issue arises in relation to overall journey times, as now discussed.

A first estimate of overall journey times will result from the simple addition of the section running times. It is unlikely in practice that many trips will achieve significantly shorter journey times than those resulting from the calculation, assuming they will be constrained by the requirement to not run early at timing points. However, a more substantial proportion of trips may have significantly longer journey times, as they may operate behind schedule at most/all intermediate timing points: it should be possible to estimate this proportion, and its distribution by minutes late, if sufficient AVL/GPS data has been collected.

The crucial question for the operations planner/scheduler is not the route running time required on its own, but the total time to be allowed for running the route plus 'layover' at the terminus prior to starting the next trip.

Layover time (sometimes known as 'recovery time') is effectively 'slack' time added to the schedule both to give the driver a short rest break (in normal circumstances) and to improve reliability in case unforeseen or unpredictable delays occur. It is traditionally scheduled at the end of a journey so that customers are not inconvenienced by additional time spent waiting in case 'unforeseen' events occur. Linked with the evidence that reliability generally deteriorates as progress is made along a route, this is one of the reasons why some experts argue against local bus routes being too long: when this occurs the layover or recovery time at the end of the route may be too far away to prevent customers perceiving a poor and unreliable service.

There appear to be no general rules regarding appropriate layover times in the bus industry, either in New Zealand or internationally. Table 4.4 sets out the layover time policies adopted by the regional authorities in the three main centres. The policy adopted by GWRC has much to commend it, in that minimum layover times are related to the distribution of running times, specifically the 95%ile. There would also seem merits in the ECan policy of giving more generous layover times for longer trips, in order to provide drivers with a longer rest break.

Table 4.4 New Zealand policies re layover times (three main centres)[(a)]

Centre	Layover policy, notes
Auckland	• No specific policy. • Reasonable layover times affected by length of trip, time of day, location of route, etc. • Any defined layover times would not necessarily be adhered to by the operator (who does their own scheduling).
Wellington	• General policy, to be progressively implemented, is for a minimum layover time of 3 mins, after allowing for the 95%ile terminus-terminus running times (ie times exceeded on only 5% of trips). • Implication is that average layover time will in practice be significantly above the 3 mins figure.
Christchurch	• General policy is for following minimum layover times based on normal (timetabled) route running times: – 5 mins if running time <30 mins – 7 mins if running time 30–60 mins – 10 mins if running time >60 mins. • Minimum layover times are specified in detail in each contract.

(a) Taken from tables 3.1/3.2/3.3.

In terms of the running time allowance that is input to the total trip time calculation, there also appear to be no general rules adopted internationally (although noting that such operational criteria are rarely published).

Box 4.1 Basis for setting scheduled running times – some international bus agency examples

- *Tri-met (Oregon, USA).* 40%ile of actual running times – hence biases schedule towards late rather than early operation.
- *OC Transport (Ottawa, Ontario, Canada).* 'Subjective', based on distribution of observed running times.
- *Eindhoven (Netherlands).* 85%ile of actual running times –gives attainable schedule in great majority of cases, but involves significant 'holding'.
- *Dublin Bus (Ireland).* Average of 50%ile and 80%ile of observations made over four weeks in the 'shoulder' periods of the year (September/October and February/March in this case). Experience was that this formulation was a good compromise given the natural variability in traffic levels, passenger loadings and bus running times across weekdays. (Dublin Bus has more recently moved away from this policy.)

Sources: Furth et al 2003, quoted in NZ Bus 2011; The TAS Partnership inputs to this project (Dublin).

Box 4.1 summarises practices adopted for determining scheduled running times by four PT agencies in Europe and North America. This illustrates the considerable variation in adopted practices (unfortunately information is not readily available for layover time practices in these agencies, to be considered alongside the running time practices).

We note that GWRC adopts the 95%ile of actual (unconstrained) running times as its standard, accompanied by minimum layover times as in table 4.4.

The setting of appropriate total trip times (including layover allowances) is a critical determinant of both service reliability and operational efficiency. If allowed running times are too short, the proportion of trips running late will increase; if they are too long, the proportion of trips running early may well increase, the amount of waiting at intermediate timing points will increase (to the annoyance of passengers) and an inefficient operation will result.

The 'optimum' policy for scheduled running times in any situation ultimately needs to be determined empirically, although with the opportunity to take advantage of approaches and guidelines developed by PT authorities and researchers internationally. NZ Bus has undertaken recent work on this topic, including a review of the international literature, in order to develop policies and approaches appropriate to the Wellington and Auckland situations. Box 4.2 provides a synopsis of NZ Bus's recent (2011) paper on this topic, which covers in particular approaches and methodologies for determining:

- scheduled route running times and 'half-cycle' (including layover) times
- scheduled running times by segment (between timing points)
- time periods over which constant running times should be adopted.

The paper also comments on how application of these methods will assist in meeting contractual requirements (relating to early and late running) in Wellington and Auckland. The paper should provide a significant input into the present efforts in the two centres, in particular, to develop optimum running times for timetabling purposes. NZ Bus and other operators are working closely with the two regional authorities to develop and implement optimum running times by route, based on analyses of the extensive RTI database now available (refer tables 3.1, 3.2).

Box 4.2 Summary of NZ Bus paper on acceptable time parameters

Scope

Paper outlines policies and methodologies to set appropriate running times, 'half-cycle' times and recovery times for urban bus services at the route level, and the application of these methodologies to help fulfil contractual requirements. Applications are dependent on good data on the observed distribution of running times, based on AVL/RTI or similar datasets.

Policy aspects

- Effective/efficient timetable planning is dependent on detailed data on observed running times, as timetables need to take account of the distribution (eg 95%ile) of running times rather than just mean values. Information on the full distribution requires extensive data, which is conveniently obtained from AVL/RTI sources.
- A useful concept in timetable planning is the 'half-cycle time', ie the time from a bus's departure from one terminal to its next terminal departure (in the return direction). This time has to be sufficient to accommodate the running time experienced on most trips plus an allowance for driver recovery at the terminus, and be such as to ensure that the next trip can start on schedule in the great majority of cases (eg it could be defined as, say, the 80%ile running time plus 5 minutes, or the 95%ile running time).

Methodology

Three aspects of setting schedules are addressed: the setting of running, half-cycle and recovery times for a route; setting of running times by route segment; and defining homogeneous periods in which the running and half-cycle times will be kept constant.

Running, half-cycle and recovery times

- Discusses approach to setting schedule times, recovery times and half-cycle times relative to the observed distribution of running times.
- Suggests formulation so that the scheduled arrival time at the terminus would be the 60%ile running time (ie 60% of trips would arrive early or on time); and the half-cycle time would be the 95%ile running time (ie the following trip would have to start late on only 5% of occasions).

Segment running times

- Scheduling at the route segment level (ie between successive timing points) can either precede or follow establishing half-cycle etc times (as above). Two alternative approaches are outlined.
- 'Low feasibility' method (with no holding at timing points). Scheduled running times for each section are based on a low percentile (eg 40%ile) of observed cumulative running times from the start terminus. This would result in only a 40% (say) chance of a bus departing early, and such departures would not be far ahead of schedule.
- *'Passing moments'* method (allowing holding at timing points). Scheduled running times are based on X%ile running times from each timing point to the end of the route, where X would be a high figure (say 85%): individual segment running times are thus derived by working backwards from the end of the route. This method is sensitive to where on the route delays occur, and tends to distribute slack time more towards the end of the route.

Homogenous periods

- Once optimum running times are determined, as above, theoretically on a trip-by-trip basis, in practice these need to provide the basis for selecting time periods within which the scheduled time will be set as constant.
- A logical approach to this is to derive homogenous time periods that are as long as possible subject to the constraint that no more than X% (say 20%) of the scheduled trips in that period have an optimal running time that varies by more than a given tolerance (say ±2 mins) from the mean of the optimal times for the period.
- Software packages are available to facilitate such analyses, although no rigorous optimisation methods appear to exist. However a ready alternative is the use of graphical methods, which may well be preferable in practice.

Contractual requirements and implications

- Current/proposed contractual requirements set by the regional authorities, in particular those relating to early and late running, influence the preferred approaches to setting schedule running times and half-cycle times.
- ***Early running.*** Current requirements are such that there is a strong incentive to ensure that trips do not leave starting points or intermediate (timing) points early (or more than 0.59 minutes early). The two methodologies relating to setting segment running times (above) address this issue. The 'passing moments' method should largely eliminate early running, providing that drivers wait at timing points as necessary; however, this practice may not be appropriate in some circumstances (eg for the Wellington trolley bus system). The 'low feasibility'

method will bias the system towards late running, but without eliminating early running.

- ***Late running.*** Current/proposed contracts allow greater tolerance of late running than early running. One significant cause of late running is the effect of late running on one trip propagating into following trips. This problem should be reduced by setting appropriate half-cycle times, as outlined. The 'passing moments' method of setting segment running times should result in late running being rare, while the 'low feasibility' method has some bias towards late running, but not significantly so. Use of either method along with setting the optimum half-cycle times should reduce the amount of late running currently experienced.

Source: NZ Bus 2011.

4.4.5 Bringing the demand and supply sides together – creating a simple and attractive timetable

Bringing together work on demand forecasting and the total round trip time for a prospective bus route allows production of a business case showing the predicted financial performance of a route at different frequency options. Each of the frequency options can be supported by a separate timetable. The key issues here are how a simple and attractive timetable can influence the reliability of the services:

1 From the customer perspective, a simple and attractive timetable can give confidence for the straight-forward reason that it is easy to understand.

2 A simple timetable is likely to be one which is easier for the operator to manage on a day-to-day basis.

The following are features of service and timetable design that will help in creating simple, attractive and reliable timetables:

- Simple route structure. Designs to be avoided include those where:
  - there is a mixture of long and short workings on a route
  - there are route variants which diverge from the main route and then rejoin it later.

  Such designs are likely to complicate operational control, be difficult for the user to understand, and lead to bus bunching and poor reliability.
- Even headways. Uneven headways, with differing gaps between services (eg 30 minutes, 20 minutes, 30 minutes etc) are likely to result in uneven loading and running time variations, thus further exacerbating the uneven headways as the bus progresses along the route.
- User-friendly headways. From the customer viewpoint, the most user-friendly services are those that repeat on an hourly cycle, eg every 10, 15, 20 or 30 minutes. While 45 minute headways may minimise any excess layover time on a given route, they will result in a timetable that is unattractive to users.
- Service coordination over common route sections. In cases where two or more routes share a common route section, it is desirable that the combined routes result in even headways over this section; otherwise, with uneven headways, some of the services will pick up more passengers than others and bus bunching is likely to occur.

4.4.6 Factors which may compromise the 'ideal' timetable - variable running time

One of the most complicating factors in timetable design is dealing with variations in journey times caused by different traffic conditions and passenger demand levels throughout the duration of the timetable. Variations can occur for many different reasons, some of which are predictable and some of which are unpredictable. The task of designing an 'ideal' timetable should be to account for the predictable variations.

Earlier sections discussed the natural underlying and predictable variation of journey times by season, school days compared with holidays, day of the week and time of day, etc. it was also noted that 'layover' time or 'recovery time' may provide sufficient slack time within the total journey to allow for the variation in driving style between different drivers and variations caused by factors such as different weather conditions – without designing so much slack that there is too much 'waste' within individual trips.

However, layover time would rarely be sufficient to accommodate the variation in running times on a typical route over the day. Examining the timetable for one of Wellington's major routes (route 3: Karori – Lyall Bay), the weekday timetabled times vary between 39 minutes (late evening) and 62 minutes (PM peak). This means that the designer of the timetable has the challenge of building in incremental running time throughout the different sections of the route as the peak period approaches and then progressively removing the additional running time again after the peak period. This task can only be done effectively if the designer is aware of the sections of route where the additional time is needed – this will require good data on actual section running times, from AVL/GPS data or manual surveys.

In many cases, school/student travel is a major cause of peaks in passenger demand and hence in running times, particularly outside school/colleges in the PM school peak. In such cases, careful consideration is required of the merits of providing a 'school special' service in preference to the effects of a large number of students disrupting the regular route services.

When adding 'variable' or 'differential' running time into timetables, there is a trade-off between accuracy (ie a timetable which is 'accurate' for the majority of road conditions) and simplicity (a timetable which is simple and attractive for users). Using Wellington's route 3 as an example, despite the large variations in running times the timetable designers have been successful in achieving regular interval services through most of the weekday and all weekend: the weekday services (from Karori) operate every 10 minutes from after the AM peak (0905) to after the PM peak (1755), then every 20 minutes to 2050, thereafter every 30 minutes.

4.4.7 Factors which may compromise the 'ideal' timetable - operational issues

The designers of timetables need to consider a number of practical 'bus operational' issues, including:

- where and when any 'driver reliefs' will take place
- how any driver hours requirements are to be accommodated
- where vehicle(s) will be garaged (with associated 'out of service' running at the start and end of the day).

From both a customer viewpoint and a reliability perspective, 'driver reliefs' will ideally take place when as few passengers as possible are on buses and, preferably, when the bus is 'out of service'. In these circumstances no passengers are delayed during their journey as a result of waiting for drivers to 'changeover' and no disruption takes place to scheduled running times.

In practice, 'driver reliefs' will typically take in the order of two minutes. This can impact upon reliability because it is rare that every single trip in a schedule requires a 'driver relief'. As a consequence, some journeys will suffer a delay of around two minutes while others will not.

Driver reliefs can also become associated with poor driver behaviour. Temptation to 'run early' can be greatest for a driver just before a break so that the break is extended. Equally, temptation to 'run late' can be greatest when taking over from another driver, either at the start of a driver's duty or at the end of a break. These factors again lead to a fall-off in reliability when ‘driver reliefs’ take place part way along a route.

If ‘driver reliefs’ are planned to take place at a terminus point, this then leads to greater standing time being required at the terminus point – something which is usually a scarce resource.

In any event, ‘driver reliefs’ will need to be planned to take account of driver hours’ regulations as well as efficiency and cost parameters. These parameters will in turn be driven by the agreements and terms and conditions of employment between the operator and its drivers, as well as physical factors such as location of the depot base in relation to the route. This last point – the location of the depot base – is likely to govern the amount of ‘out of service’ running at the start or end of the working day and between the peak periods when fewer resources are required to run ‘inter-peak’ timetables.

4.4.8 Timetable resilience – sensitivity testing

Prior to finalising any proposed timetable, it is important to test its sensitivity to marginal changes in both supply and demand.

On the supply side it is desirable to ask the questions as to how the timetables would best be redesigned if i) one more bus; and ii) one fewer bus were available for the route. Quite often, it may be found that the favoured timetable makes poor utilisation of the ‘last’ bus (eg it is required for only one trip in the AM peak): the question should then be asked as to how the timetable could be improved to achieve better vehicle utilisation. Conversely, if this ‘last’ bus were not available, how could the timetable be adjusted to operate with one less bus, while still being as attractive as possible for users. In each case, the incremental costs involved in these marginal timetable changes may be compared with the incremental fare revenues expected (based on demand elasticity estimates).

