Gap acceptance road safety modelling: pilot study

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An important note for the reader

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We also acknowledge the assistance of Christchurch City Council in providing crash and traffic flow data for the chosen pilot sites in Christchurch.

Abbreviations and acronyms

Beca	Beca Infrastructure Ltd
CCC	Christchurch City Council
LTMA	Land Transport Management Act
NZTA	NZ Transport Agency
RCA	Road Controlling Authority

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Executive summary

This gap acceptance road safety modelling pilot study was undertaken for the NZ Transport Agency by Beca Infrastructure Ltd (Beca) between September 2008 and June 2010. The aim of this research was to develop an alternative approach to crash prediction modelling that focused on evaluating the crash risk at urban high-volume priority-controlled intersections. The existing crash prediction models for priority-controlled intersections are not appropriate for higher-volume intersections, where gap availability is limited and the crash risk is increased. The anticipated output from this modelling was a tool that local authorities and NZTA could use to evaluate when the crash risk at such intersections reaches a level where modifications to intersection layout are required. This would allow the local authority and the NZ Transport Agency to be proactive in terms of making and requiring intersection upgrades.

It became apparent during the early part of the study that it would not be possible to collect data from enough sites to establish the relationship between gap selection and crash occurrence. Hence, the focus in this stage of the project was to pilot the methodology that would be used in a future stage, which would involve a lot more data collection, to build the safety models.

The pilot study presented in this report includes:

- development of safety modelling methodology
- site selection
- pilot crash analysis
- pilot data collection
- pilot data analysis
- an outline of the next steps for the development of a model.

An initial framework for the development of safety models has been set out as part of this study. Model development to date has included the derivation of a probability distribution function for vehicle headways, and development of an algorithm for identifying the functional relationship between gap acceptance and waiting time.

Sites were selected based on the number of recorded crashes that had occurred in the previous five-year period. The aim was to identify at least 100 high-volume urban priority-controlled intersection sites, located on two-lane arterial and collector roads. The site selection process involved identifying possible sites in major cities throughout New Zealand and selecting the most suitable sites. The pilot study was then undertaken using eight Christchurch sites. Finding urban priority-controlled intersections on two-lane roads with a high crash rate proved to be the most difficult task in the research project – high crash-volume sites have often already had intersection improvements, including changes in the form of traffic control, and finding appropriate sites often requires local knowledge.

During the pilot data collection, the basic road layout and geometry of the sites were recorded. A one-day snapshot video analysis was undertaken between 7.30am and 8.30am to record the headway and accepted gap at the pilot study sites. In cases where the predominant right-turn traffic flow was in the pm peak, afternoon surveys were also completed.

The video data was analysed and the following information was recorded:

- time of arrival of the vehicle waiting to make a right turn
- observed waiting time

- accepted gap taken by drivers
- observed turning times
- headways of traffic stream.

The intention was to compare the selected gaps with the crash history of each site. A range of gap profiles was observed between the datasets for each site. At the majority of the sites, a delay of 4 seconds or less was observed. However, sites with higher traffic volumes on the main through-route showed longer delays. In these cases, the majority of drivers waited between 8 and 14 seconds, and some vehicles waited more than 25 seconds.

The lack of a clear trend between crashes and gap acceptance revealed the need for additional data collection. It is suggested that future studies use larger sample sets of at least 100–150 sites. Streamlining the data analysis process by automatically processing the data (using machine vision) would significantly reduce the analysis time required to complete further site analysis.

Abstract

A key problem for local authorities is the lack of robust techniques for evaluating crash risk at high-volume, urban, priority-controlled intersections. Some crash prediction modelling tools are available, but they do not accurately predict crash rates at the higher-volume priority-controlled intersections, where at times, there are limited gaps in main road traffic flows, which often gives rise to safety problems. This research project aimed to develop safety models that would enable practitioners to better understand crash risk at urban intersections.

Video data was collected at eight Christchurch sites for the peak traffic periods. The data was analysed to measure vehicle headway and the gap acceptance profile (bell graph) of drivers making two movements – the right turn in and the right turn out. This pilot study established a framework procedure and presents the results from the data analysis.

Further work is required to collect data from a larger sample of priority-controlled intersections across New Zealand. Ideally, automated analysis of video data would be applied. Using this additional data, the development of a safety model linking gap selection and crashes should be possible.

1 Introduction

1.1 Background

A concern of transportation engineering professionals is the issue of traffic volumes at priority-controlled intersections at which the crash risk has increased to an unacceptable level, thereby justifying an upgrade to a roundabout or traffic signals, on a safety basis. This problem provides an important reason to undertake road safety research.

In fact, there is an urgent need for research in this area, as it is difficult in the current environment, particularly in new developments, to ascertain exactly when an intersection needs to be upgraded due to safety concerns – especially if the issue is brought to the Environment Court. If we are to safely manage our road networks (sustainable road safety), as required under the Land Transport Management Act (LTMA), then we need the evidence to back up the requirement to upgrade intersections.

There are several existing crash prediction models for urban and rural intersections. These crash prediction models relate the crash rate to certain explanatory variables such as traffic volume, speed and road geometry, among others, and are based on applying curve-fitting methodologies to observed data.

The predictive equations obtained from these models are limited by the ranges and quality of the data collected. For example, applying these models to road sections or intersections of especially high volumes amounts to an extrapolation of the original data. Secondly, curve-fitting methodologies, at a fundamental level, reflect correlation and not necessarily causation. This issue becomes especially important in crash prediction in general, since there is often a significant degree of correlation among the explanatory variables themselves. Thirdly, there is no inclusion of driver behaviour in the existing models.

The importance of this research is particularly relevant to Road Controlling Authorities (RCAs) in their efforts to manage and mitigate the safety impacts of new developments, particularly on the rural road network. RCA's will increasingly be looking to pass the costs of such mitigation measures onto developers and need good quality research to back up the design and developer contribution policies. Beca Infrastructure Ltd (Beca) has experience working with the RCAs in this area, and currently finds it difficult to provide strong evidence for intersection upgrades on safety grounds, other than a monitoring clause that requires intersections to be upgraded if the number of crashes exceeds a threshold after five years or so. This is very much a reactive approach to the problem, whereas good planning requires a proactive approach. Also, it is highly possible that the developer may have moved on after five years and that the cost of upgrades will then fall on the RCAs, which have a limited pool of funding.

1.2 Research scope and objectives

The following sections describe the objectives of this project, which was undertaken by Beca Infrastructure Ltd (Beca) for the NZ Transport Agency between September 2008 and June 2010.

1.2.1 Overall study objectives

The overall objective of this research was to build an alternative approach to crash prediction modelling that focused on the practical causes of crashes and as such, would counter and complement the existing approach.

It was expected that this would be achieved by investigating high-volume priority-controlled intersections, especially in urban areas with a large proportion of privately owned commuter vehicles. In particular, the research considered the turning movements across and into the major flow of traffic. These movements corresponded to the two crash types for which the study aimed to investigate and produce models.

The approach proposed for this research involved consideration of the gap acceptance shown by drivers at intersections with high opposing traffic volumes. This was expected to enable development of causative models for predicting crash rates in these contexts, based on:

- the distribution of headways (in the opposing flow) and its dependence on traffic volume and urban context
- the dependence of gap acceptance on waiting time and the opposing traffic volume – this varies by driver as some drivers (eg less experienced drivers) prefer bigger gaps
- stochastic combination of headways and gap acceptance.

The mathematical models formulating these distributions and relationships would be based on observed data on following distances and gap acceptance from high-volume urban areas of New Zealand. To fulfil these objectives, it was envisaged that data would be collected for 50–100 priority-controlled intersections in New Zealand.

1.2.2 Modifications to the study objectives

A number of significant issues were encountered by the project team during the course of this study. These included insufficient suitable sites, and constraints with respect to the budget available and effort required for data processing.

In view of the above limitations, the scope for this study was modified, in consultation with the NZTA, in order to reflect what was practically achievable within the allocated time frames and budget.

The study objectives were thus realigned to focus on providing a base and methodology for further work to be undertaken in future studies. In view of this realignment of objectives, it was decided to treat this study as Stage 1 (Pilot study) of broader research that would aim to fulfil the objectives described earlier.

1.2.3 Pilot study objectives

The amended objectives of the Pilot study were as follows:

- Develop a suitable data collection methodology that will enable the achievement of the data collection aims of the overall study.
- Undertake gap acceptance surveys at eight priority-controlled intersections in Christchurch.
- Analyse the data collected from the eight sites to identify trends in headways, waiting times and accepted gaps.
- Undertake a basic crash analysis to highlight the relationships between gap acceptance and crashes at the selected sites.

1.3 Report structure

This report is divided into the following sections:

- Section 2 summarises the discussions from the project steering group meetings.
- Section 3 describes the research methodology.
- Section 4 details the site selection procedures and introduces the selected sites.

- Section 5 provides an overview of the data analysis undertaken.
- Section 6 presents results for each of the eight selected sites.
- Section 7 contains the results from the crash analysis.
- Section 8 summarises progress made in this study and highlights the next steps for future studies.

2 Steering group meeting

To formally start the research project, a workshop meeting was undertaken with the steering group. The meeting was held over videoconference on 24 October 2008. Shane Turner and Alistair Smith of the study team provided a presentation on the research proposal and facilitated discussions with the group's members. The steering group members who attended the meeting were David Croft, Sandy Fong (NZTA), David Gamble and Tony Spowart (NZTA). The following members put in apologies: Tim Cheesebrough (Christchurch City Council), Stanley Chesterfield (NZTA), John Jansen (NZTA), David McGonigal (NZTA), Bhagwant Persaud (Lyon and Persaud Inc) and Fergus Tate (NZTA).

The objective of the meeting was to present the research to the steering group members to bring them up to speed on the study's objectives and methodology, and then engage in a discussion to workshop any issues, ideas or concerns raised by members.

The meeting proved to be a valuable opportunity to address aspects of the research, particularly data collection. Discussion included site selection issues, and various selection criteria were identified and information provided on likely problems and opportunities.

Members of the steering group also discussed the proposal's methodology, particularly relating to data collection. Various issues and potential problems with the proposed methodology were raised.

The meeting's key objectives of allowing a discussion of the research methodology, increasing the participants' familiarity with the research topic and accessing the knowledge and experience of the steering group members were achieved.

3 Research methodology

3.1 Methodology overview

The methodology outlined below was developed in order to ascertain the distribution of following times in the major traffic flow, as well as driver behaviour with respect to the acceptance of gaps in that flow for two key turning movements.

Suggestions from the steering group relating to site selection were incorporated into the site selection process. However, the study team had difficulty finding a sufficient number of appropriate sites. This also resulted in some rethinking of the methodology, with the inclusion of a pilot survey of two sites to test the innovative video capture and data analysis method.

The research methodology required three key tasks, as described below.

3.1.1 Task 1: Data collection

High-volume priority-controlled intersections located in Christchurch were selected for this study, with a preference for sites located in urban areas and carrying commuter traffic. Data was collected from these locations on one day each, between 7:30am and 8:30am. To ensure accuracy and sufficiency of data collection, pilot surveys were conducted and evaluated at two locations before proceeding with data collection for the remaining sites.

The following data was collected from each intersection, through video and manual surveys:

- curvilinear distance between the waiting position and the point where the vehicle was safely through the opposing flow
- approach lane widths
- time of passing of each straight-through vehicle in the major road across the middle of the intersection
- speed of straight-through vehicles in the major road
- 5-year (2004–2008) crash history
- turning counts.

The following data was collected for the right-turning movement out of the major road:

- the time of arrival of a vehicle from the opposite direction, waiting to make the right turn out of the major road
- the time of the waiting vehicle’s right turn out of the major road.

The following data was collected for the right-turning movement out of the minor road:

- the time of the arrival of a vehicle from the minor road, waiting to make the right turn into the major road
- the time of the waiting vehicle’s right turn into the major road.

Figures 3.1 and 3.2 illustrate the geometric parameters that were collected for each site.