On the demand side, operational planners need to consider how they would best respond to changes, particularly increases, in demand: typically there is a seasonal pattern to demand, with a peak in around March (once all schools and colleges/universities are in full operation). While the ideal solution may be to reschedule the services on the routes affected, this is likely to be disruptive and unpopular for both passengers and operators: it is unlikely to be appropriate where the demand increase is thought to be temporary (eg seasonal) and/or a ‘quick fix’ is required.

The next section (4.5) describes a number of potential operational ‘fixes’, including solutions which may be implemented ‘on the day’, and notes the benefits of an operating strategy which includes spare resources. Where and when a situation of over-loading arises and is repeated – as opposed to occurring on a one-off basis - reliability will automatically suffer unless a solution is implemented.

4.5 Potential measures to address unreliability – priorities for buses

4.5.1 Overview

One of the major causes of bus unreliability is operation in mixed traffic in congested situations: in many locations in peak periods, traffic congestion is a major contributor to delay and in particular to the variability of delay (eg refer figure 4.2). As has been demonstrated world-wide, measures that separate buses from general traffic can be effective in reducing both the mean delay and the variability in running times.

Priority may be granted for bus operation at stops, at intersections, and by preferential/exclusive lanes. Usually there is a trade-off between granting priority to buses and improving traffic flow for the other vehicles. Local authorities are often reluctant to provide this priority, especially where the route is already congested (and hence bus priorities are most needed)!

The following sub-sections provide a brief description of the types of priority measures commonly introduced (internationally and, to a lesser extent, in New Zealand) to protect buses from traffic congestion.

Further international and New Zealand evidence on the impacts of bus priority measures, including on travel time and reliability, is given in appendix E.

4.5.2 Priority at stops

A common source of delay to buses at bus stops (apart from the time required for passenger boarding and alighting) is difficulty in re-entering the traffic stream when pulling away from the stop.

This difficulty may be reduced or overcome through measures such as:

- giving buses 'pull-out' priority (through local/national regulations)
- restricting parking near bus stops
- providing an extra lane downstream from the bus stop (this is often particularly appropriate on the approach to an intersection, where the additional lane may be continued from the bus stop up to the intersection itself (refer 4.5.3 below)
- extending the footpath at the stop location by installing a 'bus boarder' strip in the roadway (thus eliminating a pull-out manoeuvre and easing the boarding process).

4.5.3 Priority at intersections

At intersections, bus priority can be divided into passive and active schemes. Passive priority at intersections is normally achieved through one of four types of measures:

1. Exempt buses from turning prohibitions so as to facilitate bus routes
2. Extend the green interval at signalised intersections for buses
3. Divide the green interval into two parts within the same cycle
4. Provide preference to streets carrying bus routes through Yield and Stop signs.

Active priority permits buses to pre-empt traffic signals, using in general one or a combination of three procedures: 1) immediate priority upon the arrival of the buses, 2) priority dependent on the crossing-street traffic queue, and 3) priority granted only to buses that are running late. Priority is usually granted through a 'B' signal, which allows buses to proceed prior to the green phase for other traffic.

4.5.4 Priority through preferential/exclusive lanes

Preferential treatment for buses on street lanes can be categorised as follows:

Type of preferential lane

- exclusive curb lane
- semi-exclusive curb lane (shared only with cars about to turn)
- exclusive median lane (with stop islands)
- exclusive lane in the centre of a street
- transit vehicle malls (known as bus malls, limited to pedestrians and buses)

- exclusive freeway/highway lanes
  - ramp bypass (for entering a freeway/highway during traffic congestion)
  - congestion bypass (exclusive lanes to bypass traffic bottlenecks).

Integration with traffic flow

- with-flow lane (by pavement markings and signs – but may experience enforcement problems)
- contra-flow lane (easy enforcement)
- exclusive lanes.

Period of operation

- single-peak operation
- two-peak operation
- permanent operation.

Authorities adopt a variety of policies as to what (if any) other types of vehicles may be allowed to use bus lanes (eg coaches, taxis, cycles, motor-cycles, trucks). Some 'exclusive' lanes for buses are shared with high-occupancy vehicles (cars carrying a specified minimum number of people, for encouraging carpools).

In terms of on-street bus services, there is now a considerable body of evidence showing that, in appropriate circumstances, priority measures of the types described here can be effective in reducing both average bus travel times and the variability of these travel times (ie unreliability) – refer appendix E.

4.5.5 Quality bus corridors

Comprehensive route-long length bus priorities (often referred to as quality bus corridors in the UK) allow a combination of the bus priority measures detailed above, linked to other improvements such as:

- passenger information at bus stops
- improved waiting facilities
- simplified high-frequency bus services
- new, high-quality vehicles
- restrictions on parking, waiting and loading.

In the UK, the measures have typically been introduced as part of a 'Quality Bus Partnership' between local authorities and the principal bus operator(s) that have invested in new low-floor buses and are seeking to maximise return on their investment.

In combination, these measures not only improve bus operations but also the image and public perception of the service to encourage mode shift from car to bus. They are regarded as highly successful in a number of cities (eg Dublin). Some of the options currently being considered (in the Wellington Public Transport Spine Study) for the implementation of a high-quality PT system through the Wellington CBD will incorporate many of the features of a quality bus corridor (as outlined above).

4.5.6 Segregated bus rapid transit systems

Maximum priority for buses may be provided by bus rapid transit (BRT) systems: such systems involve buses operating on a dedicated right-of-way, with signal priority, modern vehicles with level boarding, off-vehicle/ automated fare collection, bus stops/stations with enhanced amenities, automated information systems and unique branding. BRT systems in New Zealand/Australia include:

- Auckland – Northern Busway
- Adelaide – NE O-Bahn
- Brisbane – E Busway, Northern Busway
- Sydney – Liverpool-Parramatta Transitway.

BRT systems essentially overcome some of the major causes of unreliability with on-street bus services that arise from operating in mixed traffic, subject to congestion, signal delays, etc.

Table 4.5 shows estimates for the impacts of Auckland's Northern Busway on both average bus lateness and the variability (standard deviation) of lateness, comparing the services using the Busway with non-Busway services on the North Shore. It is seen that both the mean lateness and the variability of the lateness were almost 50% lower for the Busway services.

Further discussion of BRT issues and merits is outside the scope of the present project.

Table 4.5 Effects of Auckland's Northern Busway on lateness of bus services (mean and standard deviation)[(a)]

Item	Lateness – mean	Lateness – standard deviation
Non-Busway services	4.37 mins	8.22 mins
Busway services	2.25 mins	4.35 mins
Difference – mins – %	-2.12 mins -48%	-3.47 mins -45%

Source: Transport Futures 2012, annex A3.1

(a) Data relates to arrival times at the CBD terminus.

4.6 Potential measures to address unreliability – reducing boarding and alighting times

On typical urban bus services, the time spent by buses at stops for passenger boarding and alighting is a substantial factor contributing to both slow running times (on average) and to the variability in running times (refer figure 4.1). Potentially, reducing boarding/alighting times could therefore have major benefits in allowing faster scheduled travel times and greater service reliability: there would be substantial pay-offs in terms of reduced capital and operating costs, increased patronage and revenues.

We examined the evidence on whether and to what extent the introduction of electronic (smartcard-based) ticketing (ET) in the main NZ centres over recent years has been effective in reducing boarding/alighting times. Unfortunately, the impacts of this technology in NZ have not been monitored in detail, hence the evidence is limited.

Our conclusions on this topic were as follows[17]:

- It is not possible to generalise about reductions in boarding/alighting times resulting from the introduction of electronic ticketing systems. Much will depend on the prior situation, the details of the system introduced, the take-up rates of the system and the bus layout adjacent to the doorways.

[17] We are grateful to Ian Turner (consultant to BCA), who has contributed to these conclusions.

- In the Go Wellington (NZ Bus) case, when the Snapper ET system largely replaced the previous 10-trip paper ticket system, indications were that, on average, the Snapper boarding times were somewhat faster than using the 10-trip tickets. This advantage was partially off-set by the slower alighting times with Snapper.
- In the case of the NZ Bus Auckland and Hutt Valley services, average boarding times previously (under the old Wayfarer contact card systems) were relatively long, in the order of 10 seconds per passenger. In these cases, introduction of the Snapper system (or other modern contactless smartcard system) would be expected to reduce boarding time significantly – although again hard evidence is limited.
- We note that the bus layout in the vicinity of the doors can be a significant factor in preventing the potential boarding/alighting time benefits of modern ET systems from being realised. In the case of the Go Wellington (NZ Bus) services, observations indicate that the potential rates of boarding at the front doors are often constrained by (i) alighting passengers using the front doors at the same time as passengers are attempting to board; and (ii) insufficient space to allow for smooth two-stream entry (ie separating Snapper users from people paying the driver). This appears to be a significant deficiency to be addressed if the potential boarding/alighting time benefits are to be achieved.

As noted above, faster boarding/alighting times would provide benefits in terms of reductions in running times on average, which can translate into faster schedules, and reductions in the variability of running times. The latter would be a significant factor in ameliorating the problem of bus bunching, as discussed in the section (4.7.2) following.

4.7 Potential measures to address unreliability – operational management and control

4.7.1 Delivering the timetable – overview of operational aspects

As we have seen earlier, there are a number of root causes which can adversely affect operation of a bus timetable and, depending upon the root cause, different corrective actions will be appropriate. In this section (4.6) it is assumed that the service timetable has already been reviewed and if necessary corrected, so that in all normal traffic conditions and with 100% output and performance by the operator, the timetable will be delivered in a reliable manner. This section focuses on what might then go wrong, and the corrective measures available to those involved.

Root causes of problems at this ‘operating’ stage can be split between events outside an operator’s control and those within an operator’s control; and secondly, for those events which are internal to operators, between those which impact primarily on the number of buses on the road and those which primarily affect the time-keeping and reliability of buses on the road:

- Unpredictable delays (external to operators): examples include unpredictable traffic congestion, crashes, adverse weather and passenger incidents (for example, illness) – these events impact primarily on the timekeeping of buses on the road.
- Unpredictable events (internal to operators): examples include vehicle breakdown, shortage of buses or shortage of drivers – these issues again impact primarily on the number of buses on the road and then secondly on reliability and timekeeping for those on the road.
- Performance issues causing late running (internal to operators), eg late departure from the depot – impacting primarily on service timekeeping and reliability.

- Performance issues resulting in early running (internal to operators), eg poor driver adherence to schedules – impacting primarily on timekeeping and reliability.

Some operational problems are essentially of a medium/longer term nature and are generally best resolved through amending the timetable/schedule for the service. Examples include situations classified as (refer figure 4.2) awaiting opportunity to move; awaiting traffic signals; stuck in traffic; boarding and alighting; or awaiting time to move.

By contrast, issues of bus operator problem or specific traffic problem are primarily of a shorter-term nature: they will normally be best resolved through control and intervention, either 'on the day' when they occur or, if they show signs of repeating over a number of days or the medium term, through specific medium-term actions.

Examples of specific potential actions are given in the remainder of this section.

Although operators have it within their power to carry out 'root cause' analysis whenever a failure occurs, good practice will be to establish 'trigger points' at which investigations are commenced and, where possible, actions taken through medium-term changes: this will ease the pressure for those making 'on the day' decisions and reduce the number of short-term actions required.

Our commentary on corrective intervention actions in the remainder of this section is divided into three main areas:

- The approach of the operator (section 4.6.3).
- Methods of improving operation over the medium term – feeding back into revised plans and, potentially, revised schedules (sections 4.6.4 to 4.6.6).
- Methods of improving operation in the very short term, including 'on the day' (sections 4.6.7 to 4.6.10).

Before those sections, we discuss the topic of 'bus bunching', which is an important operational issue affecting bus service reliability.

4.7.2 Bus bunching

This sub-section discusses the phenomenon known as 'bus bunching'. Bunching is one of the most prominent and irritating (to users) symptoms of unreliable services. It is, unfortunately, a common phenomenon, noticed by both the public and bus passengers alike, and almost always detrimental to the image and reputation of the bus industry. Bus users and the public at large will, understandably, question why they must wait a long time for a bus and then see three come together – the first one usually overloaded, the last one empty.

Bus bunching is essentially the outcome of variations in journey times between successive trips along a route. Such variations arise from one, or a combination, of three possible causes:

- a bus running late (the most common cause)
- a bus running early, ahead of schedule
- a missed trip, or some other factor leading to abnormally high demand on the following trip.

Each of these causes, or some combination of them, can result in two or more buses running nose to tail:

- **Late running**. Bus bunching may result from just one bus running late. The impact of this one bus starting to run behind its schedule is that more passengers than would otherwise be the case are waiting to board this bus. Boarding of these additional passengers causes the one late-running bus to run more slowly than would otherwise be the case.

- As the delay becomes greater, the one late running bus starts to 'eat into' the time (or gap in service) to the next bus. As more passengers arriving at bus stops expecting to catch the second bus in fact now catch the late running (first) bus, there is a consequent impact for the second bus: it now has fewer passengers, its overall journey time decreases as it has to spend less time at stops boarding passengers and it thus catches up with the first bus.
- **Early running.** This may arise from the early dispatch of the bus from the terminus, unexpectedly few passengers to pick-up/set down, unusually light traffic conditions, or the driver speeding. The early bus will tend to pick up fewer passengers than usual, and thus progressively catch up with the bus in front. In some situations, drivers may have incentives to run early (eg if they are approaching a meal break or the end of their shift).
- **Missed trip.** Where a bus is missing from the schedule, the next bus will have to pick up the passengers that would usually be carried by two buses. In this case and in other situations of unexpectedly high demand, this bus will almost certainly end up running late, having to pick up more extra passengers and most likely get caught up by the next bus.

Figure 4.4 (taken from Ceder 2007) illustrates the mechanisms by which these three possible causes can lead to bus bunching. The base of figure 4.4 consists of an even headway timetable and random passenger arrivals, from which three vehicle trajectories are shown on a time-space diagram; the slope of each trajectory between two adjacent stops constitutes the vehicle's average speed. In all three cases described, bunching occurs between the second and third vehicles at stop 2:

- Part (a) of the figure illustrates the late running case, in which traffic conditions cause the second vehicle to slow down before stop 1. This slowing down becomes more pronounced at each successive stop, as more passengers accumulate after the departure of the first vehicle. Meanwhile, the third vehicle finds fewer and fewer passengers waiting (shortened headways between the second and third vehicles), and eventually it catches up the second vehicle, in this case at stop 2.
- Part (b) illustrates the early running case, in which the driver of the third vehicle is in a rush, departing early and speeding up.
- Part (c) represents the missing trip/high demand case, in which the second vehicle confronts passenger overflow at stop 1, which forces it to extend its dwell time at that stop. Thus, this vehicle departs stop 1 late as is the case in part (a).

In addition to causing bunching, all three of these cases result in unbalanced loadings on the second and third vehicles. We note that the extent of bus bunching problems is largely dependent on passenger boarding/alighting times: the longer these times are (per passenger), the more serious the bunching problem becomes as services proceed along the route. Reductions in boarding/alighting times, such as may result from electronic ticketing (eg tag-on/tag-off) systems, will thus help to minimise bunching problems (refer section 4.6).

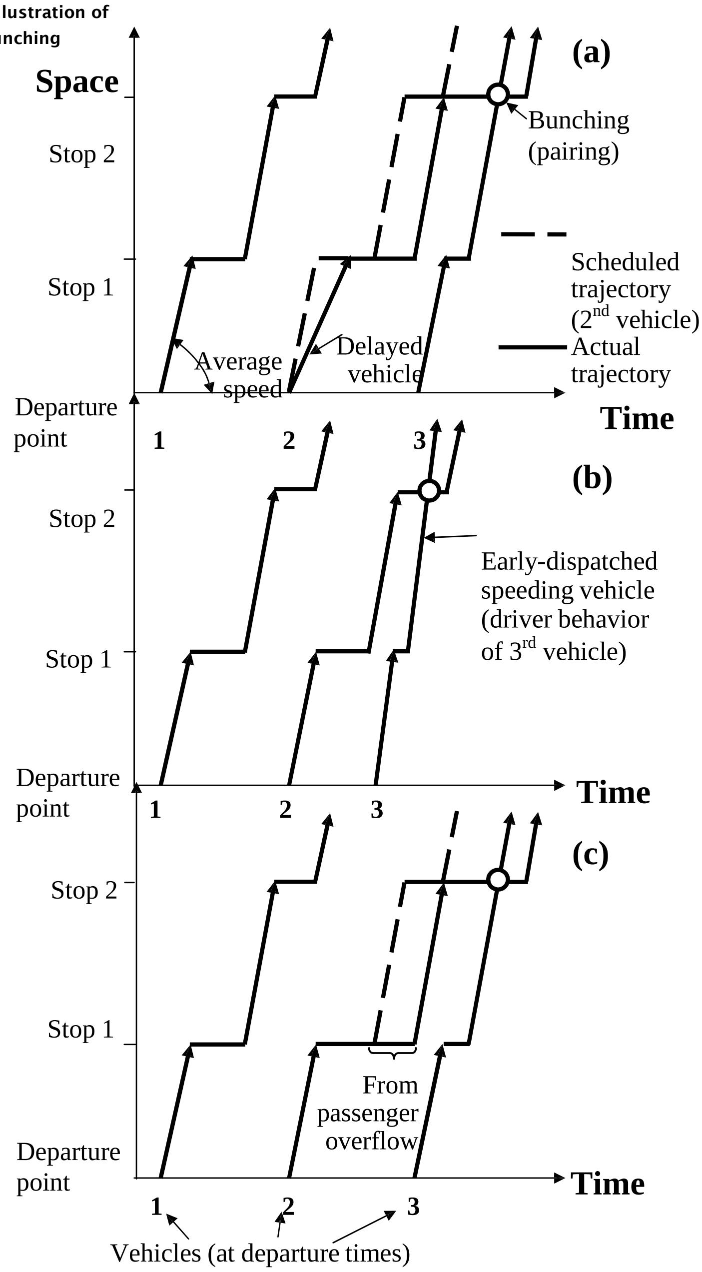
While it is seen that bus bunching can result from a number of factors, in many cases these factors are within the responsibility of the operator and the problem could be ameliorated by better operator management and resourcing. The availability of real-time information puts operator management/ supervisors in a much better position than previously to rapidly identify such problems and arrange for remedial action.

A late (or missing) bus can, if no action is taken, impact adversely on the entire operation of the service, and potentially other services through inter-working. Missing buses are almost always within the responsibility of the operator. Where late running occurs, drivers will have greater understanding for their employer if the operator demonstrates that they have:

- ‘on the day’ contingency plans (and resources) in place to adjust operations and return services to schedule expeditiously
- a regular programme of background monitoring in place and they review and take action on poorly performing services

Figure 4.4 Illustration of bus bunching

Figure 4.4: Illustration of bus bunching



Three typical processes creating a pair of vehicles (at Stop 2), notwithstanding scheduled even headways and random passenger arrivals: part (a), with second vehicle delayed because of traffic; part (b), with third vehicle dispatched early and speeding up because of driver behaviour; and part (c), with extra demand at Stop 1 for the second vehicle.

Early running may often be largely the fault of the driver, who may have incentives to run early (eg if they are approaching a meal break or the end of their shift). To counter the benefits to individual drivers from their running early, an operator must regularly communicate with its employees about its standards, and both retain and enforce the threat of disciplinary action to correct unacceptable behaviour. Operators who fail to take such action will fail in the eyes of the majority of their employees.

In the case where a bus has to carry additional passengers due to the previous bus not operating, the driver concerned is most unlikely to be able to keep to schedule, and may well be unhappy at having to 'carry the load which should be shared by two buses'. This situation is not conducive to good driver (or passenger) morale and management should avoid this wherever possible.

Having described the origins of bus bunching the remainder of this section focuses on good operational practices. One sub-section (4.6.9) specifically addresses options to tackle bus bunching problems.

4.7.3 The approach of the operator to 'operating its plan' - 'setting the tone' for control and intervention

Within the overall specifications set by the regional council, operator management is responsible for setting the parameters within which their staff carry out their work. Typically, this will include setting targets. These may, for example, include targets to operate a certain percentage of scheduled service and/or targets to operate services reliably. In many situations, there may be conflicts between these two objectives.

Supervisory staff would typically have a good understanding of the percentage of scheduled services operated, as they monitor bus dispatch from the depot. However, information on the punctuality of the services operated is typically not readily available to supervisors (unless they have timely access to RTI outputs). Hence, unless instructed to the contrary, supervisors are likely to place greater emphasis on ensuring that the scheduled services operate (ie reliability) than that they operate to timetable (ie punctuality). In this context, we note comment in the literature (Nicholson and Kong 2004), that:

> *An improvement in some reliability measures may not always result in an improvement for the passenger, for example, the number of bus miles actually run compared with scheduled is not necessarily a good barometer, as the buses may still run late (or in bunches).*

In practice, if additional resources cannot be added (including the use of any lay-over or drop-back included in the schedule), then improving punctuality is likely to require some services to be 'not operated'.

One test of how much weight a bus operator gives to punctuality is to ask the question 'What rules or standards do you have, requiring your drivers to contact their supervisors and seek instruction if they are running late, and what is the cut-off point (in minutes) when you would wish them to contact you?' in the Wellington trolley bus contract, as an example, any bus running more than 10 minutes late at the start of a trip is counted as 'not operated': as a result, by that standard, an operator should seek to take action with any bus approaching that threshold and therefore ask a driver running, say, seven to eight minutes late to contact them for advice.

As part of target setting, trigger points can and ideally should be established to identify the point at which medium term actions will be relevant to assist and to reduce the number of short-term 'on the day' interventions. Illustrative examples of trigger points might be:

- Kilometres (or trips) operated (weekly basis). Trigger point when the percentage of scheduled trips operated is >20% below the average result for the previous week or >10% below the average performance achieved in the previous four weeks.

For example, if 0.4% of scheduled trips are recorded as 'not operated' in a particular week, the trigger point for the following week would be breached if missed trips exceeded (0.4 x 1.2) = 0.48%.

- Service reliability (monthly basis). Trigger point when the percentage of services within the window of timeliness is >5% below the average result for the previous month or >5% below the performance achieved in the same month in the previous year.

Trigger points provide points at which action plans should be developed to implement medium-term actions. They can also be seen as a mechanism for taking the 'un' out of 'unpredictable'. Instead of delays or events being unpredictable, trigger points can identify the points at which the combined effects and impacts of unpredictable events become predictable. The challenge for the operator is then to determine the correct course of action, thus requiring investigation of the causes of deteriorating performance.

In addition to their responsibility for setting out a strategy (and targets) for reliability and punctuality, managers are also responsible for developing tactics for both control of reliability and intervention, which are the primary focus of the remainder of this section:

- One tactic for both controlling reliability and improving intervention is to have contingency plans prepared and ready to deploy (section 4.6.5).
- 'Control' of driver adherence to schedules requires medium-to-long-term plans and actions to monitor performance. Supervisors (and how they are deployed) are likely to be vital to any plans here. We suggest that an operator's control of its drivers' timekeeping is very much related to the culture within the operation (section 4.6.6).
- 'Intervention' on driver adherence to schedules is more an issue of 'on the day' activity (section 4.6.7).
- Deployment of supervisors, together with processes for communication is critical for successful 'on the day' intervention (section 4.6.8).
- Options available to supervisors to cope with gaps in service or buses bunching (section 4.6.9) and tactics for the deployment and use of spare resources 'on the day' (section 4.6.10).

Addressing the actions which can be taken 'on the day' or actions to control driver adherence to schedules in the medium term, in the next sub-section (4.6.4) we cover the actions which may be necessary in the medium term to balance resources available against those required.

4.7.4 Medium term improvement actions – adjusting schedules and/or resources

This section addresses ensuring that the resources required to provide bus services are sufficient and in place. The most important resources are vehicles and drivers, followed by supervisory staff.

If an operator identifies that a trigger point has been breached as a result of a shortage of serviceable vehicles or a shortage of staff, then options available include:

- rescheduling the service so that fewer vehicles or staff are required
- taking steps to obtain additional vehicles or staff – whether on a short-term basis (if the cause of the problem is perceived as being only short term in duration) or on a longer-term and more permanent basis if required.

Without rescheduling a service to adjust to staff and vehicle resources available, operators may implement on a temporary basis the actions summarised in table 4.6.

If an operator considers that these actions are unlikely to generate a sufficient improvement in resources available (or that they will not be sustainable for the length of time required), then the time will have arrived to consider one of the following actions:

- Reschedule the service so that fewer vehicles or staff are required. (This could be done only with agreement from the regional council.)
- Revise the operating strategy so that sufficient vehicles and/or staff can be provided to maintain the resource levels required. This may involve:
  - an amendment to terms and conditions for drivers and/or maintenance staff to ensure that the operator remains competitive in the labour market, and/or
  - a change to the management team or structure so that, where terms and conditions of employment for key front line staff are competitive, the management team is able to uphold the resources employed at the required levels.

Table 4.6 Examples of medium-term actions available to operators in the event of a shortage of resources

	Within own resources	Over and above own resources
Staff	• Seek assistance from any other 'in house' depots/companies • Liaise with driving staff for additional working (overtime, or rearrange holiday periods) • Reallocate non-driving employees with licences to driving duties	• Hire in drivers from a third party provider
Vehicles	• Seek assistance from any other 'in house' depots/companies • Revise planned maintenance activity (for example, to concentrate on corrective maintenance and repair) • Liaise with maintenance staff for additional working	• Hire in additional vehicles on a short term basis • Seek additional skilled maintenance support from suppliers

An operator may also conclude that a trigger point has been breached as a result of growing traffic congestion or an increase in passenger numbers. Any situation in such a case is most likely to require revisions to the timetable/schedule, or possibly the provision of larger capacity vehicles. The potential solutions will require changes to the operator contract, and associated payments, so can only be taken in conjunction with the regional council.

Before committing to any such changes, both operators and regional councils are likely to want to have reasonable certainty that the underlying causes triggering a change will not be reversed too soon. Frequent changes to bus services are not popular with customers or stakeholders: they require people to change their travelling habits and learn new times as well as incurring costs to change timetables and marketing material. Frequent changes also make it harder to attract new users: instead of communicating a message of certainty and permanence, the non-user considering use of the bus is faced with additional complexity.

One of the reasons why definition of 'trigger points' may be useful is that it can remove the risk of indecision from the decision-making process.

Medium-term improvement actions can be forced upon operators (rather than being self-generated from monitoring trigger points) in the event of advanced notice being provided of road works or a road closure.

The impact of a road closure can result in a clear requirement for additional kilometres to be operated on a diversion route –most operators are reasonably experienced at being able to predict the impact upon journey times when additional route mileage is incurred.

Advanced notice of road works is more complicated for an operator than a road closure. Both experience and human nature suggest that, over time, motorists try to find their own diversion routes around road works and, as a result, the impact of road works on congestion can often be reduced after the initial days of introduction. This effect, combined with the fact that road authorities are rarely able to predict likely delays from road works, frequently leaves the operator in a 'suck it and see' situation. This essentially means having to react 'on the day' depending upon the circumstances: in this type of situation the best possible preparatory action will be to assess likely delays and have spare vehicles and drivers available.

A useful approach for all operators is to document the actions and contingency plans which they develop over time. This allows the operator to build up a history of the success or otherwise of different actions. From these records it is then possible to communicate the successes throughout the organisation and to stakeholders. Supervisors and others can then learn from the success or failure and, if a similar event or disruption occurs again, a similar intervention can be introduced. (Essentially the process is not dissimilar to reviewing a safety risk assessment following an incident, and determining what, if any, lessons can be learnt.)

4.7.5 Medium term improvement actions – developing route contingency plans

Where operators accept the challenge to ensure that 'contingency plans' (CPs) exist, they should ensure that they are extant for each route and regularly reviewed. The CP should provide the basic necessary information for 'on the day' reaction.

Examples of useful content for route CPs are:

- diversion route (including vehicle types which can use the diversion route)
- turning points (that is, points along the route at which vehicles can be turned to operate 'short workings')
- the location and time of availability of any easily accessible spare resources, potentially including:
  - points within drivers' duties where 'spare' duty time is available
  - points within vehicle duties where a vehicle is not 'in service' or scheduled for maintenance
  - a list of part-time/casual drivers and their usual availability and/or other work (this information may exist in a different format, across all routes operated from a depot – but still confirming the routes with which part-time drivers are familiar).
- any easy and alternative 'fall back' schedules which could be implemented (demonstrating, for example, the round trip running times and resources required to run a simple half-hourly headway service).

4.7.6 Medium-term improvement actions – controlling and improving driver adherence to schedules

Management of driver performance and adherence to schedules is an important issue, to ensure that drivers appreciate the importance of:

- starting journeys on time (both on morning run-out from the depot and along the route)

- not running early (and that the operator cares and commits management time and resources to ensuring early operation is not tolerated)
- good timekeeping at crew change-overs.

Where GPS-based systems exist, it is usually straightforward to produce reports showing which drivers ‘run early’. On the other hand, it is a more time-consuming task to ask drivers, after the event, why they ran late. Reports can again usually be requested to show ‘unlucky’ drivers who regularly ‘run late’ but it is more complicated to identify reasons why particular trips run late.