Figure 3.1 Sample intersection geometry measurements

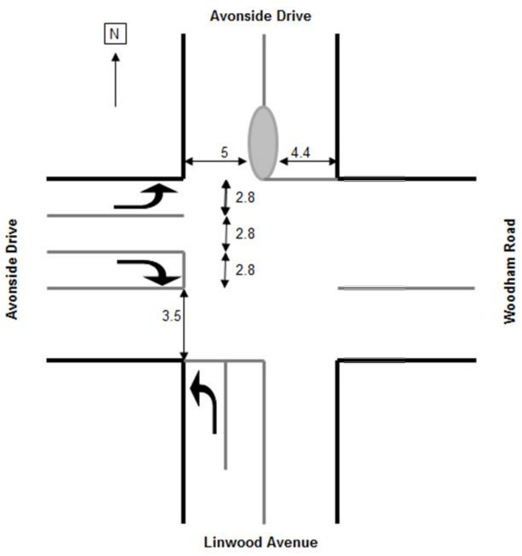
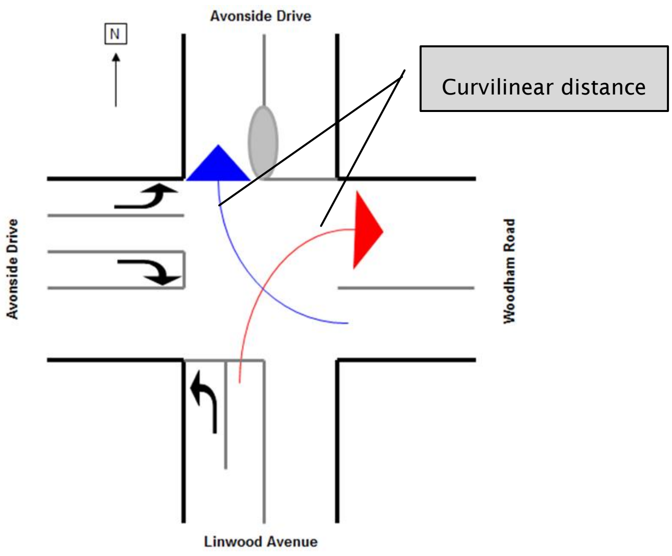


Figure 3.2 Surveyed movements showing curvilinear distance



3.1.2 Task 2: Data analysis

Data collected during the surveys was analysed and processed to obtain the following:

- observed turning times
- accepted gaps taken by drivers
- waiting times of drivers
- headways of the traffic stream.

3.1.3 Task 3: Safety analysis

Crash data from the selected intersections was analysed to identify any relationships with the gap acceptance and headway information listed above.

3.2 Development of site surveying methods

Data collection formed an important aspect of this research. A further complication was encountered in this aspect because of the relatively untested and innovative data collection methodology proposed for this study. To ensure the collection of robust data, a survey work instruction sheet was developed, describing the survey process and detailing the data collection procedure. A copy is provided in appendix B.

3.2.1 Pilot surveys

As discussed earlier, a pilot survey was required to ensure that any issues regarding the robustness of the data collection method, and any 'teething problems' with the survey methodology, could be addressed before the bulk of the data was collected. Prior to undertaking the pilot survey, an initial assessment of likely sites was undertaken.

Based on this initial assessment, the following sites were selected for conducting pilot surveys:

- Site 1: Springfield Road/Edgeware Road intersection
- Site 2: Springfield Road/St Albans Street intersection.

Both sites are located about 5km north of the Christchurch CBD.

Manual sample surveys and site observations were undertaken at these locations. Figures 3.3 and 3.4 show the two selected intersections and video camera locations at each.

Figure 3.3 Springfield Rd and Edgeware Rd

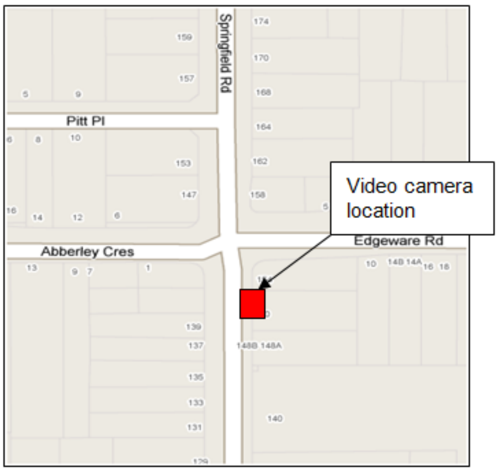
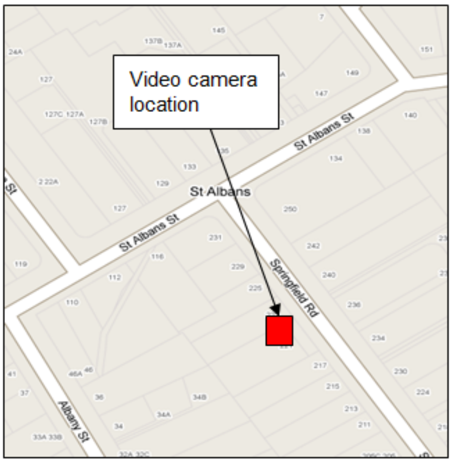


Figure 3.4 Springfield Rd and St Albans St



The first pilot survey was undertaken at the Springfield Road and Edgeware Road intersection on 15 April 2009. The survey period was from 7:45am–8:45am and 4:30pm–5:30pm. The site proved to be a good example of a priority-controlled intersection, with sufficient numbers of right-turning traffic in and out of the major road and minor road. As shown in figure 3.3, the video camera was located to the north-west of the intersection to capture right-turning traffic movements. No technical issues were identified during the survey period. An initial assessment of the video capture undertaken during the survey indicated that the camera performed satisfactorily and the recorded video could be viewed and analysed relatively easily.

To ensure there were no problems with the video data collection process, a second pilot survey was undertaken north of the first pilot site, at the intersection of Springfield Road and St Albans Street, on 21 April 2009**.** This also confirmed the appropriateness of the video capture method for gathering data on gap acceptance behaviour.

3.2.2 Main (pilot) surveys

Subsequent to confirmation of the data collection methodology through the pilot surveys, data collection for eight sites was undertaken in May/June 2009. Section 4.2 provides further details on the final selected sites.

As per the confirmed methodology, the main surveys involved data collection between 7:30am and 8:30am on one day each.

4 Site selection

The selection of suitable sites was a critical part of this research. The viability of potential intersections for survey was determined based on criteria expected to be suitable for the study. These consisted of priority-controlled intersections that were located along two-lane roads primarily in urban areas.

The physical nature of each site was analysed based on the following criteria:

- priority-controlled intersection form
- intersection layout
- presence of medians and turning lanes
- locations of nearby accesses (eg lanes, driveways)
- parking
- visibility issues.

Should any adjacent intersection be signal-controlled, additional care and interpretation of gap acceptance results would be required. This is because with adjacent signalised intersections, there are likely to be pulse effects where long gaps in the traffic occur or alternatively, where large amounts of traffic and therefore short gaps appear. This may affect gap acceptance for drivers, as they may be able to see the adjacent signals and so wait for a guaranteed large gap to be created by a red signal at the signalised intersection. Therefore, an effort was made to select sites that were located away from signalised intersections.

4.1 Preliminary site selection

Initial site selection was based on a review of a list of sites supplied to the study team by David Croft (NZTA). Crash analysis for each site was undertaken for the period 2004–2008 and included injury and non-injury crashes. Sites with over 15 crashes over the five-year period were included. Because there were insufficient suitable sites identified in Christchurch, Wellington and Auckland, the search was widened for sites outside these major centres. A list of these sites is provided in appendix A.

However, to ensure that the integrity of the original research objectives and methodology would be met, the study team, after reviewing the additional sites, decided to focus on the major city locations to ensure that high-quality and consistent data was collected to provide the best opportunity to build robust models that would achieve the overall objectives of the research project. It was expected that sites outside the main urban areas would be used as back-up sites if required. These sites are identified in the grey cells in the table in appendix A.

4.2 Final site selection

Although the original site list contained insufficient suitable sites in Christchurch, the study team preferred to run the pilot study in this region because of the advantages of collecting data and managing the survey here.

Based on their knowledge of Christchurch, the study team compiled a new list of possible sites. Members of the team then undertook preliminary field assessments of each site, reviewing the intersections and observing turning movements, to confirm the sites' suitability according to the criteria mentioned earlier – except that sites with less than 15 crashes were now included in the list of possible sites.

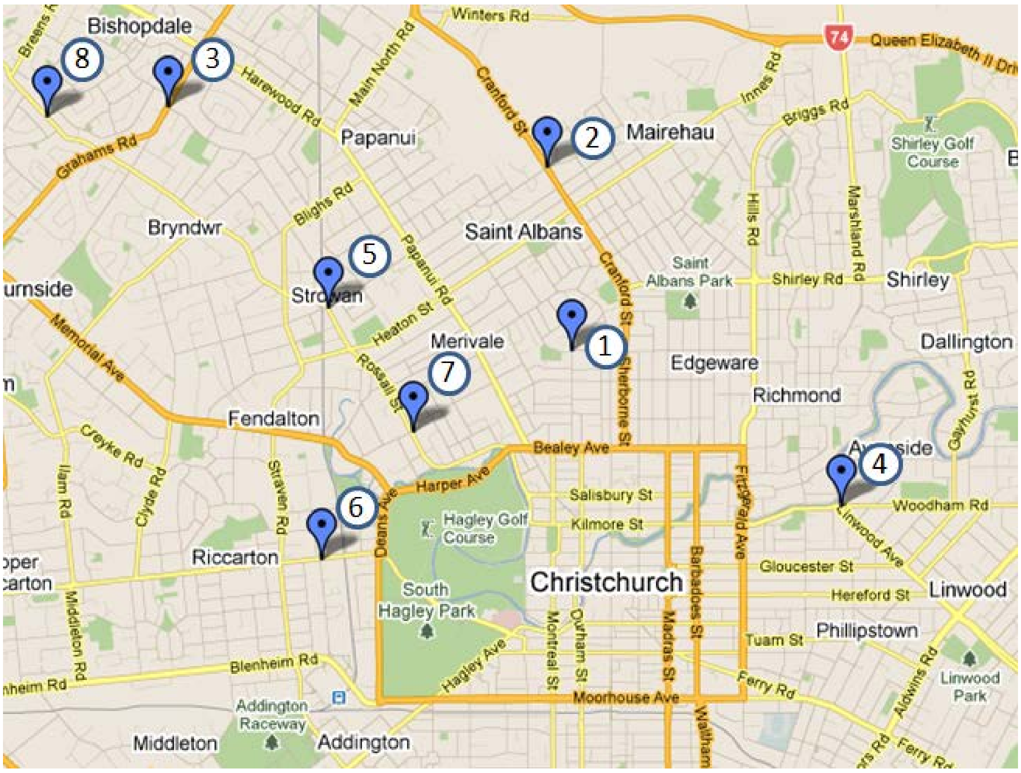
Based on this second round of site selection, and a consideration of the cost and effort required for data analysis for each additional site, a total of eight Christchurch sites were finally selected. These are shown in table 4.1.

Table 4.1 Christchurch survey sites

Site no.	Road 1	Road 2
1	Edgeware Road	Springfield Road
2	Cranford Street	McFaddens Road
3	Greers Road	Condell Ave
4	Linwood Ave	Woodham Road
5	Strowan Road	Normans Road
6	Riccarton Road	Mandeville Street
7	Rossall Street	Holmwood Road
8	Wairakei Road	Farrington Ave

Figure 4.1 shows the location of the selected sites in Christchurch.

Figure 4.1 Selected sites



Although the significant amount of additional effort that would have been required to collect and analyse data from sites located in other cities resulted in only Christchurch sites being included in the pilot study, it is suggested that future studies should draw upon a larger sample set of sites, from Auckland and Wellington, among others. The table in appendix A provides such sites for future evaluation.

5 Data analysis

This section of the report provides analysis, on a site-by-site basis, of the results for gap acceptance and delay at each intersection. Each site report notes the following:

- the site's location in regards to the local and wider highway network
- intersection characteristics – including junction geometry, turning distances and approximate visibility from the minor approach
- traffic flow during the peak period of the survey
- the frequency of accepted gap times for right turn into, and right turn out of, the minor junction intersection.

In total, eight sites were analysed, including the Springfield Road/Edgeware Road intersection surveyed during the pilot survey. The other intersections included in the analysis were:

- Cranford Street/McFadden's Road
- Greers Road/Condell Avenue
- Linwood Avenue/Woodham Road
- Normans Road/Strowan Road
- Riccarton Road/Mandeville Street
- Rossall Street/Holmwood Road
- Wairakei Road/Farrington Avenue.

6 Site data

6.1 Springfield Road/Edgeware Road

6.1.1 Site location

In the wider highway network, Springfield Road provides a link between the city, via Bealey Avenue, and the residential suburb of St. Albans. The intersection is two-way stop-controlled, and all adjacent junctions are also give-way priority-controlled.

6.1.2 Intersection layout

The intersection is four-armed, with approach lane widths of 6.0m and departure lane widths of 5.5m on Edgeware Road and Springfield Road. A 2.5m median exists on the Edgeware Road West approach. The curvilinear distance for the right turn out of Edgeware Road is 15.0m, whilst the right turn into the minor road curvilinear distance is 16.7m. Edgeware Road is the minor arm in this intersection.

It should be noted that good levels of visibility exist for both minor arm approaches to the intersection. It could therefore be expected that the follow-up headway would have a downward trend, as the second queuing vehicle from the minor arm is likely to be aware of the approaching traffic on the major arm and therefore would be more prepared to go, and be more decisive in their decision to move.

Figures 6.1 and 6.2 highlight the junction geometry and the surveyed movements.

Figure 6.1 Junction layout

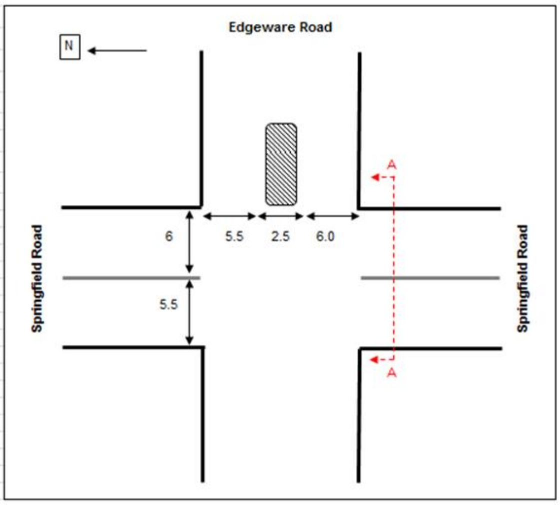
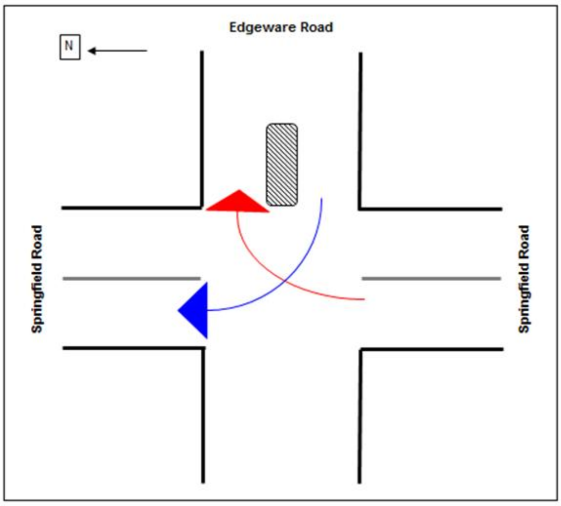


Figure 6.2 Surveyed movements



6.1.3 Accepted gap distribution

The intersection was surveyed for the AM peak period between 07:45 and 08:45 for the approaches of Edgeware Road East and Springfield Road South. Figures 6.3 and 6.4 provide a visual representation of the accepted gap time distribution for drivers making right-turn movements into and out of the minor arm.

The graphs assume a degree of interpretation, as it was difficult to ascertain exactly what the average gap acceptance for drivers was at the intersections. Where there were large gaps in the traffic, such as 30 seconds, it could not be identified what the accepted gap would have been for those particular drivers if there had been more traffic.

Both graphs, however, do show a positively skewed distribution, with the majority of vehicles accepting a gap of 10 seconds, and around half of the drivers making a right-turn movement using traffic gaps in the range of 8–14 seconds. However, as mentioned above, the accepted gap data does not identify an individual's minimum accepted gap, as it is also dependent upon the volume of traffic being experienced at the time. This information can therefore be used to gain an overview of the traffic conditions and an appreciation of driver gap acceptance, although at a later stage should be combined with data from other sites to generate a larger dataset from which more definitive conclusions can be drawn.

Figure 6.3 Frequency of gap acceptance – right turn in

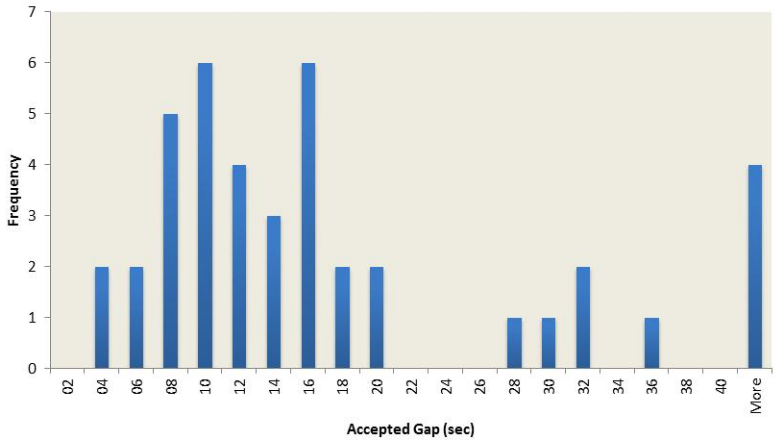
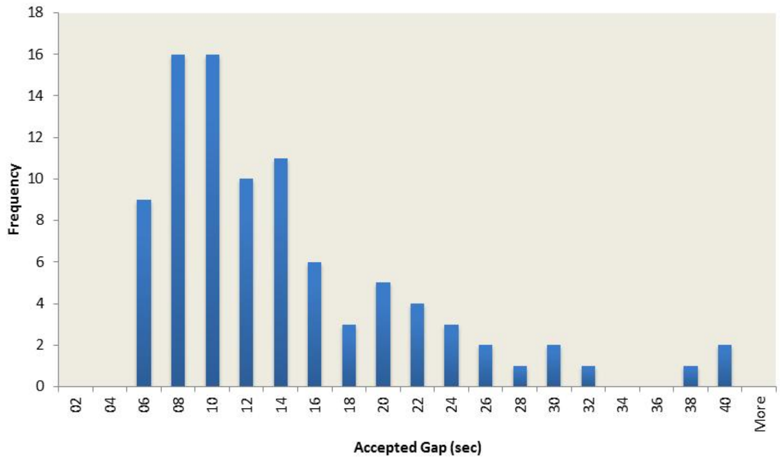


Figure 6.4 Frequency of gap acceptance – right turn out



In total, 41 vehicles were surveyed making the right-turn-in movement from Springfield Road, with 92 vehicles making the right-turn-out movement during the one-hour peak period.

6.1.4 Waiting time

Intersection delay was also recorded, and again has been used to identify the level of traffic and its influence on gap acceptance. Figures 6.5 and 6.6 highlight the frequency of waiting time that drivers experienced during the AM peak period.

Figure 6.5 Frequency of waiting time – right turn in

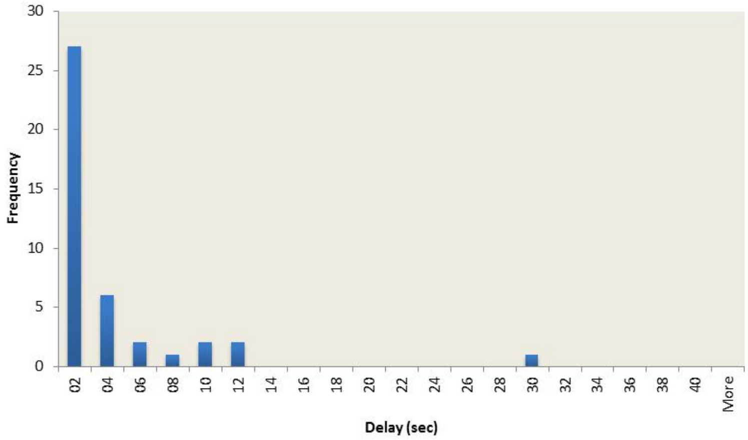
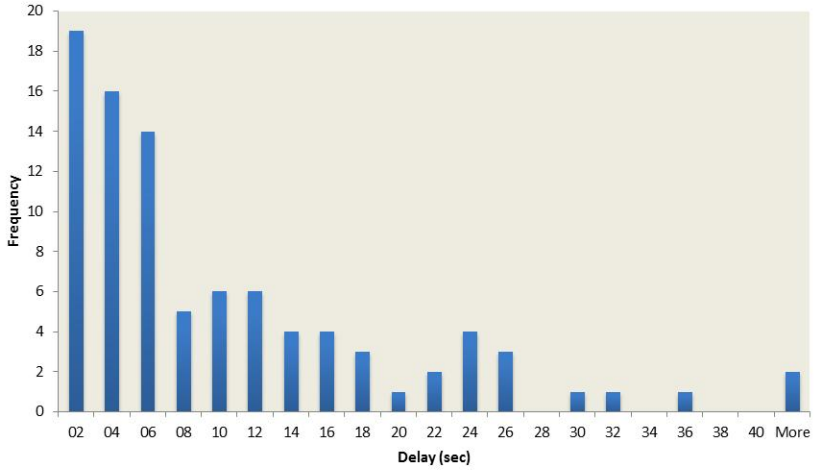


Figure 6.6 Frequency of waiting time – right turn out



It can be seen that the vast majority of traffic making the right turn in from Springfield Road experienced a very low waiting time, which suggests that the volume of opposing traffic was also low. However, those drivers wishing to make the right-turn movement out experienced far greater wait periods, as would be expected for manoeuvres against two opposing movements. However the majority of drivers only experienced a waiting time of between 0 and 6 seconds.

6.1.5 Headways

The headway information taken from the surveys identified the sum of accepted and rejected gaps, and provided another indication of the volume of traffic and availability of gaps. Figures 6.7 and 6.8 show the frequency of headway experienced at the junction during the AM peak.

Figure 6.7 Frequency of headways – right turn in

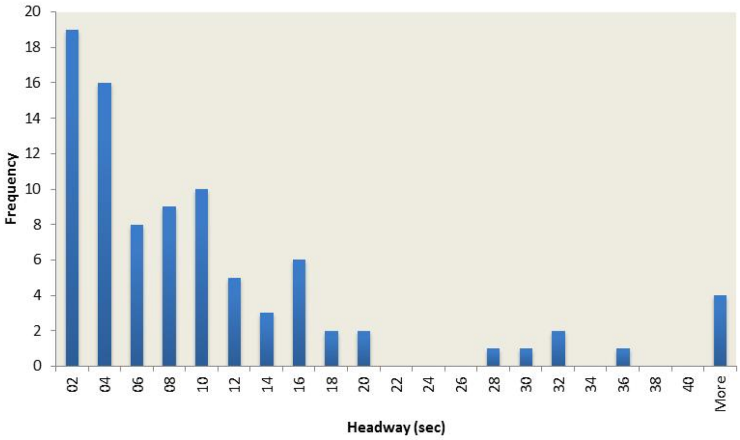
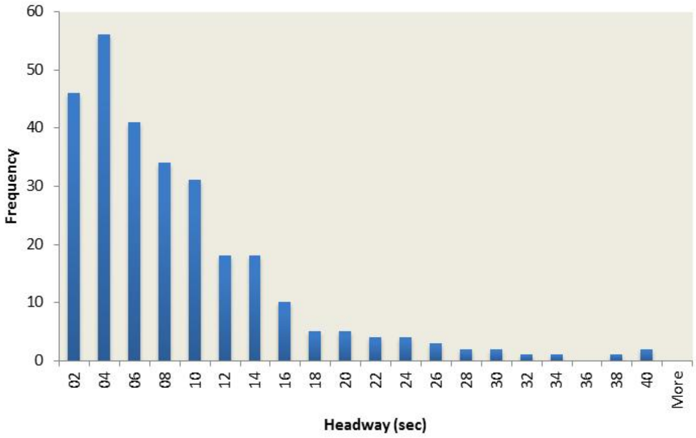


Figure 6.8 Frequency of headways – right turn out



The data identified that for both the right-turn-in and the right-turn-out movements from/to Springfield Road, a positively skewed distribution existed and that headways were typically between 0 and 10 seconds.

6.2 Cranford Street/McFadden's Road

6.2.1 Site location

The intersection of Cranford Street/McFadden's Road is located in the northern Christchurch suburb of St Albans. Cranford Street acts as a major arterial road and provides a primary route between the city and SH1 for connections to Kaikoura and the northern part of the South Island.

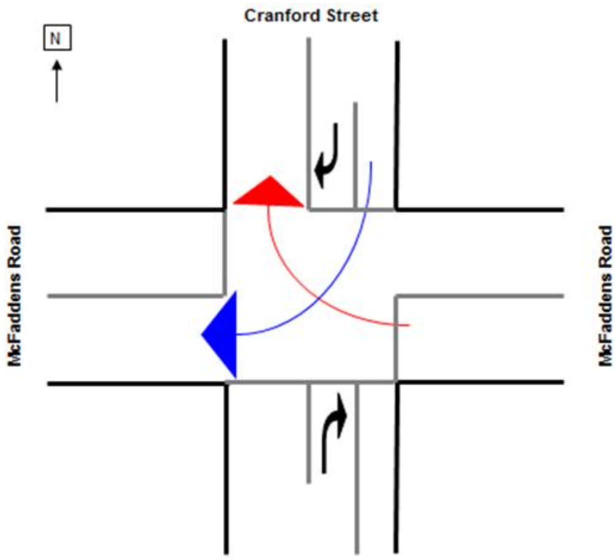
The closest signal-controlled junction is at the intersection of Cranford Street and Innes Road, which is approximately 400m from the Cranford Street/McFadden's road intersection. The distance between these intersections means that traffic has sufficient distance to spread more evenly and therefore is less likely to generate a significant pulse-loading effect.

6.2.2 Intersection layout

The intersection is four-armed, operating with right-turn bays on both Cranford Street approaches, which are both approximately 25m in length. Lane widths vary between 4.2m for the right-turn bays and 5.9m for the McFadden's Road approaches. Wide pavements around the junction mean that visibility at the junction, particularly for the McFadden's East approach, is good.