Where GPS-based systems do not exist, management and control of drivers ‘running early’ will depend on the culture within the organisation and the volume and type of inspection carried out. If the culture (ie ‘how things are done around here’) at an operator’s organisation and amongst its drivers accepts no early running, then the operator will more easily be able to concentrate on continuous improvement of issues causing late running.

Overt checks will make it clear to drivers that they are being observed – and as a direct result, many drivers will change their behaviour so that they do not run early.

In the absence of GPS-based systems, to be effective in ensuring that drivers self-regulate their driving so as not to run early, supervision will need to be covertly deployed along the line of a route, at least some of the time. It is fair to say that the true test of whether drivers do or do not run early can only be measured by covert checks.

On-street background checks to establish the level of early running can take place at the same time as overall punctuality is measured. The great strength of regular and repeated campaigns to monitor early running is that it allows communication to drivers, customers and stakeholders that the operator regularly engages in this activity. A low level of early running reassures all parties that all remaining issues relate only to delays.

It is also relevant here to remember that punctuality – at least as far as late running is concerned – generally deteriorates along the line of route. As a result, supervision to correct punctuality failings covering both early and late running will be best placed away from the starting point of a service.

4.7.7 Short-term, ‘on the day’ intervention and improvement actions - triggers

In the same way that medium-term improvement actions are developed once ‘trigger points’ are crossed, the same is true of short-term ‘on the day’ actions – in other words, an indicator has to be ‘triggered’ to cause an action to be considered and then implemented.

Triggers for short-term intervention can come from a variety of sources, but commonly these will include:

- vehicle breakdowns (usually reported by drivers)
- staff shortage, due to absenteeism, sickness or late reporting
- late running (as reported by drivers, or, if a AVL-based system is available, from information available to supervisors)
- observations by supervisors on the road.

While opportunity exists for trigger points for the medium term to be formalised, the point at which action should be taken ‘on the day’ is often less clear cut. Examples of this are:

- an absence of hard and fast rules about how much a service is allowed to run late before action is taken

- faced with two instances of vehicle breakdown or staff shortage, but only one spare driver or vehicle, how does a supervisor know which instance to cover?

One of the most complex issues surrounding 'on the day' intervention actions is the question of how supervisors are deployed and what procedures exist for their communication: this question is now addressed.

4.7.8 Deployment of supervisors and procedures for communication

Management is responsible for determining how many supervisors are deployed and where and how they should be deployed.

In practice, once drivers and vehicles have left the depot (and there is a clear supervisory role in checking and establishing those events), supervision can only continue to be remote or distanced from operations out on the road if there is a control system such as RTI or radio communication in place. In the absence of RTI or radio communication, effective supervision can only take place at some location along the route.

In any event, assuming that at least one supervisor remains office-bound to answer telephone calls, radio calls or supervise an AVL system, supervision on the road will have two major benefits:

- Supervisors can intervene face-to-face with drivers and potentially discover more as a result.
- They can interact directly with customers, seeing the service as the customer sees it.

Table 4.7 summarises the strengths and weaknesses of locating supervisors out on the road versus in depots to intervene and improve performance 'on the day'.

Table 4.7 Strengths and weaknesses of supervisors centrally located or 'on the road'

	Centrally located	**Overt 'on the road'**
Strengths	• See the overall picture (of vehicles, drivers, schedule and maintenance plan) • Unlikely to react and to consider minor adjustments relevant	• Can see what the passenger sees • Can intervene face-to-face with drivers (and see instant reactions) • Can make minor adjustments (and may consider them important) • As a visible presence, can act as a 'control' for drivers
Weaknesses	• Cannot see what the passengers see • Control usually limited to audio (radio) communications	• Cannot see the overall plan • Cannot see driver hours implications, the maintenance plan etc • Knowing about the presence of a supervisor, some drivers may amend their behaviour accordingly

In deciding how and where to deploy supervisors for both intervention and control, managers also have to take account of two further issues:

- protocols for communication between 'on the road' supervisors and centrally located supervisors.
- the degree to which supervisors should 'intervene' compared with the degree to which they should 'monitor' and 'measure' without intervening.

In the ideal world any decisions made by 'on the road' supervisors would be authorised by 'centrally located' supervisors before being enacted: the reason for this is that the centrally located supervisors have far more information about the overall operation available to them, including matters such as the next work for the driver or the vehicle. In practice, such communication can be complicated and limited by factors such as the ratio of staff in the two different settings. Where, for example, an operator may have two or three depot locations and, say, 10 or 15 'on the road' supervisors, this can sometimes lead to the depot-located supervisors being gathered together into one central location, once the initial morning run-out of vehicles is complete. Staffing of the one central location can then be optimised compared with the number of anticipated calls.

For supervisors to intervene effectively, we compare the actions a supervisor can take when located part way along the line of route with the potential actions at a terminus point.

The actions which can be taken when located part way along a route are:

- radio their observations back to a central control
- direct one or more drivers, in a face-to-face discussion, to off-load their passengers and 'turn short' in order to fill a service gap in the reverse direction
- radio other drivers on the route to discover their whereabouts and, potentially, give them instructions.

At route terminus points – and preferably at the end of the route where congestion predominates, if that can be identified – the actions available include:

- monitor gaps in service
- monitor arrival times and lay-over time
- direct drivers face-to-face without them having to off-load passengers
- direct late running drivers to 'run empty' for part of their route so that they return to their schedule further down the route
- prevent early (or late) departures as a result of pro-active intervention.

There is some logic in locating supervisory staff at the points along a route which coincide with peak passenger loadings – although the main benefits of such supervision are to demonstrate to passengers that the operator has an interest in monitoring their services. In effect, the supervisory role also becomes a PR and 'assurance' role.

However, on balance intervention is much more likely to be successful – and with less impact on customer service (because drivers can be instructed to depart from schedule while there are no passengers on their vehicles) – when carried out at terminus points.

4.7.9 Options available to supervisors to cope with gaps in service or buses bunching

An earlier sub-section (4.6.2) described the phenomenon of bus bunching, and associated extended gaps between services, and its various causes. Supervisors intervening to manage bus bunching/extended service gaps are faced, on the day, with two different possible scenarios where they:

1 Have no spare resources available

2 Either have spare resources or are able to create them: examples could be sourcing an additional driver or, during the middle of the day, deploying an additional vehicle which was scheduled to be parked up until the evening peak (examples of deploying 'spare' resources are developed further in the next section).

The first scenario, of no spare resources available, will typically occur during peak period operations (when spare resources are scarce in any event), and when disruption is widespread.

Even in the most difficult circumstances, supervisors will have most success if:

- They are familiar with the ‘normal’ variation in traffic for the affected route(s) on different days – this will assist them in confirming that the bus bunching and consequent gaps in service are abnormal and require some extraordinary intervention.
- They have familiarity with other routes and know when the first vehicle and driver will be available after the peak period (see section 4.6.4).
- They possess a ‘pick list’ of lower priority routes on which, if they wish to, they could cancel selected services with relatively little damage to customer goodwill and thus create some spare resource: typically a ‘pick list’ may include services on very short routes or very high-frequency routes where, in both cases, the absence of the service may be less obvious because it either has little impact on distances involved or the additional waiting time involved for passengers.
- When appropriate, they can escalate the circumstances to all relevant levels within the operator’s organisation, to try to leverage additional resources – particularly if the cause of the disruption will continue for the remainder of the day.

If a supervisor cannot obtain additional resources, the challenge then is to take action to minimise the gaps with the existing resources. In practical terms, without any knowledge of the location of all vehicles along a route, a supervisor ‘on the road’ will only have the following two options:

- Sending one or more vehicles ‘out of service’ for part of their scheduled route, so that they ‘catch up’ time that they have lost and seek to regain their scheduled time. The balancing act for the supervisor is that, in instructing some vehicles to run ‘empty’ or ‘turn short’, with the intention of allowing those vehicles to regain their planned or scheduled times:
  - some additional mileage will be recorded as ‘lost’ (at least it will be ‘lost’ as ‘live’ or ‘in service’ mileage)
  - trusting that the ‘gaps between buses’ are evened out.
- In the case of a ‘headway mode’ service, this may then be followed by asking another driver to operate early, in order to reduce gaps between vehicles ‘in service’.

Again, detailed knowledge of the route will assist a supervisor in knowing when and where this decision can be made with the least possible impact on passengers.

While dealing with the circumstances of any bus bunching incident as it occurs, the experienced supervisor will also be working to establish where their next spare resources will come from. In addition to their own knowledge and familiarity, there will come a point for more significant disruptions where they will need to escalate the problem and seek assistance. Examples of assistance include:

- Deployment of additional supervisors who can assist in monitoring the situation at different points: even where vehicles are fitted with AVL equipment, additional supervisors deployed ‘on the ground’ can provide a presence to reassure passengers.
- The operator management team intervenes to assist the supervisor by creating additional vehicle and/or driver resources by, for example:
  - changing the planned maintenance programme on the day
  - changing the planned duties of non-driving staff who hold bus driving licences so that those staff become available

– ensuring that management effort and focus is given to the disruption, to provide the highest possible level of customer service in the circumstances.

Prior to the advent of AVL/RTI systems, it was difficult for operators to respond (in real time) to bus bunching problems, as they would have only an incomplete picture of the location of each bus on a route (even with on-the-road supervisors and radio communications). With the wide introduction of AVL/RTI systems (as in the three main New Zealand centres), operators are able to address any bus bunching problems considerably more effectively and efficiently. Control room-based supervisors for major operators are able to rapidly assess the situation, determine the preferred strategy and actions in the light of all the circumstances, and then radio instructions to the affected drivers, and finally monitor the effectiveness of the actions taken. As an example, NZ Bus (in Auckland and Wellington) now works in this manner to trouble-shoot bus bunching and other problems as they arise.

4.7.10 Deployment of 'spare' resources

Just as deployment of supervisors is a responsibility for operator management, so too is deployment of other spare resources.

'Spare' resources are something of an anathema to the operator, who places 'efficiency' at the top of their list of 'key deliverables'.

For vehicles**,** 'spare resource' may be defined as the number of vehicles retained in the fleet over and above those required for:

- meeting the peak vehicle requirement
- undertaking routine planned preventative maintenance
- unplanned maintenance (including corrective maintenance, breakdowns and accident repairs).

The most common situation causing a vehicle shortage will be when the number of 'spare' vehicles allocated is exceeded by the number unavailable for service as a result of accident damage, vandalism or breakdowns. It will be natural for the 'efficient' operator to set low targets for all these occurrences: if these low targets are exceeded, then the desire for 'efficiency' may result in an adverse impact on service reliability.

For drivers**,** 'spare resource' is somewhat more complicated to define. At a high level, operators may calculate a percentage of 'spare' drivers they wish to employ over and above those required to cover the scheduled work. A calculation of this kind may be as follows:

- number of drivers required to cover scheduled work (based on the roster), plus
- additional drivers required to cover annual leave plus any (budgeted) allowance for sickness absence, plus
- additional drivers required to cover any absence or failure to attend in excess of budgeted sickness absence.

At a lower level the 'spare driver' resources will depend upon:

- the number and distribution (by day and duty type) of any spare driver duties within the roster
- instructions or guidance (and any discretion thereon) provided to supervisors planning the daily operation, setting limits on the number of spare drivers they may authorise – on the grounds that each additional spare driver involves additional cost, and, if unused, additional wasted cost.

In practice, the numbers of spare drivers deployed are likely to vary according to:

- the availability of drivers – often based upon a combination of:
  - an operator relying upon drivers working overtime on a voluntary basis to cover all the work
  - an operator having a full complement of staff (in the light of both driver turnover and recruitment/training)
  - annual leave being balanced or ‘flat’ against a holiday year plan rather than ‘peaked’ at the popular times of year
  - sickness absence either in line with or below budget provision.
- managers allowing supervisors sufficient discretion to deploy spare drivers.

As is the case with spare vehicles, it will be natural for the ‘efficient’ operator to set low targets for sickness absence, driver turnover (and consequent training hours required to recruit and train new drivers) and, consequently, ‘spare drivers’ required. If any of these low targets are exceeded, then once again the desire for ‘efficiency’ can lead to an adverse impact on service reliability.

It is also the case for operators that, when seeking a cost saving (of say 0.5%), the easiest target for the saving will often be ‘spare’ resources which are only utilised for part of the time and/or not ‘planned’ to be utilised on a regular basis (as part of the ‘peak requirement’ or ‘drivers’ roster).

In larger operations one of the potential methods of combining the twin objectives of ‘efficiency’ and appropriate spare levels to assure reliability is to review deployment of ‘spare’ or ‘standby’ vehicles and drivers both within and across depots. Centralising ‘spare’ vehicles and drivers ready to act as a ‘rapid response’ unit and intervene to assist anywhere on a network can help by i) providing a clear picture of the utilisation of spare resources across the business as a whole, and hence ii) giving the opportunity to minimise the overall level of the resources required.

4.7.11 Summary of operational control and intervention aspects

This section has covered a range of possible control and intervention areas. It has covered the split between establishment of strategy and targets and delivery ‘on the day’ by supervisors, both to prevent problems and to correct problems should they occur.

Review of problems and corrective actions requires effective root cause analysis, which is a management responsibility rather than a supervisory responsibility. Only after effective root cause analysis can the appropriate long-term corrective actions be implemented.

Root cause analysis on its own will not result in ‘quick fixes’. These will only arise from effective ‘early warning systems’ together with close monitoring of leading indicators.

In practice, most operations employ supervisors to carry out their ‘close monitor’ of leading indicators. Managers, on the other hand, set out the strategy for operations and are then responsible and accountable to ensure that the strategies are followed. This section started by providing guidance on the roles for management in setting out their strategy to ‘operate the plan’ before moving on to cover supervision, control and intervention.

‘On the day’ delivery of planned schedules is a specialist task in its own right. As was indicated earlier, supervisors (and managers) generally receive faster feedback on their reliability performance – measured by the proportion of scheduled bus trips operated - than they do on punctuality. For this reason, regular root cause analysis on many bus operations concentrates on analysing reliability (proportion of trips operated), but sometimes to the detriment of monitoring punctuality.

4.8 Role and implications of real-time information for passengers

4.8.1 Overview

This section comments on the implications of real-time information (RTI) systems for service reliability and reliability perceptions and for the approach to addressing reliability problems. Its focus is on RTI provision for bus services, taking the current Wellington RTI system as a generic example.

4.8.2 Evidence on RTI impacts on bus users

Box 4.3 presents an overview of evidence (from UK sources) on bus passenger perceptions and responses to the implementation of RTI at bus stops. It covers the impacts of RTI on:

- general attitudes to bus travel
- perceptions of waiting time
- perceptions of personal security
- passenger behaviour and patronage.