Figure 6.9 Junction layout

Figure 6.10 Surveyed movements



6.2.3 Accepted gap distribution

The intersection was surveyed for the AM peak between 07:30 and 08:30. The accepted gap frequency distribution graphs for this intersection are included in figures 6.11 and 6.12 following.

With reference to the right-turn-in graph, it can be seen that the distribution of accepted gaps was far more evenly spread when compared against not only the right-turn-out graph, but also against other surveyed intersections. It should be appreciated that during the peak hour, only eight right-turn-out vehicle movements were recorded, against 177 right-turn-in movements. Therefore it was difficult to draw any conclusions from the right-turn-out dataset, as it was so small.

Figure 6.11 Frequency of gap acceptance – right turn in

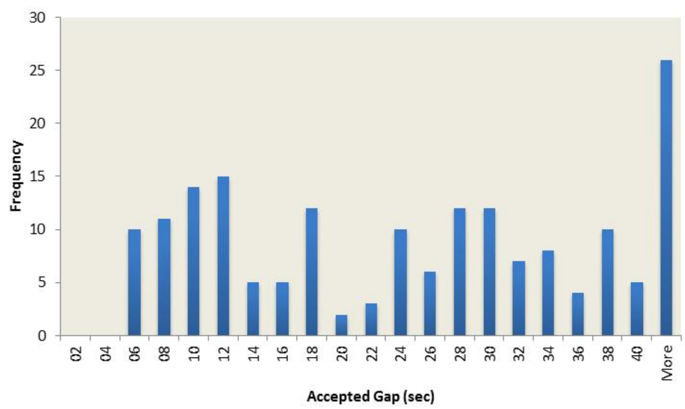
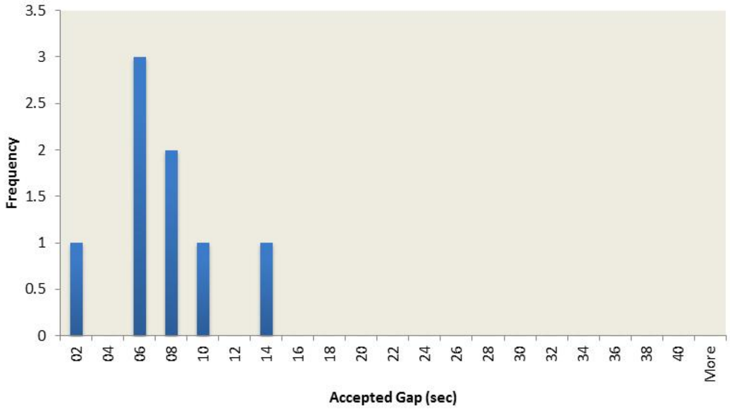


Figure 6.12 Frequency of gap acceptance – right turn out



6.2.4 Waiting time

Delays at the intersection were recorded and are highlighted in figures 6.13 and 6.14 following. As mentioned above, due to the small dataset it is difficult to draw conclusions from the right turn out; however, it can be seen that for the right-turn-in movement, the level of delay for the vast majority of drivers was minimal. The high frequency of low-delayed vehicles indicates that most vehicles did not stop when turning right from Cranford Street onto McFadden's Road. The even distribution of gap acceptance adds to the conclusion that this intersection experienced such a low level of traffic during the AM peak that only small delays occurred.

Figure 6.13 Frequency of waiting time – right turn in

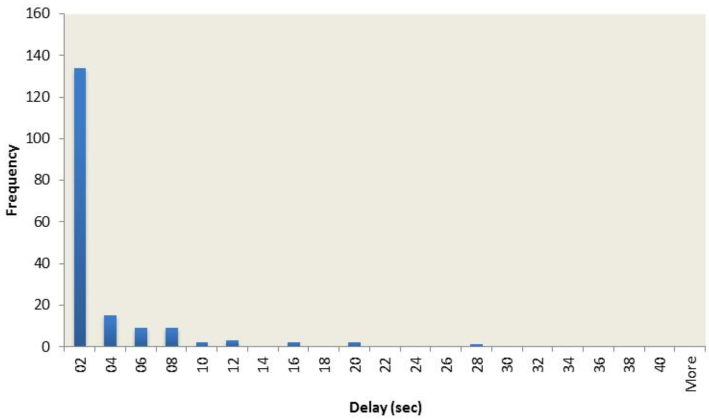
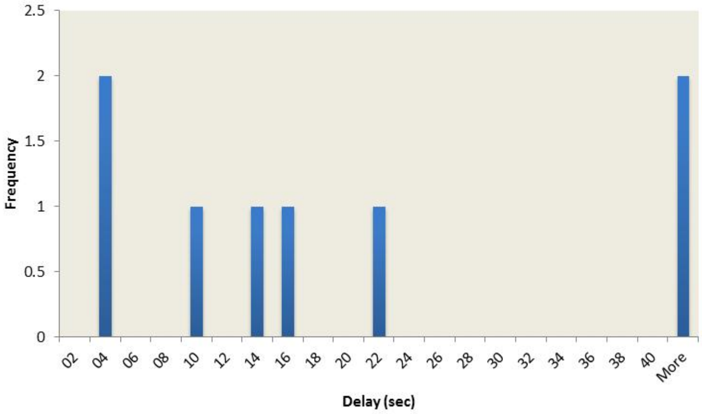


Figure 6.14 Frequency of waiting time – right turn out



6.2.5 Headways

Figures 6.15 and 6.16 highlight the headway gaps between vehicles making the right-turn movements. For the right-turn-in movement, it can be seen that the distribution was, for the most part, positive with a large number of headway gaps less than 6 seconds, but otherwise the distribution was relatively even up until 40 seconds. For the right-turn-out movement from McFadden's Road, it can be seen that the distribution of headway time was towards the lower end of the scale, indicating that headways were much smaller. This is to be expected, as headways for the right-turn-out movement referred to the gap in traffic for both directions of travel along Cranford Street, rather than the gap in just one direction for right-turn-in headways. This identified that there were fewer larger gaps to utilise when making the right-turn-out movement, which may have resulted in the accepted gap being smaller than that of the right-turn-in movement.

Figure 6.15 Frequency of headways – right turn in

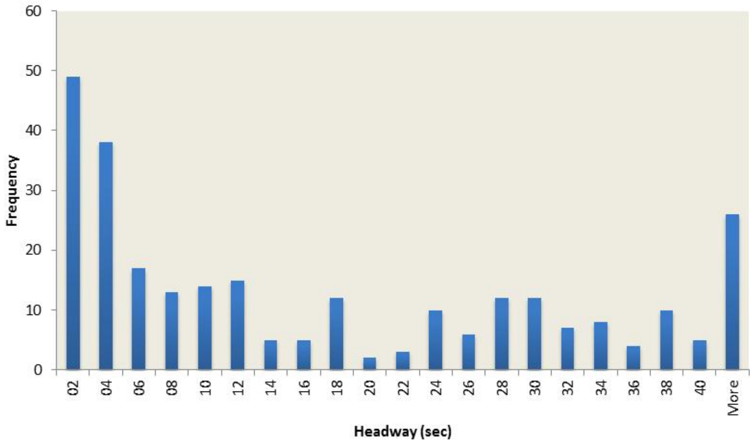
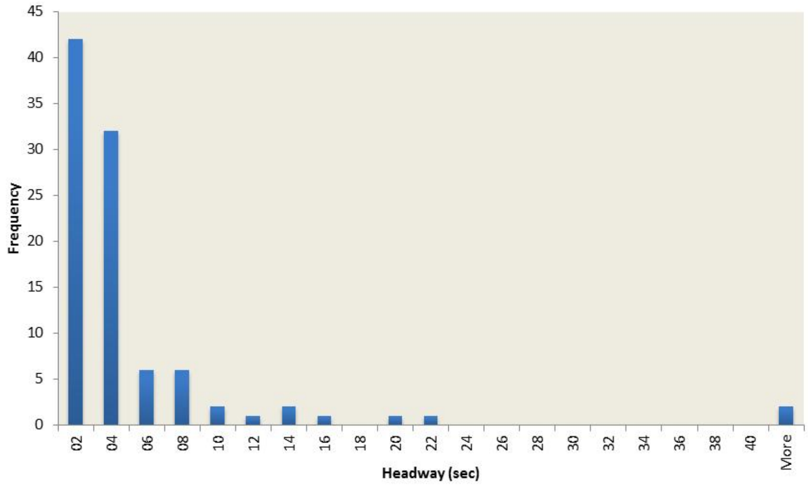


Figure 6.16 Frequency of headways – right turn out



6.3 Greers Road/Condell Avenue

6.3.1 Site location

Greers Road provides a key connection in the north of the city for journeys between SH74 (Queen Elizabeth II Drive) and routes to the airport and the south-west of Christchurch. Parking is not permitted along this road anywhere in the near vicinity of the junction.

6.3.2 Intersection layout

The intersection is three-armed, with Greers Road acting as the major arm and Condell Avenue operating as the minor arm. The Greers Road southern approach includes a short right-turn bay approximately 10m in length. Lanes along Greers Road are around 1m shorter than those along Condell Avenue, where on-street parking is permitted. Good visibility is available for movements from Condell Avenue, due to wide pavements and a lack of obstructions on the southern side of Greers Road. Figures 6.15 and 6.16 provide diagrams of the junction layout and the movements that have been included within the survey.

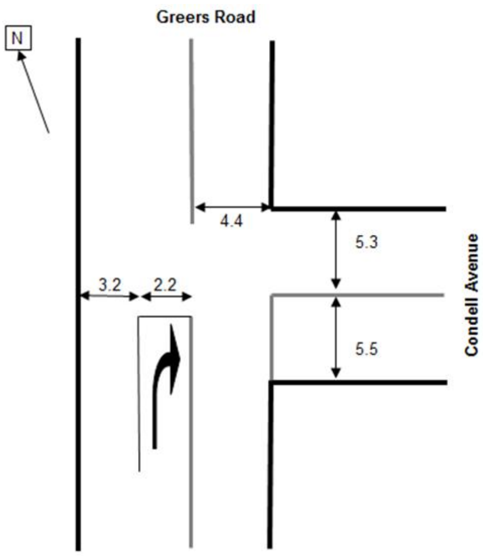


Figure 6.15 Junction layout

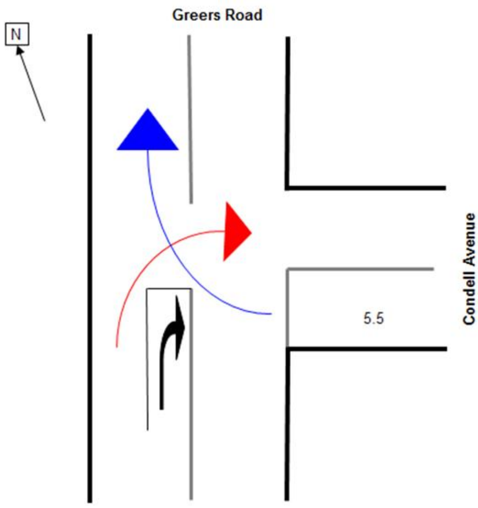


Figure 6.16 Surveyed movements

6.3.3 Accepted gap distribution

The survey for this junction was undertaken for the AM peak between 07:30 and 08:30. The gap acceptance frequency data for this intersection is displayed graphically in figures 6.17 and 6.18. For the right-turn-in movement from Condell Avenue to Greers Road, the majority of drivers accepted gaps in traffic that were generally between 6 and 14 seconds. For the right-turn-out movement from Greer's Road to Condell Avenue, which is accommodated by a right-turn bay, the distribution was similar to that as for the right-turn-in movement.