Perhaps the key finding, which is supported by other studies internationally, is that the availability of RTI at bus stops results in passenger perceptions of improved reliability, reduced waiting times and greater acceptability of waiting time – in the absence of any 'objective' changes in services. In this regard, the positive impacts of RTI on passengers are similar to those resulting from an actual improvement in service reliability.

Box 4.3 Passenger attitudes to real-time information displays at bus stops – summary of British evidence

Attitudes to bus travel

- Great majority of bus users supported the provision of RTI at bus stops, whether questioned at the concept stage or after implementation.
- The main potential downside was if they had to pay for the improved information (eg through fares increase).
- Availability of RTI resulted in more positive attitudes towards bus travel in general.

Perceptions of waiting time

- In the absence of any actual changes in service reliability, the availability of RTI at bus stops resulted in changes in passenger perceptions:
  - perceived improvements in reliability
  - reductions in perceived waiting time
  - greater acceptability of time spent waiting.

Perceptions of personal security

- Majority of bus users felt that RTI provision increased their sense of personal security (both day-time and night-time) when waiting at the stop.

Changes in passenger behaviour and patronage

- Greater willingness to wait for the bus (might otherwise have walked or adopted other alternatives).
- Less time spent waiting at the stop prior to a decision to travel by alternative means.
- Greater willingness to wait for the second bus when the first bus to arrive is crowded (ie helps to even out loadings)
- Some increase in overall patronage.

Source: Warman 2003.

4.8.3 Implications of RTI for addressing reliability problems

Figure 4.5 shows the various impacts of a typical RTI scheme for bus services (taking the Wellington project as an example) on passengers and on operators/local authorities. The main initial impacts on the two groups are seen as:

- for passengers – improvements in perceived service reliability and reductions in anxiety associated with bus travel (without any objective change in services), potentially resulting in some increase in patronage
- for operators/authorities – availability of comprehensive real-time data on the location of all buses in service.

This real-time data will put the operator in a much-improved position to undertake detailed analyses of running times, their variability and causes of this. This will provide the foundation for:

- modifying timetables (on a permanent basis), to optimise running times (by route section and time of day), layover times etc to reduce unreliability
- developing tactical responses (for application on a day-to-day basis) to minimise any unreliability issues as they arise, eg by introducing reserve buses, skip-stop operation.

The implementation of such measures should further enhance user perceptions and potentially lead to increases in patronage.

The availability of the RTI system should also have some potential additional positive impacts. For example, as shown:

- It will allow the implementation of a signal pre-emption system (at low incremental cost), further improving reliability and reducing average travel times.
- It should help to create more positive attitudes towards the bus system, thus helping to secure support for further improvement measures (eg link-based bus priority measures).

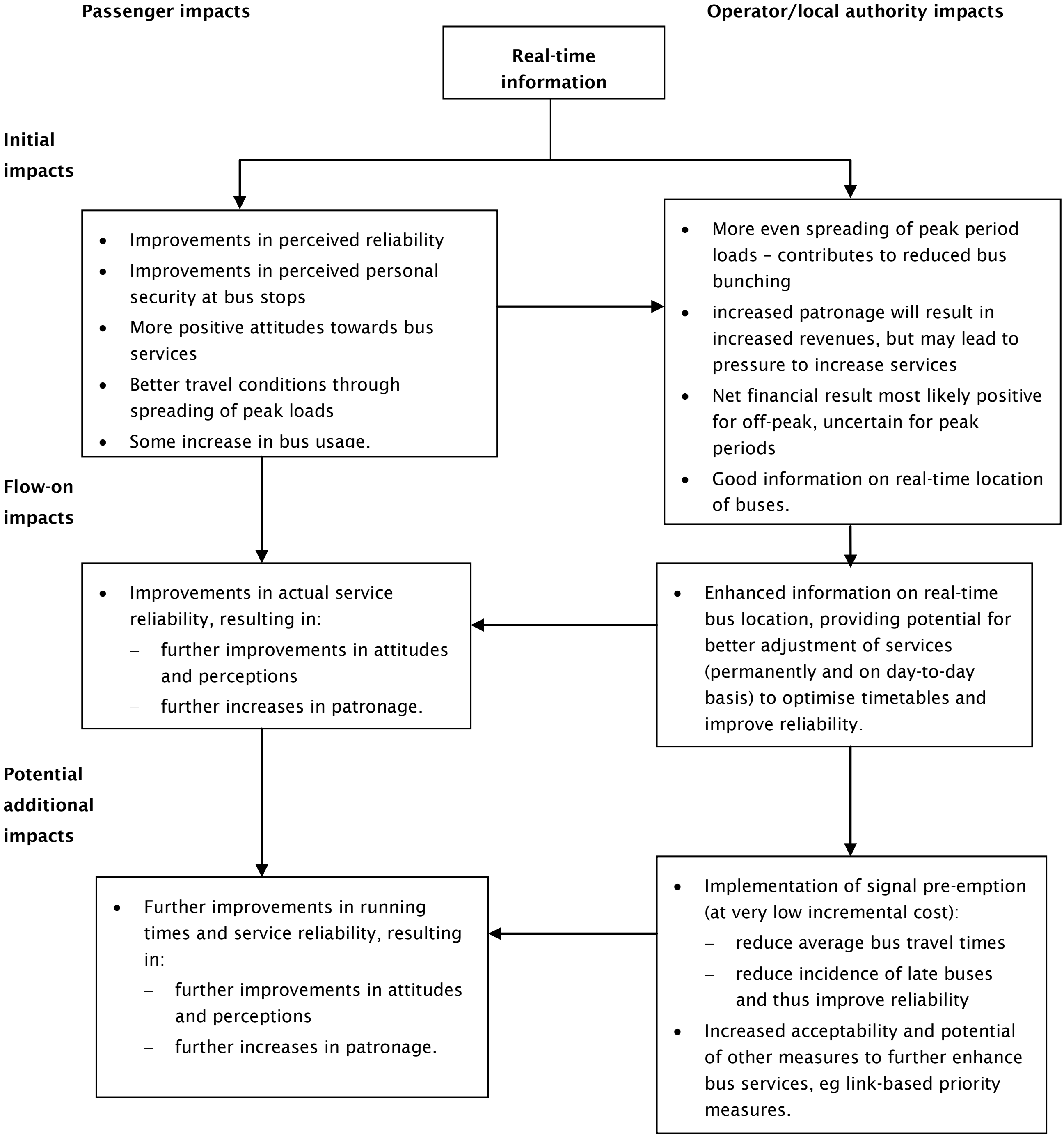
Such proposals would help to contribute to the ‘virtuous circle’ of service enhancements, more positive passenger attitudes, increased patronage, followed by increased services, etc.

In summary, we would regard RTI as an important measure in addressing bus reliability problems, as perceived by passengers, by:

- helping to improve passenger perceptions of service reliability (without ‘objective’ service changes)
- providing the comprehensive data required to assist planners/operators to modify services and develop tactical responses to improve ‘objective’ reliability.

The resulting ‘subjective’ and ‘objective’ improvements in service reliability will contribute to increasing patronage and generating more favourable attitudes to the bus services.

Figure 4.5 Impacts of real-time information for bus services



5 Conclusions and recommendations

5.1 Conclusions

This research project was intended to assist urban bus operators and planning/contracting/funding authorities in New Zealand to gain a better understanding of bus reliability and punctuality issues and how best to address them. The report has appraised reliability policies, standards and performance in the New Zealand 'big three' metropolitan regions; and has addressed the causes of unreliability, reliability standards and measurement, data collection and analysis methods, and the approaches available to tackle reliability problems through planning, timetabling and operational measures. The main conclusions drawn are summarised as follows.

5.1.1 New Zealand reliability policies, standards and performance

The project included an appraisal of New Zealand reliability policies, standards and actual performance, focused on the 'big three' metropolitan regions (Auckland, Wellington, Christchurch). The main findings were:

- Reliability (including punctuality) is one of the most important (often **the** most important) attributes of urban bus services in New Zealand, as in other countries, as perceived by users and potential users of the services. It is also one of the attributes for which perceived performance is poorest, relative to its importance. This indicates that improving service reliability warrants very high (or the highest) priority in order to enhance customer satisfaction and to increase patronage.
- Current performance standards/targets for reliability (including punctuality) differ between the three regions – in terms of both their structure and their specific standards.
- Historically, the reporting of reliability (including punctuality) performance in the three centres has been based on operator self-reporting, using manual systems, and this currently remains the case in Auckland and Wellington. With the recent availability of electronic-based information systems (using RTI/ETM data), much more comprehensive and accurate data on reliability performance is now available in the three centres.
- The project assembled recent reliability data provided by the three regional authorities from RTI/ETM data sources to show the proportions of scheduled services operating within various reliability/ punctuality thresholds. This evidence confirms that the reliability problem is indeed very significant, and that the extent of early/late running reported by operators under-states the true extent by an order-of-magnitude. Given this, it is highly desirable that Auckland and Wellington move to monitoring performance through electronic-based systems as soon as any remaining technical difficulties can be overcome.
- The NZTA has recently developed proposals for an improved PT performance monitoring regime for all regions: these include the collection of monthly data on reliability/punctuality performance at a 'unit' (route group) level, divided into peak/off-peak time periods. The NZTA also proposes changes to customer satisfaction surveys undertaken at the regional level, so as to ensure the survey results (including on reliability aspects) can be compared between regions and over time.

5.1.2 Causes of unreliability

The cause of poor reliability/punctuality in urban bus services may be classified in various ways. One high-level classification is between operator resourcing aspects (affecting whether the trip operates at all) and on-road aspects (affecting whether it operates to timetable). The former includes shortages of vehicles, driving staff and operations supervisory staff, and may also include staff quality issues. In regard to the latter, case studies indicate that the largest single causes of delays (both averages and their variability) are typically passenger boarding/alighting times, waiting at traffic signals and traffic congestion delays.

New Zealand research has also found that, in Auckland and Wellington, the current scheduled running times are often not consistent with the running time performance typically achievable, and hence the services concerned run either early or late on most occasions. This problem can be addressed relatively easily and should be given high priority.

5.1.3 Reliability performance measures and data sources

The project included an international review of literature and practices relating to a preferred ‘package’ of performance measures (indicators) to reflect the various aspects of reliability performance of urban bus systems

It was found that current reliability performance measures adopted in the main New Zealand centres are generally consistent with Australian/international practices adopted for timetabled services: these measures are currently being refined at a regional level as part of the development of new operator contracts.

The widespread availability of electronic-based information (drawing on RTI/ETM systems) in recent years is revolutionising the task of monitoring service reliability. In New Zealand as elsewhere, electronic data is becoming the main source of monitoring information, particularly for ongoing system-wide performance monitoring, with manual methods being largely limited to situations where detailed understanding of the causes of reliability problems is required.

5.1.4 Approaches to improving reliability

Efforts to improve reliability should start from a ‘root cause’ analysis of reliability problems, which will provide the evidence base for the development of effective improvement measures. The project provides an appropriate framework for such an analysis and outlines the steps involved.

Depending on the findings from the ‘root cause’ analysis, actions to address reliability problems may then be appropriate at one (or more) of three levels:

- Service planning level (medium/long term). This focuses on developing the ‘ideal’ timetable, which will minimise the probability of unreliable operation in ‘normal’ conditions, while being robust enough to allow for the expected variability around ‘normal’.
- Operational planning level (short/medium term). This involves formulating operating plans to optimise the services in response to short/medium term problems that have arisen or are anticipated.
- ‘On-the-day’ level (immediate). This focuses on rapid, effective and efficient responses to unanticipated problems as they arise, so as to minimise any adverse effects on the reliability of the operations.

5.2 Recommendations

To support and enhance efforts to improve bus service reliability in New Zealand’s urban centres, the following main recommendations are made:

- Current efforts (principally in Auckland and Wellington) to derive high-quality information on reliability and punctuality using automated (GPS-based) data sources should be continued as a high priority. Once this approach is sufficiently proven, the current system of operator self-reporting of reliability performance should be replaced with the GPS-based estimates.
- Using the GPS-based information, high priority should be given in the main (and other) regions to establishing and implementing optimum running times (by route section and overall trip), by day/time period, having regard to patterns of running time variability.
- New operator contracts should include and apply incentives/penalties on operators to improve service reliability, while recognising that it is affected by a number of factors beyond the control of operators.
- Tackling reliability problems needs to be very much a joint endeavour between regional authorities and their operators. Some form of ‘quality partnership’ between the two parties would be appropriate to develop, implement and monitor ‘reliability plans’ on an ongoing basis. Such a partnership could also act as a focus for disseminating knowledge on reliability issues across the regions, so as to provide the basis for developing and continuously improving New Zealand ‘best practices’ on the topic.

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Appendix A: Importance of service reliability to bus users

Table A.1 following provides a summary of some of the international market research evidence on the importance that bus users place on service reliability/punctuality. It is provided in support of the text given in section 2.3 of the main report.