Figure 6.17 Frequency of gap acceptance – right turn in

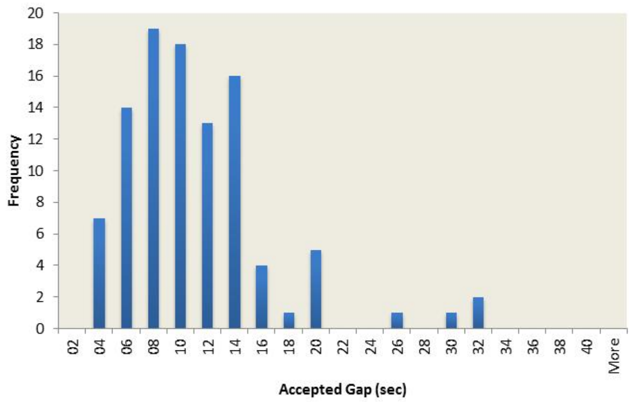
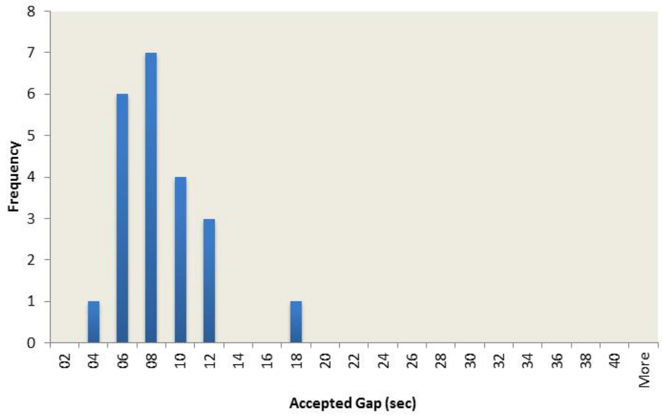


Figure 6.18 Frequency of gap acceptance – right turn out



6.3.4 Waiting time

Intersection delays for the two right-turn movements are recorded in figures 6.19 and 6.20 following. For the right-turn-in movement, it can be seen that the majority of drivers experienced no delay at the intersection; and those who did, experienced variable levels of delays. In total, 101 vehicles were recorded making the right-turn-in movement, and 21 making the right-turn-out movement. The small amount of data may account for the generally sporadic distribution of wait time frequency for the right-turn-out movement. This distribution of wait time across a wide range of time is similar to that observed for other sites.

Figure 6.19 Frequency of waiting time – right turn in

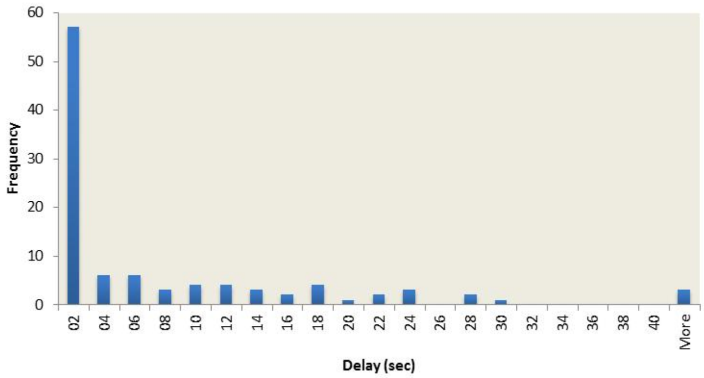
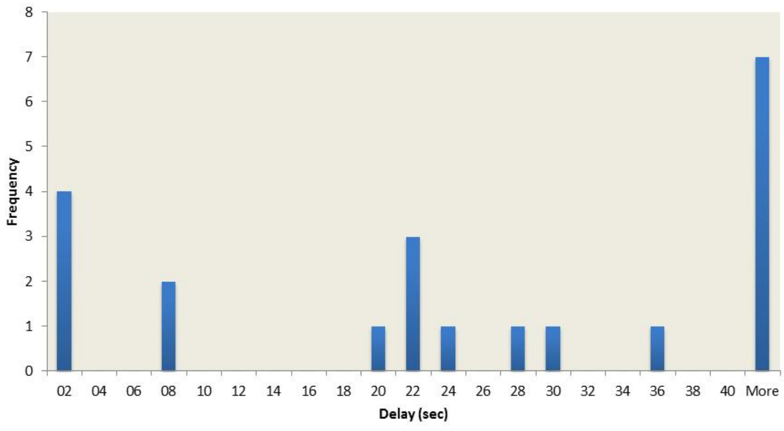


Figure 6.20 Frequency of waiting time – right turn out



6.3.5 Headways

The headway gaps that were experienced with the right-turn-in and right-turn-out movements at this intersection are shown graphically in figures 6.21 and 6.22 following. Interestingly, the two graphs are almost identical and again show a positively skewed distribution, which highlights that the headway was minimal for either movement. The above results for wait time, headway and gap acceptance highlight a general low level of traffic flow at the intersection.

Figure 6.21 Frequency of headways – right turn in

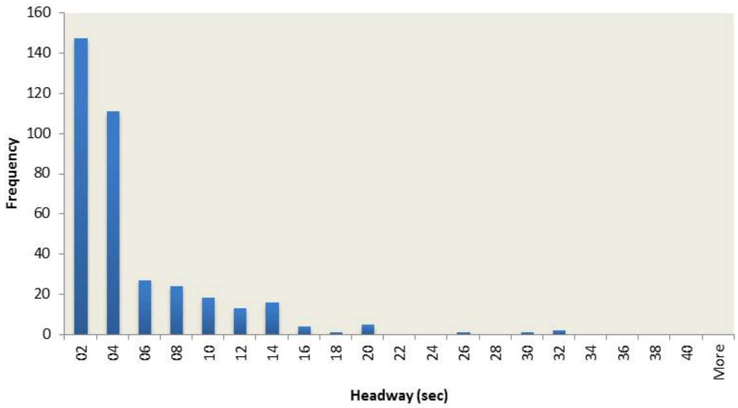
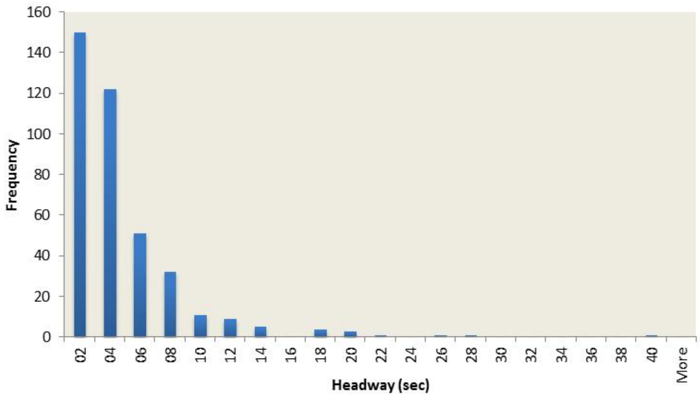


Figure 6.22 Frequency of headways – right turn out



6.4 Linwood Avenue/Woodham Road

6.4.1 Site location

The intersection of Linwood Avenue and Woodham Road is located close to the east of the Christchurch CBD and as a result, experiences a high level of traffic during peak periods. Woodham Road links onto Pages Road, which acts as the direct connection between the central city and New Brighton.

The adjacent intersection of Avonside Drive and Stanmore Road, approximately 280m from the Linwood Avenue/Woodham Road junction, is signalised. Therefore some appreciation for a pulse traffic-flow effect should be considered in the analysis of the data. A second signalised intersection is located approximately 950m to the west of the site, at the intersection of Gloucester Street and Woodham Road.

6.4.2 Intersection layout

The junction is a four-armed intersection, with Woodham Road/Avonside Drive West acting as the major arms and Linwood Avenue/Avonside North as the minor arms. Central island medians are in place for the Linwood Avenue, Woodham Road and Avonside North arms. The Avonside West arm includes additional left- and right-turning lanes that are approximately 25m in length. The Linwood Avenue approach is built at an acute angle to Woodham Road. Figures 6.23 and 6.24 provide diagrams of the junction layout and the movements that were included within the survey.

Figure 6.23 Junction layout

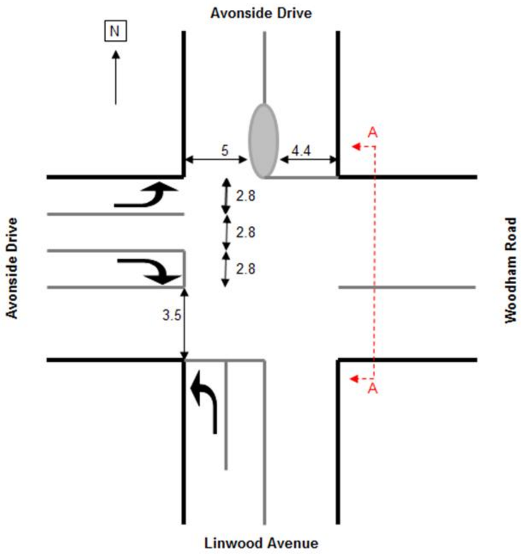
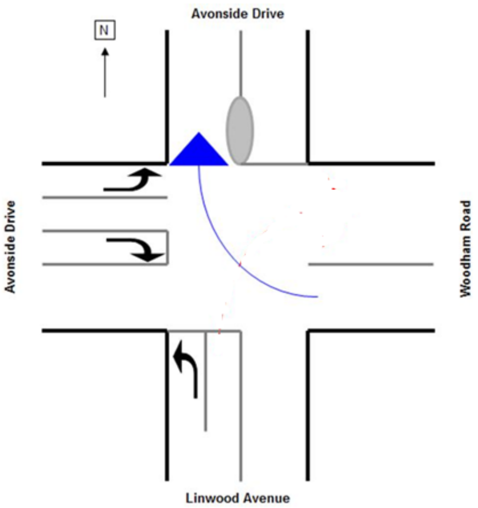


Figure 6.24 Surveyed movements

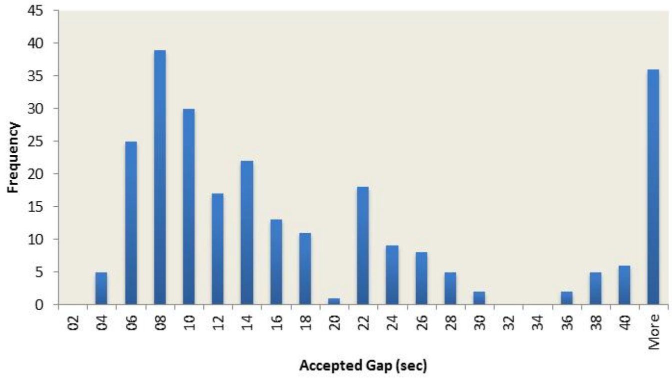


6.4.3 Accepted gap distribution

The intersection was surveyed for the AM peak between 07:30 and 08:30. The accepted gap frequency distribution graph for the right-turn-in movement for the Linwood Avenue/Woodham Road intersection are included in figure 6.25. The right-turn-out data for this intersection was not collected.

The data for this intersection shows that all drivers making the right-turn-in movement experienced some degree of delay moving between the major and minor road. Due to the larger level of traffic flow, when compared to the aforementioned sites, it can be seen that the distribution was spread across a wider time period. The peak accepted gap was 8 seconds, with the frequency of accepted gaps decreasing as time increased, up until 20 seconds. However, at 22 seconds a smaller peak occurred, which implies that larger gaps appeared in the traffic. This could be attributed to the adjacent signalised junctions and the pulse-loading effect.

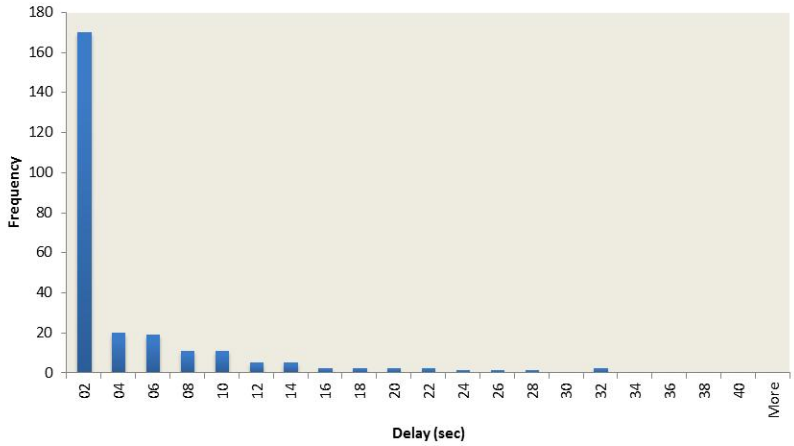
Figure 6.25 Frequency of gap acceptance – right turn in



6.4.4 Waiting time

The relationship between gap and delay is shown below in figure 6.26. It is clear from the graph that the vast majority of vehicles experienced either no delay, or minimal delay, for making the right-turn movement from the major to the minor arm. This is likely to be attributed to the fact that the distance (950m) to the signalised intersection at Gloucester Street/Woodham Road is large enough for traffic spread, meaning that acceptable turning gaps in the traffic occurred.

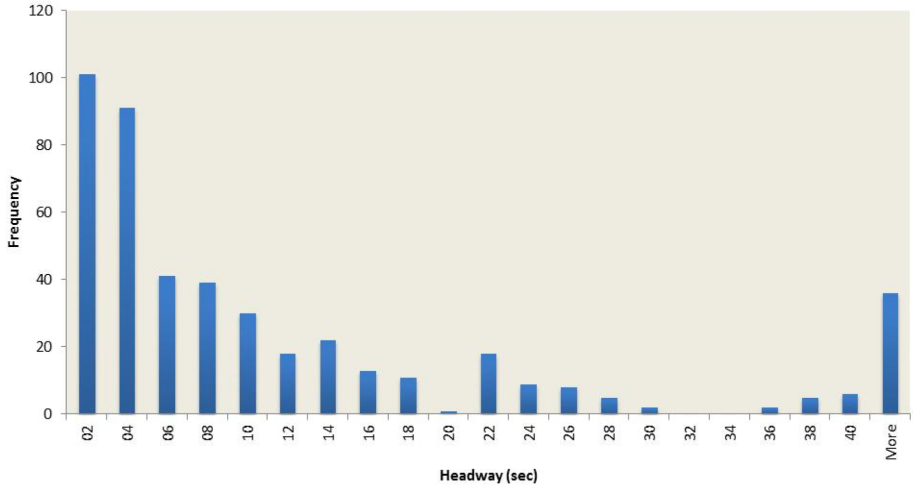
Figure 6.26 Frequency of waiting time – right turn in



6.4.5 Headways

The headway (accepted plus rejected gaps in the traffic) data for the right-turn-in movement is provided in figure 6.27 following. The results are comparable to other survey sites in terms of a positively skewed distribution, but differ due to fact that traffic at this intersection was comparatively greater and therefore a greater proportion of larger headways was experienced.

Figure 6.27 Frequency of headways – right turn in



6.5 Normans Road/Strowan Road

6.5.1 Site location

The Normans Road intersection with Strowan Road is located in the northern suburb of Strowan. Strowan Road connects onto Wairakei Road, which provides a key route between the airport, northern suburbs and the city. Normans Road connects through to Papanui Road, which also provides key links between the north of Christchurch and the city. There are no signalised intersections in close proximity to the site; however a railway crossing is located 60m north of the intersection, although this crossing remained open for the duration of the peak period.

6.5.2 Intersection layout

Strowan Road acts as the major arm and Normans Road as the minor arm for the intersection. A central median is in place on both the Strowan Road North and Normans Road East junction arms. Right-turn bays, approximately 10m in length, are in place for the Strowan Road South and Normans Road approaches. Travelling north from the intersection, Strowan Road North bends to the west, although this does not greatly affect visibility. Figures 6.28 and 6.29 show the junction layout (including lane widths) and the movements surveyed in the study.

Figure 6.28 Junction layout

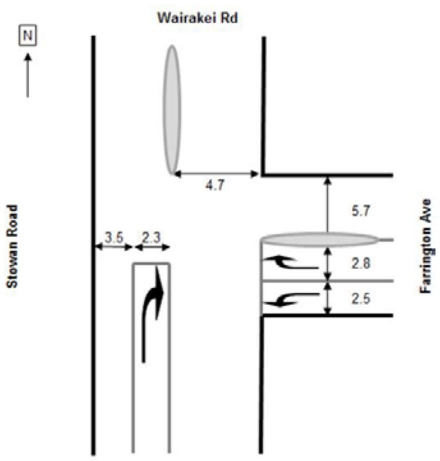
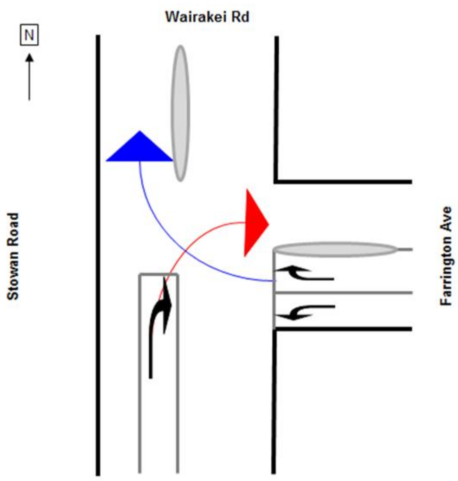


Figure 6.29 Surveyed movements



6.5.3 Accepted gap distribution

Figures 6.30 and 6.31 show graphs summarising the data for right-turn movements at the Strowan/Normans Road junction. It can be seen that the most frequently accepted gap in traffic for right-turn-in movements from Strowan Road to Normans Road was between 18 and 22 seconds. The distribution of gap acceptance for right-turn-out movements from the minor to the major road was similar to that of the right-turn-in movement, but shifted towards the lower end of the scale. The most frequent accepted gap was 10 seconds for this movement.

Figure 6.30 Frequency of gap acceptance – right turn in

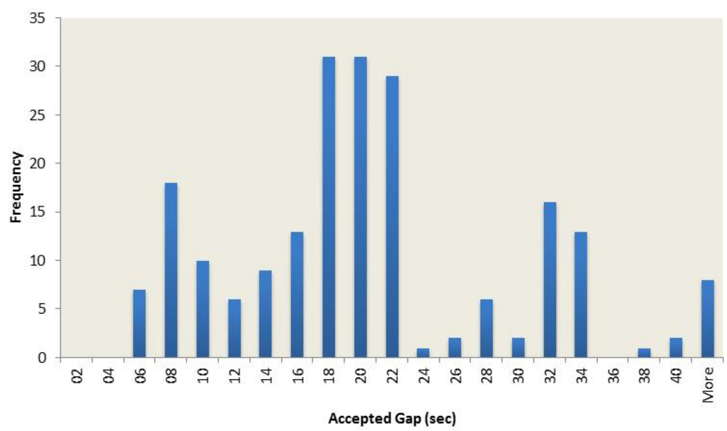
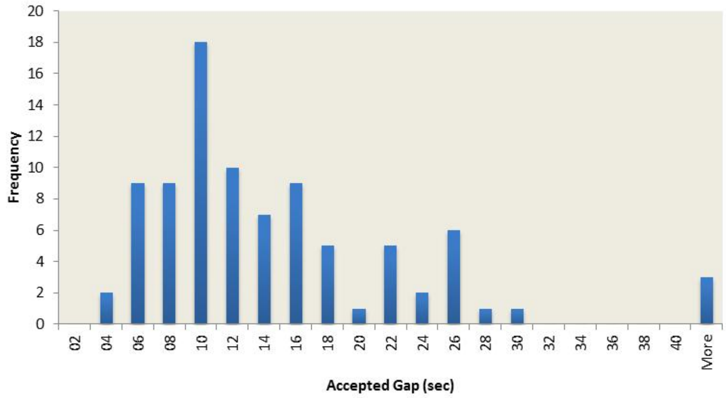


Figure 6.31 Frequency of gap acceptance – right turn out



6.5.4 Waiting time

The distribution for the frequency of wait time at the stop line is shown in figures 6.32 and 6.33. Both graphs show that for both surveyed right-turn movements, the majority of vehicles experienced little or no delay at the junction, which indicates that the intersection was operating far below capacity. The right-turn-out movement experienced slightly more delay in comparison, which is to be expected as vehicles had to give way to two opposing movements, compared with only one for the right-turn-in movement.

Figure 6.32 Frequency of waiting time – right turn in

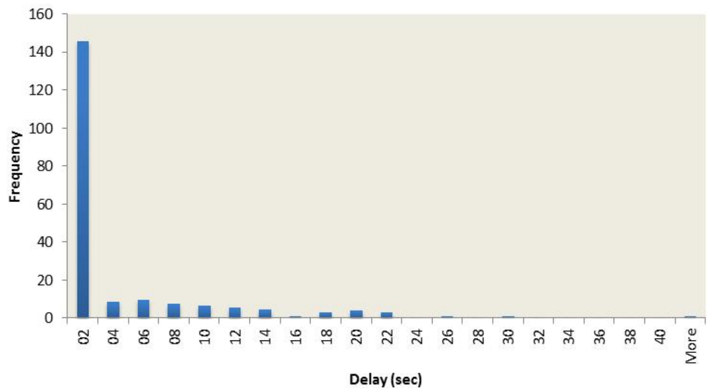
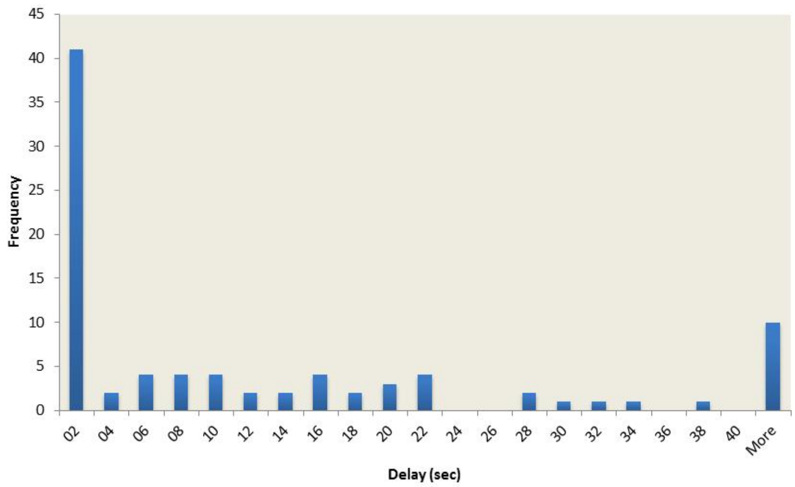


Figure 6.33 Frequency of waiting time – right turn out



6.5.5 Headways

The headway data for the site is summarised in figures 6.34 and 6.35 following. It can be seen that the distribution for right-turn-in and right-turn-out movements was very similar to those observed in the brief analysis of the previous junctions – ie the headway between vehicles (accepted plus rejected gaps) was towards the lower end of the time scale. A comparison between the graphs below and those with the accepted gap in figures 6.30 and 6.31 identifies that the majority of gaps of less than 4 seconds were rejected by drivers.

Figure 6.34 Frequency of headways – right turn in

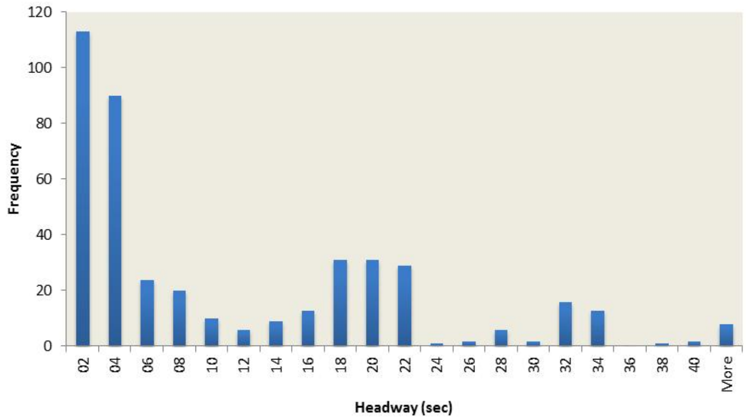
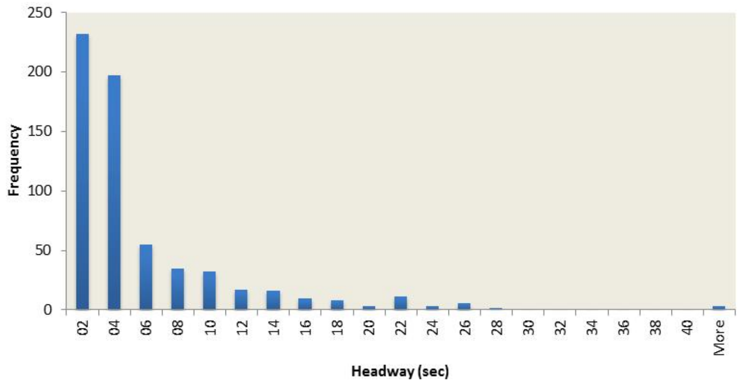


Figure 6.35 Frequency of headways – right turn out



6.6 Riccarton Road/Mandeville Street

6.6.1 Site location

Riccarton Road is a busy link throughout the day, as it not only links the city to Riccarton and SH73, but also to the Westfield Mall, which is close to the intersection of Riccarton Road/Mandeville Street. A signalised intersection is in place at the Riccarton Road/Straven Road intersection, approximately 330m from the site.

6.6.2 Intersection layout

The intersection is three-armed, with Riccarton Road acting as the major arm and Mandeville Street as the minor arm. Central medians are in place along the Riccarton Road West and Mandeville Street approaches.

The junction layout (including lane widths) and movements surveyed in the study are provided in figures 6.36 and 6.37. On-street parking is permitted along Mandeville Street, and hence the road widths are greater than along Riccarton Road.