Table A.1 Importance of service reliability to bus users – summary of survey evidence

Reference	Market segment	Findings
Auckland Transport 2012a	PT users/ potential users	Surveys and research show that the most important consideration for public transport users – and potential users – is reliability: a trip leaves on time and arrives at (or very close to) the scheduled time. This is even more important when connections are to be made with other services.
Premium Research 2011	Wellington region residents	Random household survey for GWRC PT satisfaction monitor 2011. • 'We know from previous surveys that reliability is consistently regarded as the most important service attribute.' • 'Satisfaction with reliability is still at mediocre levels, and has dropped for all modes in 2010: among recent users, 59% were satisfied with the reliability of bus services, 29% with train services, 78% with ferry services.'
GWRC 2007b (quoted in IWA 2007)	Survey of Wellington region residents and businesses	Respondents were asked about the relative importance of various journey attributes in influencing their choice of mode. For the resident sample, 90% said that 'reliability of journey time' was either very important or quite important: this was the highest rating among 8 attributes covered. For the business sample, 91% said reliability was very/quite important, the second highest attribute rating (after safety).
GWRC 2007a (quoted in IWA 2007)	Survey of Wellington bus users	Respondents who had used bus services within the previous 3 months were asked about i) the importance of various attributes in encouraging their bus use; and ii) their rating of the bus service performance on these attributes. Of 26 service-related attributes, the two that were given the greatest importance were 'reliability of the service' and 'buses arrive/leave on time'. These two attributes also had the greatest shortfalls between performance and importance, indicating that they should be given high priority for improvement to enhance customer satisfaction and to increase patronage.
ITSRR 2009	Sydney bus users	88% considered that 'buses keeping to timetable' was important/v important.
Balcombe et al 2004 (quoted in Currie et al 2012)	UK bus users	Reliability explained 34% of passengers' overall service quality rating.
Balcombe et al 2004	UK PT studies of travel choice behaviour	'Punctuality, reliability and dependability of a transport system are rated by users as very important features, affecting both their perceptions and levels of use for different modes.'
TRRL 1980	UK PT studies	'The basic attributes (of PT services) can be grouped under six general headings, with the most commonly observed relative ranking, in order of decreasing importance, being: 1) Safety, 2) Reliability, 3) Door-to-door speed, 4) Cheapness, 5) Convenience, 6) Comfort. 'Safety (from traffic accidents and personal assault)

Reference	Market segment	Findings
		is a 'passive' attribute: while people give it high priority, provided the system is perceived as safe, people will often take it for granted. 'Reliability' almost invariably ranks highly – it impinges on travel times through its effect on waiting times and arrival times.'
	US work trips by PT	An attitudinal study of PT attributes found that 'reliability' (vehicles operating on schedule) was more important than all the other 17 attributes except one (high service frequency, to reduce waiting) and ranked slightly higher than safety (from physical injury or crime) attributes. A study by Recker and Golob (1976) grouped attributes into composite factors and developed a mode choice model as a function of these factors. For bus travel, found that a composite 'bus service factor' (including waiting time ,availability, dependable arrival time) accounted for 20% of the overall variability in the attribute ratings; this service factor was the only aspect of bus travel found to be statistically significant in explaining journey-to-work mode choice.
UK DfT 2010	UK bus users	'Surveys of passengers (and potential passengers) regularly show that their major concern is punctuality and reliability'. 'Surveys have shown that punctuality and reliability are major concerns among actual and potential bus users, ahead of issues such as comfort, cleanliness and driver attitudes'. 'It is essential for passengers that the bus turns up, is reasonably on time and arrives at the destination when expected'
Bates et al 2001 (quoted in Mazloumi et al 2008)		Reliability has been identified as a more critical factor to PT riders than reducing travel time.
Morpace International 1999 (quoted in Mazloumi et al 2008)		Reliability of PT service has been identified as one of the 10 most important determinants of quality of service.
Evans et al 2004	US PT users	Surveys of commuters (Baltimore, Philadelphia) found 'arrival at intended time' to be perceived as the second most important attribute for work trips: only 'arrival without accident' was judged by respondents to be more important out of over 35 attributes listed. Similar surveys (Boston, Chicago) placed 'arrival at intended time' above travel time, waiting time and cost measures. For non-work trips reliability was judged not as important, although it still ranked eighth on the list.

Appendix B: Reliability indicators and standards – selected countries and cities

B1 Overview

This appendix summarises information on urban bus service reliability/punctuality indicators and standards in three countries, with which New Zealand is often compared on transport issues:

- Australia – standards adopted by the various state authorities in relation to their capital cities/metropolitan areas
- Great Britain – national reliability/punctuality standards set for bus services (outside London)
- United States – reliability level of service (LOS) standards suggested by Federal agencies (Transportation Research Board).

Section B5 sets out punctuality indicators and standards adopted by a selection of major bus operators in developed world cities internationally.

B2 Australia

Table B.1 sets out reliability/punctuality performance information for the five main Australian metropolitan areas/state capital cities, under the following headings:

- the measures indicators adopted
- the standards (thresholds or targets) defined for these indicators
- the performance achieved (recent data)
- notes on monitoring methods (where available).

B3 Great Britain

Table B.2 sets out national reliability standards for British bus services, as specified by the Department for Transport and enforced by the Traffic Commissioners.

These standards do not apply in London.

B4 United States

There are no national standards that are monitored/enforced in the USA. However, the Transportation Research Board (TRB) specifies a set of LOS standards for ‘frequent’ and ‘timetabled’ services, using similar performance measures to those adopted in GB. These are presented in table B.3 (Kittleson et al 2003a).

Note that the emphasis here is on defining LOS standards for bus service punctuality, analogous to the LOS standards defined for road traffic.

Table B.1 Australian metropolitan bus service reliability/punctuality indicators, standards and performance

	Melbourne	Sydney (Sydney Buses)	SE Queensland	Perth	Adelaide
Punctuality (on-time performance)					
Indicator	% of operated services within window 2 mins early – 5 mins late at end of trip	% of operated services within window 0 mins early – 5 mins late at selected points on the network	% of operated services within window 2 mins early – 6 mins late	% of operated services within window 0 mins early – 4 mins late at any timing points along route	% of operated services within window 1 min early – 5 mins late at any timing points on route
Standard	?	?	90% of services within window	?	?
Recent performance	94.0% within window (12 months to March 2012)	88.9% within window (February/March 2012, average of 4 regions)	99.5% March Q 2012; average 99.3% over 12 months to March 2012	3 months to June 2012 72.3% average; 12 months to June 2012 89.7% average	Q1 2012 (by contract): SouthLink 79.8%/ 72.4% /70.4% Light City 66.9%/51.6%, TT 65.8%
Notes	Believed to be based on operator self-reporting No financial incentives or obligations to compensate passengers for poor performance.	Performance based on new definitions/methodology defined by TfNSW (survey 0600–2200, 3 days/month, 11 locations across network) Previous indicator related to time at start of trip only	Not clear where indicator to be measured (start/end trip?)	Derived from AVL system (?)	Information available on breakdown of early/late running by number of minutes
Reliability (cancellations)					
Indicator	% of scheduled services operated and completed (on any one day)	% of scheduled services operated			% of scheduled services operated
Standard	99%	99.75%			100% (?)
Recent performance	>99.9%	99.92% (March Q 2012)			Q1 2012 (by contract): SouthLink 100.0%/99.5% /99.7% Light City 98.6%/98.1%, TT 99.7%
Notes	Believed to be based on operator self-reporting(?) No financial incentives or	Data sources unknown	Not available for bus (not in Tracker publication)?	No figures readily available	

	Melbourne	Sydney (Sydney Buses)	SE Queensland	Perth	Adelaide
	obligations to compensate passengers for poor performance.				
Sources	PTV (2012) Track record, March quarter 2012	State Transit (2012) Quarterly performance report, January–March 2012	TransLink (2012) TransLink Tracker 2011–2012 Q3	Transperth (2012) System reliability statistics	www.adelaidemetro.com.au/bus-service-report (accessed 17 August 2012)

Table B.2 GB bus reliability standards

Item	Frequent services	Timetabled services
Definition	Frequent service – service intervals 10 mins or less (individual timings do not need to be specified as part of service registration).	Services with lower frequencies, outside the definition of 'frequent' services.
Punctuality (on-time running)		
Start of trip	On at least 95% of occasions six or more buses will depart within any period of 60 mins, and the intervals between consecutive buses will not exceed 15 mins.	95% of buses will depart (from start of route) within the' window of tolerance' of between 1 min early and 5 mins late.
Other timing points	Performance mentoring to be based upon the Transport for London concept of excess waiting time. This is the difference between the average waiting time actually experienced by passengers and the waiting time which is expected from the schedule. The target to be applied is that buses which are scheduled to run frequently are expected to operate regularly, ensuring that excess waiting time does not exceed 1.25 minutes.	The absolute minimum standard which an operator will be expected to attain is that 70% of buses will depart within the 'window of tolerance'. Operators who fail to achieve this minimum standard of performance can expect to be subject to penalties imposed by Traffic Commissioners under section 155 of the Transport Act 2000, and these may be at the upper end of the scale. This approach is likely to apply where the operator cannot establish the existence of a reasonable excuse.
Reliability (cancellations)	Standard to operate at least 99.5% of scheduled mileage, after allowing for trips not run as a result of circumstances outside the operator's control. This standard appears to be the result of an agreement between DfT and the CPT (outside the regulations set by the Traffic Commissioners).	As for frequent services.

Source: UK Department for Transport 2010

Table B.3 USA (TRB) punctuality level of service standards

<table>
<tr><th>Item</th><th>Frequent services</th><th>Timetabled services</th></tr>
<tr><td>Definition</td><td>Applies to services operating at headway of 10 minutes or less.
Based on headway adherence measure using the coefficient of variation of headways.
C_{vh} = standard derivation of headway variations from schedule mean scheduled headway</td><td>Applies to routes with a published timetable, particularly to those with headways longer than 10 mins.
Based on the proportion of trips that are ‘on-time’, within a window 0 minutes early – 5 minutes late (applied to arrivals or departures, as appropriate).</td></tr>
<tr><td>Level of service standards</td><td>
<table>
<tr><th>LOS</th><th>C_{vh}</th><th>$P(h_1 > 0.5\ h)$</th><th>Comments</th></tr>
<tr><td>A</td><td>0.00–0.21</td><td>≤1%</td><td>Service provided like clockwork</td></tr>
<tr><td>B</td><td>0.22–0.30</td><td>≤10%</td><td>Vehicles slightly off headway</td></tr>
<tr><td>C</td><td>0.31–0.39</td><td>≤20%</td><td>Vehicles often off headway</td></tr>
<tr><td>D</td><td>0.40–0.52</td><td>≤33%</td><td>Irregular headways with some bunching</td></tr>
<tr><td>E</td><td>0.53–0.74</td><td>≤50%</td><td>Frequent bunching</td></tr>
<tr><td>F</td><td>≥0.75</td><td>>50%</td><td>Most vehicles bunched</td></tr>
<tr><td colspan="4">Note: Applies to routes with headways of 10 minutes or less.</td></tr>
</table>
</td><td>
<table>
<tr><th>LOS</th><th>On-time %</th><th>Comments</th></tr>
<tr><td>A</td><td>95.0–100.0%</td><td>1 late transit vehicle every 2 weeks (no transfer)</td></tr>
<tr><td>B</td><td>90.0–94.9%</td><td>1 late transit vehicle every week (no transfer)</td></tr>
<tr><td>C</td><td>85.0–89.9%</td><td>3 late transit vehicles every 2 weeks (no transfer)</td></tr>
<tr><td>D</td><td>80.0–84.9%</td><td>2 late transit vehicles every week (no transfer)</td></tr>
<tr><td>E</td><td>75.0–79.9%</td><td>1 late transit vehicle every day (with a transfer)</td></tr>
<tr><td>F</td><td><75.0%</td><td>1 late transit vehicle at least daily (with a transfer)</td></tr>
<tr><td colspan="3">Note: Applies to routes with a published timetable, particularly to those with headways longer than 10 minutes. ‘On-time’ is 0 to 5 mins late, and can be applied to either arrivals or departures, as appropriate for the situation being measured. Early departures are considered on-time only in locations where no passengers would typically board (eg towards the end of a route). Individual’s perspective, based on 5 round trips per week.</td></tr>
</table>
</td></tr>
<tr><td>Interpretation</td><td>At LOS ‘A’, service is provided like clockwork, with very regular headways. At LOS ‘B’, most vehicles are off the scheduled headway by a few minutes, but the probability of being off headway by more than one-half the scheduled headway is low. At LOS ‘C’, vehicles are often off headway with a few headways much longer or shorter than scheduled. Headways between vehicles at LOS ‘D’ levels are quite irregular, with up to 1 in 3 vehicles one-half a headway or more off headway. Bunching occurs frequently at LOS ‘E’ and most vehicles are bunched at LOS ‘F’.</td><td>At LOS ‘A’, passengers experience highly reliable service and are assured of arriving at their destination at the scheduled time except under highly unusual circumstances. Service is still very reliable at LOS ‘B’ but an average passenger will experience one late transit vehicle per week (based on 10 transit trips/week). At LOS ‘C’ an average passenger will experience more than 1 late vehicle per week on average. At LOS ‘D’ and ‘E’ passengers become less and less assured of arriving at the scheduled time and may choose to take an earlier trip to ensure getting to their destination by their desired time. At LOS ‘F’, the number of late trips is very noticeable to passengers.</td></tr>
</table>

Source: Kittleson & Associates et al (2003a)

B5 Performance measures used by major bus operators

Table B.4 presents a summary of 'regularity' indicators adopted by major international bus operators that are members of the International Bus Benchmarking Group (IBBG) (Trompet et al 2011). This summary focuses on 'headway' (high frequency) services, for which indicators of regularity are most appropriate (refer table 2.2).

In regard to this group of operators:

- The majority adopt the 'wait assessment' indicator (refer table 2.3, item B2.5a). The last column in the table indicates the target range of actual headways, relative to the scheduled headway, within which all services are expected to operate.
- Two operators adopt the 'service regularity' indicator (table 2.3, item B2.5b). This is a variant of the 'wait assessment' indicator, with the target range being expressed as a percentage of the scheduled headway rather than within a range expressed in minutes (±).
- One operator, London Buses, adopts the excess wait time (EWT) indicator (table 2.3, item B2.4). Route-specific standards for maximum EWT are set, to recognise the difference in circumstances between routes (eg levels of congestion, route lengths).
- The remaining four operators in the study adopt various measures reflecting variations in bus departure times from the scheduled times, either just at the start terminus (Dublin, Sydney) or along the route (Los Angeles, Montreal)[18].

Table B.4 Case study of regularity indicators – IBBG bus operators (2009)

Type of regularity indicator used	Bus operator	Standard for 'regular' services
Wait assessment[(1)]	Barcelona TMB	H'way range: -1 to +3 mins
	Brussels STIB	H'way range: 0 to + 2mins
	Milan ATM	H'way range: -3 to +3 mins
	Paris RATP	H'way range: 0 to +2 mins
	Singapore SMRT	H'way range: -5 to +5 mins
	NY CT	H'way range: 0 to +3 mins peak, + 5 mins off-peak
	Vancouver CBMC	H'way range: -2 to +4 mins
Service regularity	Lisbon Carris	H'way range: -20% to +20%
	Vancouver CMBC	H'way range: -20% to +20%
Excess wait time	London Buses	EWT max range 0.5 mins to 2.0 mins, set on a route-specific basis
On-time performance	Dublin Bus	Measures terminal departure times (only)
	LACMTA	Measures en route times
	Montreal STM	Measures en route times
	Sydney Buses	Measures terminal departure times (only)

Source: Trompet et al 2011.

[18] It is unclear whether these measures are applied primarily to high frequency (headway) services or to all, including lower frequency services, run by these operators.

Appendix C: Case study – London Buses: reliability monitoring, incentives, performance and impacts

C1 Overview

All bus services in London are subject to route-based contracts, with operators selected through competitive tendering procedures. Over a number of years, London Buses (the regulatory authority) has moved from gross cost to net cost contracts, back to gross contracts, and more recently to ‘quality incentive contracts’ (QICs), which are essentially based on gross costs but with some strong incentive components for operators, including incentives relating to service reliability/punctuality.

This appendix provides a ‘case study’ of London’s policies, practices and experience relating to bus service reliability/punctuality aspects under the following headings:

- reliability measures and monitoring
- incentive mechanisms
- reliability performance
- impacts of reliability on passenger waiting times
- assessment of causes of unreliability and potential policies.

C2 Reliability measures and monitoring

Under its QICs, London Buses monitors both cancelled services and the timeliness (reliability) of the services operated, and also provides financial incentives to operators according to the reliability achieved (London Assembly 2006).