Figure 6.36 Junction layout

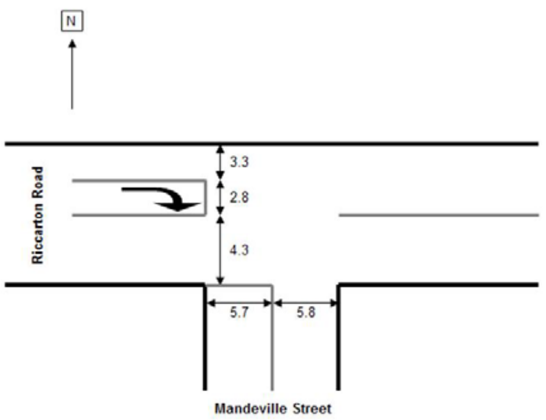
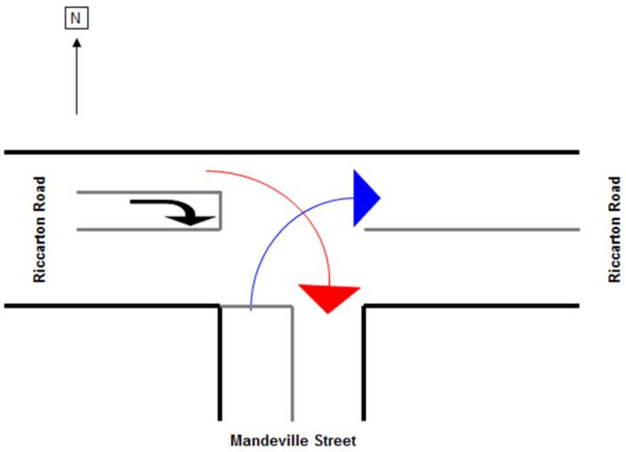


Figure 6.37 Surveyed movements



6.6.3 Accepted gap distribution

The distribution of gaps in traffic that were accepted by drivers making the right-turn-in and right-turn-out movements to/from Mandeville Street is highlighted in figures 6.38 and 6.39 following. The data showed that for those moving from Riccarton Road to Mandeville Street, the majority of drivers took gaps between 8 and 14 seconds, whilst for those making the opposite movement from Mandeville Street to Riccarton Road, the accepted gap was between 4 and 8 seconds. It may, however, be more difficult to draw conclusions for the right-turn-out movement, as only 39 vehicles were recorded, compared to 156 for the right-turn-in movement.

Please note that surveys were undertaken for the AM peak period of 07:30–08:30.

Figure 6.38 Frequency of gap acceptance – right turn in

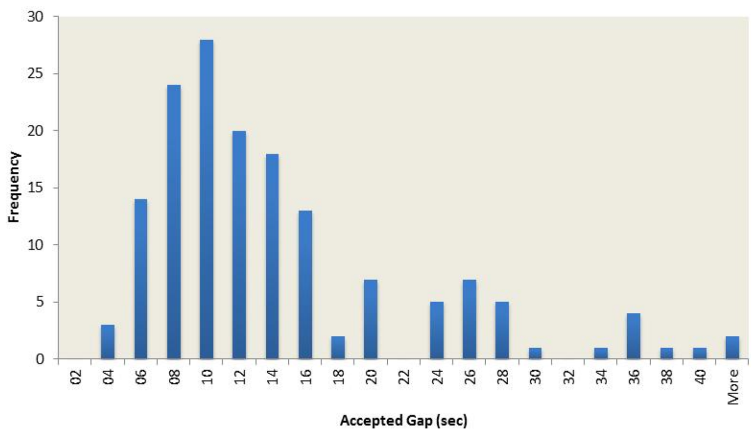
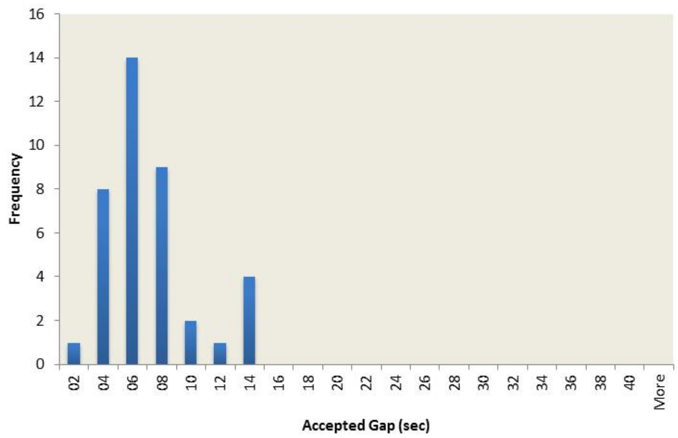


Figure 6.39 Frequency of gap acceptance – right turn out



6.6.4 Waiting time

The frequency of wait time at the stop lines for vehicles undertaking each movement is graphically represented in figures 6.40 and 6.41 following. It can be seen that little delay was experienced for the movement from Riccarton Road to Mandeville Road; indeed, only 40% of vehicles experienced delay greater than 2 seconds during the survey period. For the right-turn-out movement, however, a far wider range of delay was experienced, partly because of the lack of traffic volume taking this movement, but also because of the volume of traffic on Riccarton Road and vehicles having to give way to two separate movements.

Figure 6.40 Frequency of waiting time – right turn in

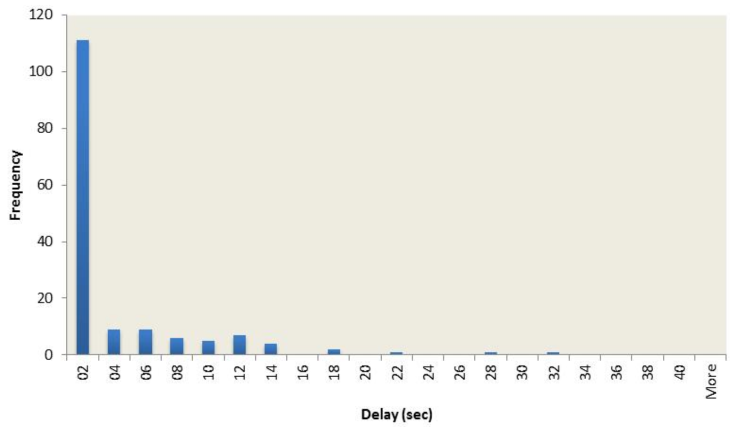
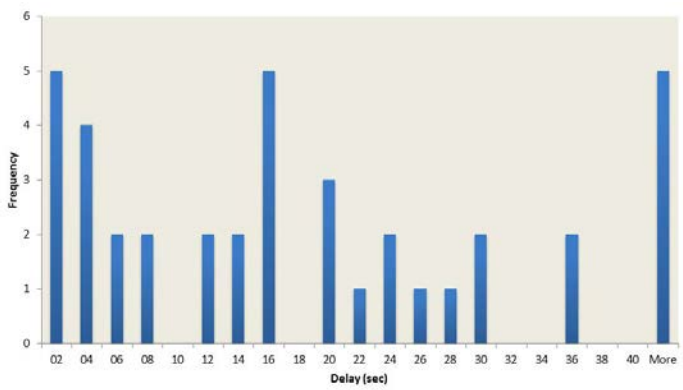


Figure 6.41 Frequency of waiting time – right turn out



6.6.5 Headways

The frequency of total headways (accepted + rejected gaps) for each movement is provided in figures 6.42 and 6.43 following. It can be seen that the majority of available gaps was 4 seconds for each movement; however, making a comparison with the accepted gaps, it can be seen that most of those 4-second gaps were rejected by motorists. For the right-turn-out movements from Mandeville Street to Riccarton Road, it can be derived that a number of gaps of 6 seconds were also rejected by drivers.

Figure 6.42 Frequency of headways – right turn in

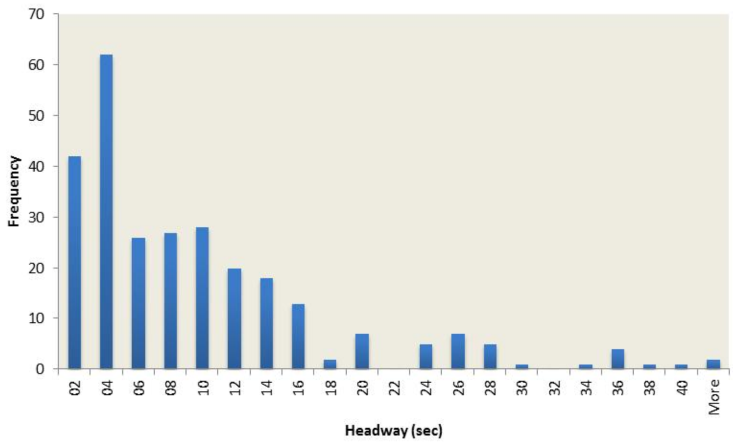
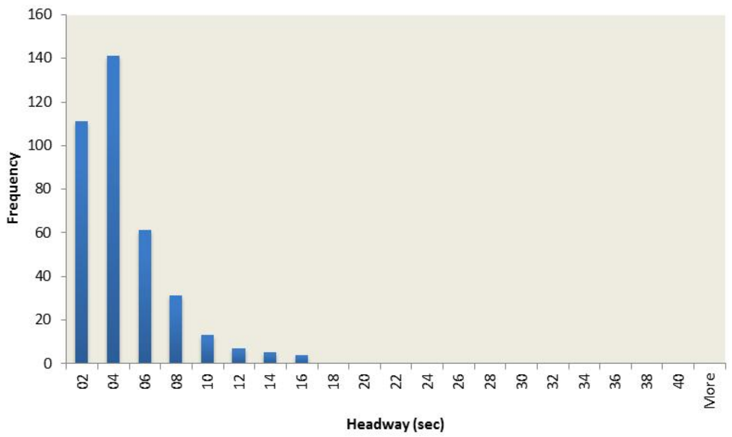


Figure 6.43 Frequency of headways – right turn out



6.7 Rossall Street/Holmwood Road

6.7.1 Site location

Rossall Street connects to Strowan Street and Wairakei Road, providing connection between the Christchurch northern suburbs, Christchurch International Airport and the city centre. Holmwood Road connects Rossall Street through to Fendalton Road, which also provides similar connections. The intersection is far removed from any local signalised junctions.

6.7.2 Intersection layout

The intersection is a three-armed give-way-controlled junction, operating with Rossall Street as the major road and Holmwood Road as the minor road. Right-turn bays are in place for the Holmwood Road and Rossall Street North approaches. The right-turn bay for the Rossall Street approach extends back approximately 40m to the previous intersection, and the right-turn bay for Holmwood Road is approximately 30m in length, although this length may be restricted by on-road parking. Figures 6.44 and 6.45 provide diagrams for the junction layout (including lane widths) and movements surveyed at the site.

Figure 6.44 Junction layout

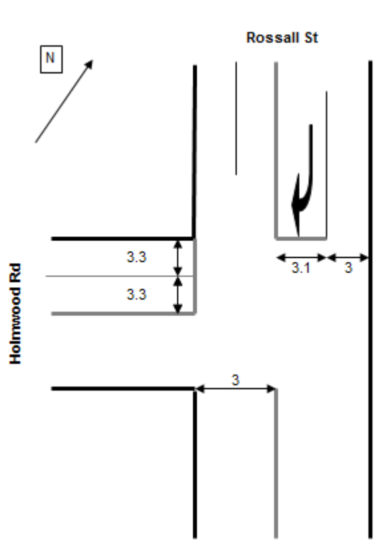
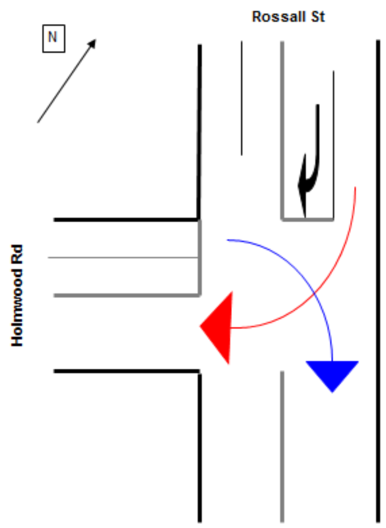


Figure 6.45 Surveyed movements



6.7.3 Accepted gap distribution

The distribution of accepted gaps for the right-turn movements is provided in figures 6.46 and 6.47 following. Unlike any of the previous intersections, this junction shows that a large number of motorists accepted gaps that were above 40 seconds, and that the general distribution of gap acceptance was generally even, between 0 and 40 seconds. This suggests that a low volume of traffic was experienced at the intersection, meaning that opportunities for right-turn movements were greater. The dataset for right-turn-out movements was more limited, due to the low volume of traffic, and therefore conclusions were difficult to draw.