London Buses measures reliability in terms of quality of service indicators (QSIs), a system which endeavours to measure reliability as experienced by passengers waiting at bus stops. There are two types of measurement, depending on whether a route operates on a low frequency (every 15 minutes or more) or on a high frequency (every 12 minutes or better).

Many passengers using a low frequency route will have a good idea of when the next bus is due to arrive and will arrive at the bus stop in the expectation of catching a particular departure. As a result, reliability is assessed in terms of ‘on time’ performance. In terms of QSIs, a bus is assumed to have arrived on time if it arrives within a window of 2.5 minutes before or five minutes after the scheduled time.

When using high-frequency routes, passengers tend not to consult a timetable but instead turn up at the bus stop in the expectation that a bus will arrive shortly. In order to measure this type of usage, EWT is used. It is calculated by measuring the difference between average actual waiting times against scheduled waiting times. The formula takes into account the fact that late buses will have more passengers waiting for them.

The reliability standard for each route is determined partly by a formula which takes into account the operating conditions and the length of the route (it is assumed that a longer route is more difficult to operate than a shorter one). In addition, the reliability history of a route is taken into account when setting the standard.

Service cancellations (lost kilometres) are also monitored. Operators are required to self-report on services not operated, with reasons (eg traffic, driver shortages, mechanical problems). London Buses carry out detailed audits of operators to ensure the accuracy of these self-reporting procedures.

C3 Incentive mechanism

Performance bonuses are payable to operators based on the observed reliability against the standard for that route. Depending on performance, operators may earn a bonus of up to 15% or a penalty of up to 10%. This system was designed to show operators that London Buses wished to promote good performance rather than simply clawing back money from poor performance.

The mechanism is illustrated, for a low frequency route, in table C.1. For such a route, every 2% improvement in the on-time figure over the standard results in a bonus of 1.5% of the annual contract price, while every 2% below the standard results in a deduction of 1% of the contract price.

It is assumed for the purposes of illustration that the route has an on-time standard of 75% (ie 75% of trips operate within the window of 2.5 minutes before to five minutes after the scheduled time). The maximum bonus of 15% is earned for reliability performance of 95% or over; while the maximum deduction of 10% applies to any performance of 55% or under. The actual payment is settled annually. If the contract were worth £2 million, the bonus could be worth up to £300,000, while the deduction could be as much as £200,000.

Table C.1 Performance against bonus/deduction

On time reliability performance	Bonus or deduction
95% and above	15.0%
93%	13.5%
91%	12.0%
89%	10.5%
87%	9.0%
85%	7.5%
83%	6.0%
81%	4.5%
79%	3.0%
77%	1.5%
75%	0%
73%	-1.0%
71%	-2.0%
69%	-3.0%
67%	-4.0%
65%	-5.0%
63%	-6.0%
61%	-7.0%
59%	-8.0%
57%	-9.0%
55% and below	-10.0%

Source: London Assembly, Transport Committee 2006.

For a high frequency route, the mechanism is similar - every 0.1 minute improvement in EWT above the standard results in a bonus of 1.5% of the annual contract price, while every 0.1 minute of EWT below the standard results in a deduction of 1% of the contract price.

Payments are calculated quarterly and are seasonally adjusted to take into account regular trends (such as the fact that traffic congestion is lighter during August and heavier just before Christmas).

As with gross cost contracts, deductions are made for any scheduled kilometres not operated for reasons which fall within the operator's control. These include staff shortages and buses not operating due to engineering issues.

C4 Reliability performance[19]

Key network level bus service reliability statistics are shown in table C.2. The percentage of scheduled kilometres that are operated has been 97% or greater for the last seven years, the 97.1% value for 2009/10 being comparable to the 97.0% recorded the previous year. Both years were affected by periods of relatively severe winter weather, as well as industrial action by drivers.

Two measures of service reliability are provided for 'high-frequency' routes (see footnote to table). Both 'actual' and 'excess' waiting times have consistently reduced over the decade – as a result of additional buses and significantly improved bus service reliability. Values for 2009/10 were closely comparable to those for 2008/09 - again reflecting best-ever performance. The use of Quality Incentive Contracts, combined with various initiatives to improve control of routes, such as the recent introduction of iBus, has helped to maintain the high levels of reliability currently being achieved.

Table C.2 Indicators of bus service reliability

	Kilometres scheduled	% of scheduled kilometres			High-frequency services ave wait time (mins)[(a)]		Low-frequency services[(b)]
Year	(millions)	Operated	Lost due to traffic congestion[(d)]	Lost due to other causes[(e)]	Actual	Excess	% of timetabled services on time[(d)]
1995/96	335	98.2	1.0	0.8	6.5	1.7	71.4
1996/97	339	97.9	1.2	0.9	6.4	1.8	70.3
1997/98	351	97.4	1.3	1.3	6.4	1.8	70.0
1998/99	355	96.9	1.6	1.5	6.6	2.0	69.0
1999/00	370	95.7	1.8	2.5	6.7	2.1	67.8
2000/01	383	95.3	2.1	2.6	6.8	2.2	67.7
2001/02	395	96.4	2.0	1.6	6.6	2.0	69.4
2002/03	425	96.1	2.6	1.3	6.4	1.8	70.5
2003/04	457	97.2	1.7	1.1	5.8	1.4	74.6
2004/05	467	97.7	1.6	0.8	5.6	1.1	77.1
2005/06	473	97.7	1.7	0.6	5.6	1.1	77.2
2006/07	479	97.5	1.9	0.6	5.5	1.1	78.1
2007/08	480	97.5	2.0	0.5	5.5	1.1	79.1

[19] Taken from Transport for London/Mayor of London 2010.

	Kilometres scheduled	% of scheduled kilometres			High-frequency services ave wait time (mins)(a)		Low-frequency services(b)
Year	(millions)	Operated	Lost due to traffic congestion(d)	Lost due to other causes(e)	Actual	Excess	% of timetabled services on time(d)
2008/09	492	97.0	2.3	0.7	5.5	1.1	80.8
2009/10	497	97.1	2.3	0.6	5.5	1.1	80.5

Source: Transport for London/Mayor of London 2010.

Notes:

(a) High frequency services are those operating with a frequency of 5 or more buses per hour.

(b) Low frequency services are those operating with a frequency of fewer than 5 buses per hour.

(c) Buses are defined as 'on time' if departing between two and a half minutes before and 5 minutes after their scheduled departure times.

(d) Also includes other lost kilometres outside the control of the operator.

(e) Includes all lost kilometres within the control of the operator.

C5 Impacts of reliability on passenger waiting times[20]

In practice, schedule reliability saves regular commuters even more time than the assumption of random passenger arrivals at the transit stop (as in table C.2) would indicate. A study of 10 bus stops in London found that where bus arrival times were consistent, passenger waiting times tended to be less than expected based on random arrivals. Passengers were benefitting by setting their arrival time to coincide with bus arrival times. Where service was inconsistent, waiting times more nearly approximated times based on random arrivals (Jolliffe and Hutchinson 1975, cited in Evans et al 2004). Table C.3 lists service reliability and passenger statistics for the bus stops with the most reliable and least reliable services of the 10 examined.

Further evidence, relating to New York, on the effects of unreliability on passenger waiting times is given in appendix D.

Table C.3 Observed London bus headway reliability and passenger wait times

	Scheduled headway	Observed headway	Standard deviation	Waiting time for random arrivals	Observed waiting time
Stop with most reliable service	23.0	23.9	2.2	12.9	5.8
Stop with least reliable service	20.3	23.5	10.7	14.0	13.1

Source: Abkowitz et al 1978, cited in Evans et al 2004.

C6 Assessment of causes of unreliability and potential policies

As show in table C.2, in recent years about 2.5% – 3.0% of all scheduled bus trips in London were not operated. Of these, around three-quarters were 'lost' due to traffic congestion and other factors outside the operator's control, the remaining quarter were lost due to factors within the operator's control. For the

[20] Taken from Evans et al 2004.

services that were operated, around 20% of the low frequency services operated outside the 'on-time' window (2.5 minutes early to 5.0 minutes late).

Table C.4 summarises investigations by the London Assembly (Transport Committee) into the factors affecting bus service reliability/punctuality and some of the policy options being pursued/considered to improve reliability performance.

Table C.4 London bus unreliability – appraisal of causes and potential policies

Headway	Description, comments	Potential policies
Staff shortages	• Applies to drivers, other operations staff, mechanics/maintenance staff. • Results from both recruitment and retention difficulties. • Also problem with staff quality re customer service etc.	• Greater flexibility in contract payment rates, with inflation linkage to average London wage rate movements. • Improve driver terms/conditions on London-wide level (eg with free travel on all London PT services). • Improved staff training and support, in part to raise the image of bus driving. • Provision of better staff facilities at depots, bus stations, layover points. • Classify bus drivers as key workers and improve access to affordable housing.
Congestion	• A major issue, cause of both lost mileage and unreliable services. • Congestion problem is spreading by both time of day/week and location. • Effectiveness of current bus priority measures reduced by inadequate enforcement.	• Implementation of whole-route priority measures to replace previous piecemeal approach. • Extension of operating times for priority measures, to 12*7 minimum. • Clearer marking of priority lanes etc. • Greater enforcement of bus lanes and associated priority regulations.
Bus boarding times	• Problem only affects one-person operation services – at the time there were proposals to double the number of conductors, but the Transport Committee had major reservations whether this would be a cost-effective approach.	• Increase the proportion of off-bus ticketing, cashless services etc. • Improve bus design to increase boarding rates. • If resources available, rather than employ on-bus conductors, preferable to increase off-bus staffing (eg selling tickets at busy stops, providing customer services at major interchanges).
Inadequate route performance supervision	• On-route supervisors had been cut back, due to lack of incentives in the (then) gross cost contracts to operate services reliably, • Automatic monitoring (AVL) and real-time (countdown) systems unreliable and lacked comprehensive coverage.	• New QICs were introduced to provide incentives for reliable operation. • Recommended improvements in AVL system to provide a higher level of bus operator and passenger confidence.

Source: London Assembly (Transport Committee) 2001.

Appendix D: Evidence on effects of unreliability on wait time (New York CTA)

The following evidence and commentary on the effects of bus service unreliability on passenger waiting time is from research undertaken by the New York CTA (Evans et al 2004).

> *Increased reliability results in actual transit vehicle arrival times occurring in a tighter distribution around the scheduled time. The range of actual vehicle arrival times at the beginning and end of a trip and at transfer points, determines the wait time, the overall travel time and the likelihood of missed connections and late arrivals that a rider faces. Maintenance of on-time service has a positive effects on riders and ridership because patrons experience less waiting time, decreased travel time, fewer missed connections, more on-time arrivals at their destinations and reduced uncertainty overall.*
>
> *Waiting times, even for a frequent service, are affected more substantially by service irregularities than the average headway achieved would indicate. Passengers of frequent services arrive more or less continually at the transit stop. Consequently, a larger number of passengers are adversely affected by long unscheduled gaps between buses and trains than are benefitted by corresponding short gaps. Table H1 lists the percentage of passenger wait time in excess of the optimum achievable with full schedule adherence, for 15 New York City Transit Authority bus routes. The passenger wait time is calculated on the basis of actual bus arrivals, assuming random passenger arrivals* (Henderson et al 1991).

Table D.1 Reliability impacts on wait time for individual New York city bus routes

NYCTA bus route	Waiting Time Index[a]	Wait in excess of optimum (%)
B46	0.58	+72
M7	0.58	72
B35	0.62	61
M4	0.65	54
BX41	0.68	47
M3	0.69	45
M16	0.66	52
M2	0.72	39
Q32	0.68	47
M34	0.68	47
M11	0.77	30
BX55	0.79	26
BX28	0.81	23
M79	0.82	22
BX30	0.95	5

Source: NY State Office of the Inspector General for the MTA, as graphed in Henderson et al (1991), with excess wait calculations by the handbook authors.

[a] The Waiting Time Index is the minimum average wait (assuming passengers arrive without reference to the schedule), divided by the actual average wait (calculated using the same assumption). The wait in excess of optimum is the actual average wait less the minimum average wait, divided by the minimum average wait, and expressed as a percentage.

Appendix E: Impacts of bus priority measures – New Zealand (Auckland) and United Kingdom evidence

E1 Overview

This appendix provides a summary of evidence on the impacts of bus priority lanes and associated measures in Auckland and selected UK cities (London, Birmingham/West Midlands and Edinburgh). it focuses on journey time and reliability impacts of those measures to the extent that this information is available.

The material presented here is largely drawn from an earlier, more detailed, appraisal of international evidence on the impacts of bus priority measures undertaken by IWA as part of work for Wellington City Council to evaluate the likely impacts of its bus priority proposals (IWA 2008).

It should be noted that the bus priority lanes are typically implemented as part of a 'package' of measures to improve conditions for bus travel, and sometimes other modes also. In many cases therefore the evaluations available relate to the whole package of measures introduced rather than the bus lanes alone.

E2 Auckland

This section presents an overview of the impacts of the bus priority programme implemented by Auckland City over the period 1998 – 2003

The results of this impact assessment are summarised in table E.1: these are taken from the annual bus lane monitoring reports prepared for the Auckland City Council (now Auckland Council), but include our interpretation of the results (particularly in matters of the statistical significance of changes in performance).

The emphasis of our assessment has been on the impacts of each bus lane scheme on travel on each road directly affected, in terms of:

- bus services – average travel times, travel time, reliability, loadings, patronage
- car travel – average travel times, traffic volumes.

The assessment of these impacts required data for both the 'before' and 'after' periods, in directly comparable form.

Of the eight schemes for which suitable impact assessment data were available, effects on travel times and/or reliability appeared to be significant in only four schemes:

- Dominion Road: quite substantial (three to four minutes) bus time savings in AM peak, and also reduced variability in AM peak bus travel times (no other effects significant).
- Mt Eden Road: small (c.one minute) bus travel time savings in AM peak (no other effects significant).
- Fanshawe Street: evidence of small increase in PM peak travel times, for both buses and cars (but statistical validity uncertain).
- Quay Street: evidence of small increase in AM peak travel times, for both buses and cars (but statistical validity uncertain).

Table E.1 Overview of Auckland City bus lane schemes

Route	Scheme introduction date	Monitoring section	Operating periods[1]	Bus impacts					Car impacts	
				Travel time	Reliability	Bus trips	Loadings	Patronage[2]	Travel time	Volumes
1 Dominion Rd	Mar 98	Mt Albert Rd – Valley Rd	AM,PM	AM: Saving 3-4 mins (c 25%) PM: No clear impact[3]	AM: Some improvement (c 30-40%) PM: some reduction?	Substantial increases since 2001	NA	Increases in order of 10% within first year[5]	No clear impact[4]	Small reduction (up to 10%)
2 Mt Eden Rd	Mar 98	Balmoral Rd – Symonds St	AM,PM	AM/PM: Saving c 1min (10%)	No clear impact	Some increases since 2001	NA	Increases in order of 10% within first year[5]	No clear impact	No clear impact
3 Sandring-ham Rd	Apr 99	Balmoral Rd – New North Rd	AM,PM	No clear impact	No clear impact	Substantial increases since 2001	NA	Increases in order of 30% - 35% in first year.	No clear impact	NA
4 Fanshawe St	July 00	Beaumont St – Nelson St	AM,PM	No clear impact (PM increase?)	No clear impact	Substantial increases since 2001	NA	?	No clear impact (PM increase?)	NA
5 Great South Road	July 00	Campbell Rd - Erin St	AM,PM (In only)	No clear impact	No clear impact	Substantial increase in 2001	NA	?	No clear impact	NA
6 Great North Road	Sept 00	Carrington Rd - Newton Rd	AM,PM	No clear impact	No clear impact	Substantial increase	NA	?	No clear impact	NA
7 Quay St	June 03	The Strand – Tangihua St	AM	Increase c.0.5 mins (c.30%)	No clear impact	Little change	Some reduction in full buses(?)	?	Increase c0.3 mins (c.25%)	NA
8 Karanga-hape Rd	June 03	Pitt St – Howe St	AM	No clear impact	No clear impact	Little change 2002 - 2004	Some reduction in full buses(?)	?	No clear impact	NA

Sources: Gravitas Research and Strategy Ltd (2004; 2007); McCoy and Knarston (2004); Collyns JNC (2001); Auckland City Council (1998; 1999).

Notes: (1) Unless noted, the 'standard' operating/survey periods are weekdays 0700–0900 (inbound) and 1600–1800 (outbound).
(2) Patronage figures involve comparison of Stagecoach data for period Nov/Dec/Jan 1998–99 with corresponding period 12 months earlier (refer ACC Buses first progress report, March 1999). It is noted that i) increased patronage is attributed to increased frequencies, improved reliability and marketing; ii) other routes in the Isthmus did not show comparable increases.
(3) McCoy and Knarston (2004) give bus travel time reductions for section Mt Albert Rd–NW Railway of: AM peak 33% (1997–98) and 26% (1997–04); PM peak 9% (1997–98) and 7% (1997–04).
(4) McCoy and Knarston (2004) give car travel time increases of 2%–3% (1997-98) and 12%–15% (1997–2004).
(5) McCoy and Knarston (2004) give patronage growth of 10% (AM peak, In), and 8% (PM peak, out) over 1997–98; and c.70% (AM peak, In) and 82% (PM peak, out) over 1997–2004. However, it is noted that this is the result of a number of other measures (especially frequency improvements) in addition to the bus lane scheme.

In only one of these cases (Dominion Road) was there clear evidence of improvements in service reliability.

The statistical confidence that can be placed on most of the before/after comparisons is rather limited, principally because in most cases very limited 'before' data were collected: for most schemes monitoring was undertaken on only one or two occasions in the 'before' period, generally for two days on each occasion. Given the day-to-day variability that is apparent in such monitoring results, a greater number of 'before' observations would have been highly desirable (with the benefit of hindsight)[21].

It might be noted that, for most schemes, no 'before' data are available for bus loadings (% full buses, etc) and for traffic volumes: hence before/after comparisons are not possible.

The Auckland City Council monitoring reports do not provide any data on bus patronage on the routes affected by the schemes. For the three early schemes, the principal bus operator (Stagecoach) did undertake some before/after patronage comparisons (from its bus boardings/ticketing system database): these indicated substantial patronage growth on the affected routes, which was ascribed to the bus lanes (refer tables E.2 and E.3).

E3 London

Table E.4 presents a summary of the two main traffic management programmes incorporating bus priority and related measures that have been undertaken in London since the mid-1990s. Both programmes involved a package of different measures: the Red Route programme was designed to improve movement for all classes of traffic, but with particular support for the movements of buses.

Both programmes have been judged as effective in improving bus travel conditions and as economically efficient. They resulted in substantial improvements in bus reliability and significant (but less substantial) improvements in overall bus journey times: the Red Route programme showed improvements of up to 27% in bus journey time reliability (and also improvements in car travel reliability); while the London Bus Initiative also improved bus reliability, with excess waiting times reducing by 15% on average.

E4 Other UK case studies

Table E.5 provides an overview of bus route improvement case studies, focussing on bus priority measures, in the West Midlands (Bus Showcase schemes) and Edinburgh (Greenways): these two cities are among the leading UK examples of taking a comprehensive approach to improving bus services on a whole-of-corridor basis.

In both cases, bus priority lanes were introduced as part of wider packages of measures to provide improved bus services. These packages have generally been successful in improving bus service reliability, improving the image of the bus, increasing patronage and inducing some modal switch from car use. Evidence on the specific impacts on bus travel times and reliability was not available.

E5 Overall conclusions from international experience

Our main conclusions from this review of experience with bus priority measures implemented in Auckland, London and other UK cities are as follows:

[21] It would also be useful if the travel time and reliability data could be broken down into, say, half hour periods within each two-hour peak, so as to provide a better understanding of any changes in performance.

Table E.2 Patronage impacts of AKL bus lane schemes 1998–2000

Time period	Growth period	Patronage growth (%) over 1998 ('before')[a]		
		Dominion Road	Mt Eden Road	Sandringham Rd
AM peak[b]	1998-99	3.9	-1.2	n/a
	1998-00	8.2	14.9	32.5
	1998-00	12.4	13.5	n/a
PM peak[b]	1998-99	12.2	10.5	n/a
	1999-00	10.7	7.3	33.7
	1998-00	24.3	18.5	n/a
Week total[b]	1998-99	11.4	23.4	n/a
	1999-00	4.4	5.4	50.0
	1998-00	16.3	30.1	n/a

Source: Collyns (2001).

Notes: [a]AM peak = 0500–0900; PM peak = 1600–1900; week total = Monday to Friday only. [b]Figures from Stagecoach NZ, relating to two-week periods in May each year.

Table E.3 Patronage impacts of AKL bus lane schemes 1998–2002

Time period	Growth period	Annual patronage growth (%)[a]		
		Dominion Road	Mt Eden Road	Sandringham Rd
AM peak	1998-99	15	18	4
	1999-00	12	16	11
	2000-01	9	1	8
	2001-02	21	5	13
	1998-02	70	45	40
Interpeak	1998-99	5	3	3
	1999-00	8	8	12
	2000-01	8	-4	7
	2001-02	32	6	15
	1998-02	62	13	42
PM peak	1998-99	18	14	7
	1999-00	10	16	11
	2000-01	11	-2	5
	2001-02	26	10	14
	1998-02	81	43	45

Source: Graphs provided by Stagecoach NZ.

[a] All figures approximate (read from graphs).

- In the appropriate situations, with-flow bus lanes can be effective in significantly improving bus travel times and reliability, without in general any significant adverse impacts on other traffic. The London schemes show that improvements in journey time reliability of up to 25%–30% may be achieved.
- Typically, such schemes will result in significant increases in bus patronage and mode switching from car travel (often substantially greater than would be anticipated on the basis of the travel time savings alone).

- Such investments typically provide good rates of return (and benefit–cost ratios) in economic terms: the main economic benefits arise from bus user time savings and reliability improvements.
- Any adverse impacts of bus lane schemes on the retail and business sectors along the roads concerned have generally been minimal or very slight (and less than sometimes feared in advance by those concerned).
- Bus lane schemes are likely to be most effective if considered as part of an integrated package of measures to increase the attractiveness of bus travel, within a ‘whole-of-journey’ approach. Such an approach should embrace access to/from the bus system, bus stop improvements, enhanced vehicle standards, increased service frequencies, real-time information, etc.

Table E.4 London Bus route enhancement programmes – summary

Item	Red Route programme	London Bus initiative (phase 1)
Objectives	• Improve movement of all classes of traffic. • Provide special help for efficient movement of buses. • Reduce adverse impacts of congestion. • Restrain car commuting into central London. • Facilitate movement for people with disabilities.	• Overall: ‘to deliver a step change enhancement of the quality of London’s bus services’. • To provide ‘a change in travel habits and increase usage of London’s buses’. • To deliver improvements on a ‘whole route’ basis. • To make buses more attractive for potential users. • To make buses the first choice of mode on routes concerned.
Summary description	• Applied to 500km principal road network in London. • Bus priority measures: – bus lanes – selective vehicle detection – bus advance areas. • Ban on stopping at bus stops. • Improved bus stop design. • Controls on parking/stopping. • Enhanced pedestrian and cyclist facilities. • Environmental and landscaping treatments.	• 27 high frequency bus routes across London selected for treatment, divided into 3 priority categories. • Over 400 route km subject to bus priority measures. • Measures included 100 new bus lanes, 50 pedestrian crossings, 300 signalled junctions with bus priority and 140 junction improvements. • Scheme involved partnership of TfL Bus Priority team, London Buses, individual boroughs, bus operators and enforcement agencies.
Implementation period	• Pilot project 1991. • Main programme 1994-1999.	• Main programme implementation 2000-2003.
Costs	• Total cost in order of £120M (1994 prices). • Bus priority measures costs c. £12M.	• Total cost in order of £60M.
Outcomes	• Bus journey times: average reduction in journey time c.10% (all time periods); journey time reliability improved up to 27%. • Car journey times: up to 20% faster and 20% more reliable. • Traffic volumes: reduced by around	• Bus reliability/passenger waiting times: excess waiting times fell by 15% average. • Bus travel times: mixed results, with little overall change on routes surveyed (results affected by improved pedestrian facilities and increased bus patronage). • Bus patronage: increased over 3-year

Item	Red Route programme	London Bus initiative (phase 1)
	5%, 1995–2000. • Parking: illegal parking fell dramatically. • Accidents: decreased by c.7% overall relative to London trends. • Retail sector: impacts appeared to be more positive than negative.	before/after period slightly more (c.2%) than on the LB network as a whole.
Economic evaluation	• Prior evaluation estimated first year rate of return in range 160%–200%. • No formal post evaluation undertaken.	• Estimated first year rate of return of around 20%.
Conclusions	• Programme judged as effective and worthwhile in terms of its benefits to all road users, especially buses, pedestrians and cyclists.	• Programme judged as highly successful. • Being followed up by an ongoing £50M programme of further route and hot-spot bus priority initiatives.

Table E.5 Bus route enhancement programmes – West Midlands and Edinburgh

Item	West Midlands (bus showcase)	Edinburgh (Greenways)
Programme overview	• Corridor-based programme to provide radical improvements to bus services, to enhance their attractiveness to new users and to assist in addressing congestion problems.	• Corridor-based programme focussed on enhanced form of bus lanes together with associated infrastructure and enforcement measures.
Objectives	• Increase attractiveness of bus services to existing and potential new users. • Improve peak period bus speeds relative to cars. • Reduce bus journey times and improve bus reliability • Increase bus patronage.	• Improve bus reliability. • Reduce bus journey times (by 30% by year 2010). • Reduce car traffic (by 30% by year 2010). • Meet EU local pollution guidelines.
Summary description	• Comprehensive corridor treatment for strategic bus routes with high demand and growth potential. • Accessible and safe pedestrian routes to/from bus stops. • Enhanced waiting environment at bus stops, including high quality shelters. • Low floor buses with accessible kerbing. • Enhanced bus service frequency ('turn up and go' basis). • Bus priority, selective vehicle detection and other measures to enhance bus speeds and reliability. • Automatic vehicle location and real-time information. • Enhanced service quality measures (bus cleaning, driver training in customer care, etc).	• Bus priority lanes along major radial routes, with green surfacing and red lines to prohibit stopping. • Dedicated enforcement team of wardens. • Better bus shelters with comprehensive bus information. • Enhanced provision for pedestrians and cyclists. • Traffic calming measures in side streets.

Item	West Midlands (bus showcase)	Edinburgh (Greenways)
Implementation period	• Initial scheme introduced 1997. • A further eight corridors now completed.	• First two schemes (subject to monitoring) implemented in 1999.
Costs	• Capital expenditure to date in the order of £25 million.	• Capital expenditure approximately £500,000/km (compared with approx £100,000/km for conventional bus lanes).
Outcomes	• Completed Showcase routes have mostly achieved patronage increases in the range 10%-30%, with mode shift in the order of 5% from car.	• Scheme effective in protecting buses from congestion and improving reliability. • Generally small decrease in volumes of other traffic on these routes. • Modest (order of 5%) increase in bus patronage.
Economic evaluation	• N/A	• N/A
Conclusions	• The Showcase concept is generally regarded as successful: bus reliability has been improved, the image of bus services has been improved, bus patronage has increased and modal transfer of around 5% has been achieved.	• Schemes seen as successful in improving quality and image of bus services. The programme has been extended to additional corridors.

Appendix F: Glossary

AO	approved organisation
AT	Auckland Transport
AVL	automatic vehicle location: a system, usually linked to GPS, which flags up the geographical position of vehicles
AWT	average actual waiting time: the average time passengers actually have to wait at a bus stop for a service which is advertised as operating in 'headway mode' (assuming that passengers arrive randomly and evenly at the stop)
BPF	the UK Bus Partnership Forum, formed in 2003, was arranged to bring together senior representatives from the UK bus industry, central and local government
BRT	bus rapid transport
CJTD	customer journey time delay
CP	contingency plan
CV	coefficient of variation
DfT	Department for Transport UK
ETM	electronic ticket machine
EWT	excess waiting time, ie difference between actual waiting time (AWT) and scheduled waiting time (SWT)
GMPTE	Greater Manchester Passenger Transport Executive
GPS	global positioning satellite technology
GWRC	Greater Wellington Regional Council
Headway mode	Where an operator sets out to provide even intervals between departures on a service and advertises the service according by advising the customer about the intervals
IBBG	International Bus Benchmarking Group
IVT	in-vehicle time
KPI	key performance indicator
LOS	level of service
Performance Monitoring TFG	a 'task and finish' group set up by the BPF (UK) to study the performance of bus services and make recommendations for improvement
PT	public transport
PTOM	public transport operating model, a procurement/contracting model to be introduced for the NZ bus and ferry sector
QIC	quality incentive contract
QSI	quality of service indicator
RA	regional authority (New Zealand)
RTI	real-time information: effectively this means real-time information about vehicle locations, as provided by AVL

RTPI	real-time passenger information
Scheduled service mode	Where an operator sets out to operate a service in accordance with a precise schedule (timetable), advertising specific times at different point along the route
SD	standard deviation
SP	stated preference
SWT	Scheduled waiting time: the time passengers would wait, on average, for a service running in headway mode exactly according to schedule. SWT is equal to half the service headway, assuming that passengers arrive randomly and evenly
TfL	Transport for London
TTV	travel time variability
Unit	in the PTOM context, a collection of routes that are ‘bundled’ within a single contract.