Figure 6.46 Frequency of gap acceptance – right turn in

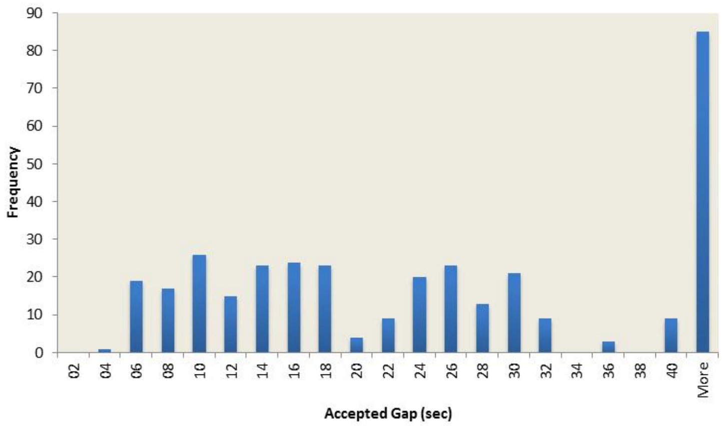
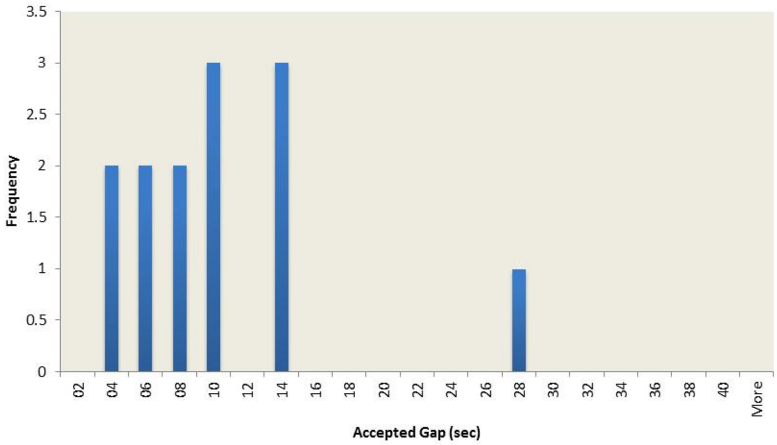


Figure 6.47 Frequency of gap acceptance – right turn out



6.7.4 Waiting time

With a high frequency of accepted gaps of greater than 40 seconds, it is unsurprising that the vast majority of vehicles experienced no delay at the intersection whilst making the right-turn-in movement from Rossall Street to Holmwood Road. The frequency for delays experienced per movement is highlighted in figures 6.48 and 6.49.

Figure 6.48 Frequency of waiting time – right turn in

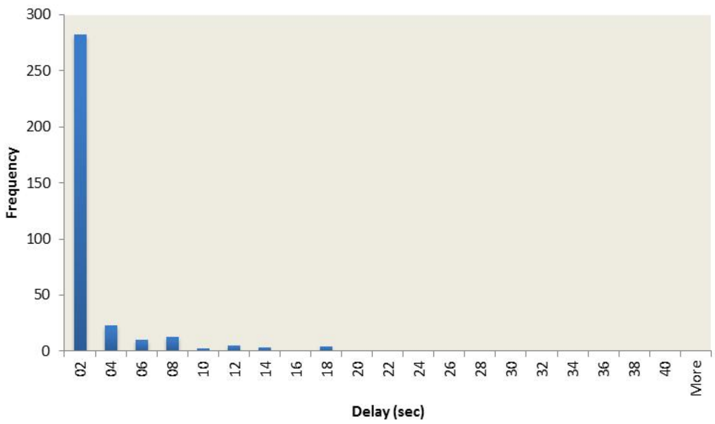
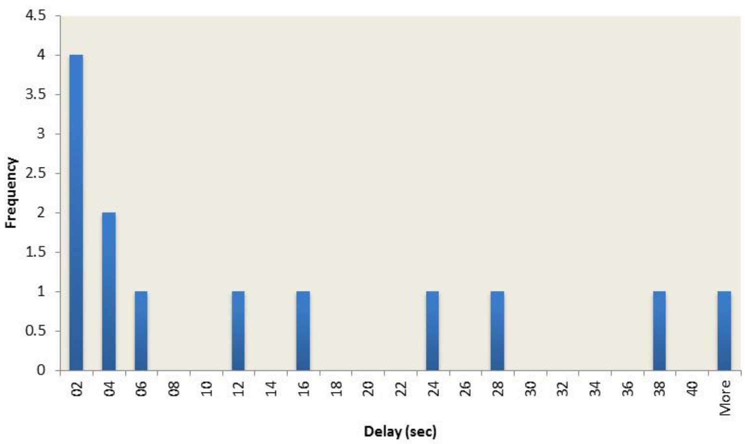


Figure 6.49 Frequency of waiting time – right turn out



6.7.5 Headways

The results of headway frequency per movement are provided in figures 6.50 and 6.51 following. The distribution for frequency of headway (accepted + rejected gaps) for the right-turn-in movement was similar to that seen for the accepted gaps in respect of the generally evenly distributed headways. This again suggests a low volume of traffic. Also, perhaps the small waiting times necessary for the next available gap in traffic meant that almost all gaps of less than 4 seconds were rejected.

Figure 6.50 Frequency of headways – right turn in

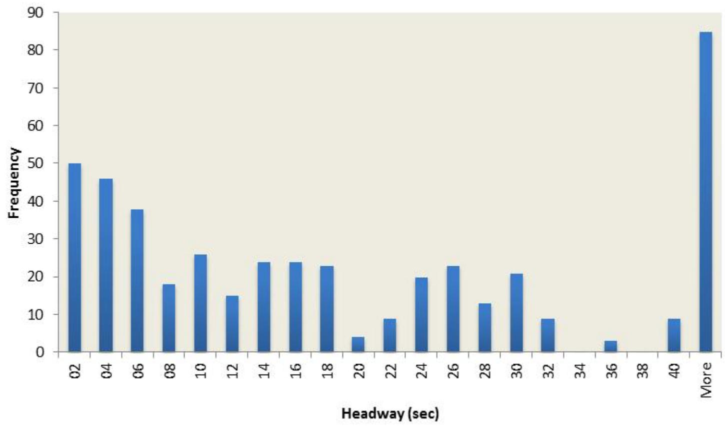
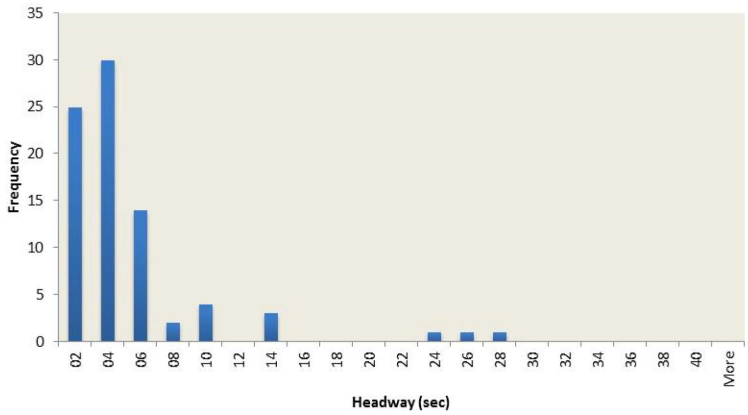


Figure 6.51 Frequency of headways – right turn out



6.8 Wairakei Road/Farrington Avenue

6.8.1 Site location

The site is located to the far north-west of Christchurch in the residential suburb of Bishopdale. Wairakei Road acts as a main arterial road between the city and the airport, located approximately 3km north of the site. The closest signalised intersection is located approximately 500m south of the site at the junction of Wairakei Road and Grahams Road.

6.8.2 Intersection layout

This junction is three-armed, with Wairakei Road acting as the major arm and Farrington Avenue as the minor arm to this junction. A right-turn bay, which is approximately 12m in length, is in place for the Wairakei Road southern approach.

Figures 6.52 and 6.53 provide diagrams highlighting the junction geometry and the surveyed movements.

Figure 6.52 Junction layout

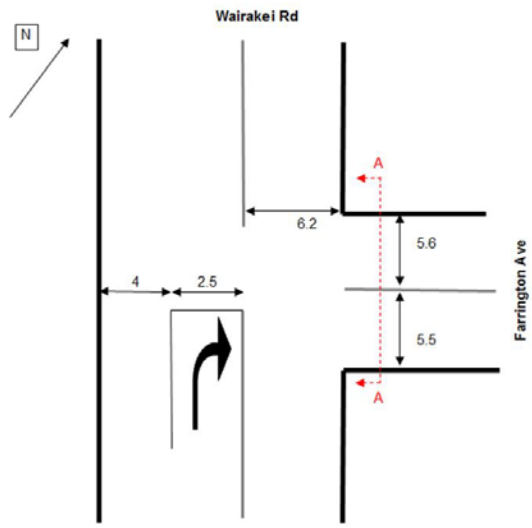
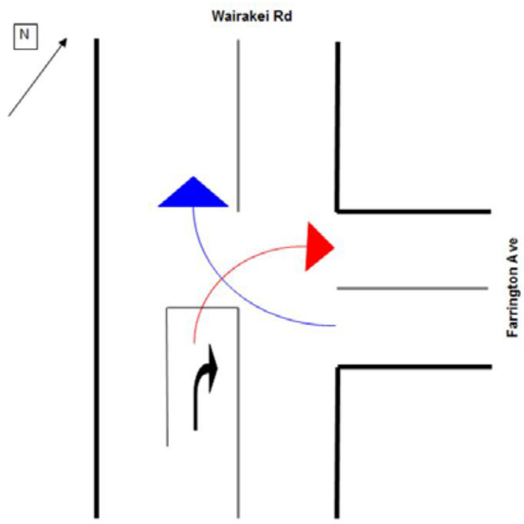


Figure 6.53 Surveyed movements



6.8.3 Accepted gap distribution

Figures 6.54 and 6.55 show the distribution of right-turning traffic that was observed during the surveyed AM peak period between 07:30 and 08:30. It can be seen that a fairly even distribution of accepted gap times of between 8 and 28 seconds was observed for the right-turn-in movement, which suggests a low traffic volume, as many motorists accepted large gaps that were present in the traffic. For the right-turn-out movement, the greatest proportion of drivers accepted lower gaps, typically between 6 and 10 seconds.

Figure 6.54 Frequency of gap acceptance – right turn in

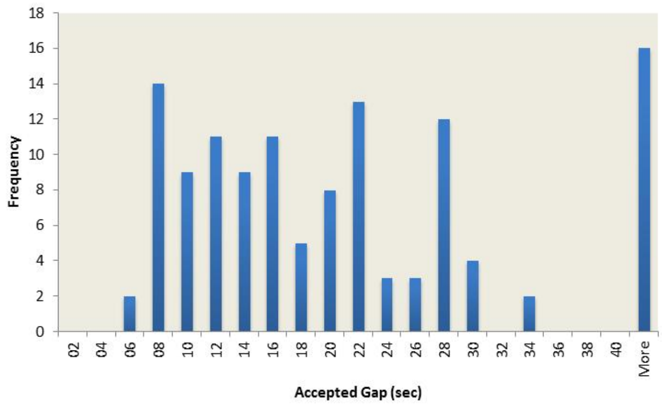
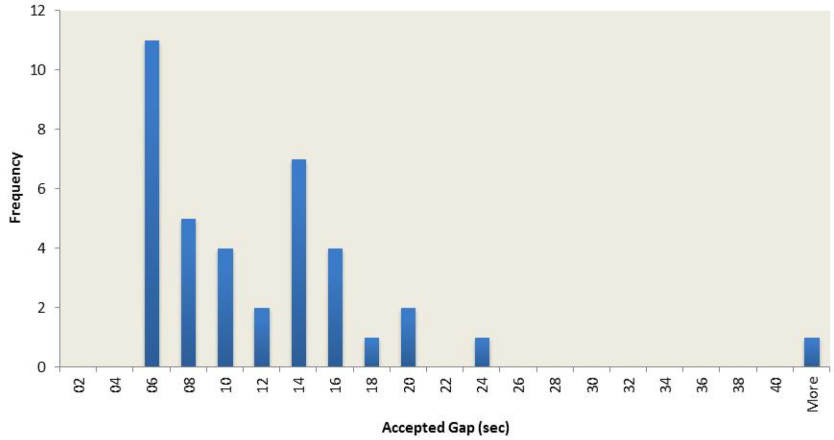


Figure 6.55 Frequency of gap acceptance – right turn out



6.8.4 Waiting time

The frequency of wait time at the stop lines for vehicles undertaking each movement is graphically represented in figures 6.56 and 6.57 following. It can be seen, as suggested above, that there was a low level of traffic at the time of the survey – as represented by the minimal level of delay experienced by the vast majority of drivers making the right-turn-in manoeuvre. For the right-turn-out drivers, the level of delay was greater, although in most cases not significant.

Figure 6.56 Frequency of waiting time – right turn in

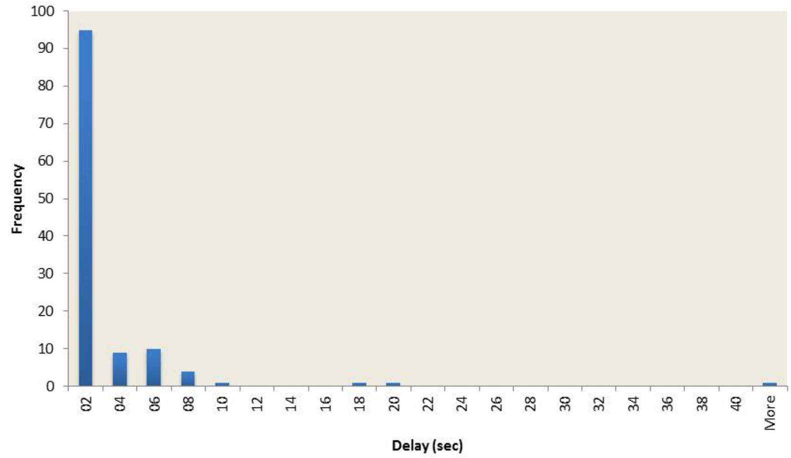
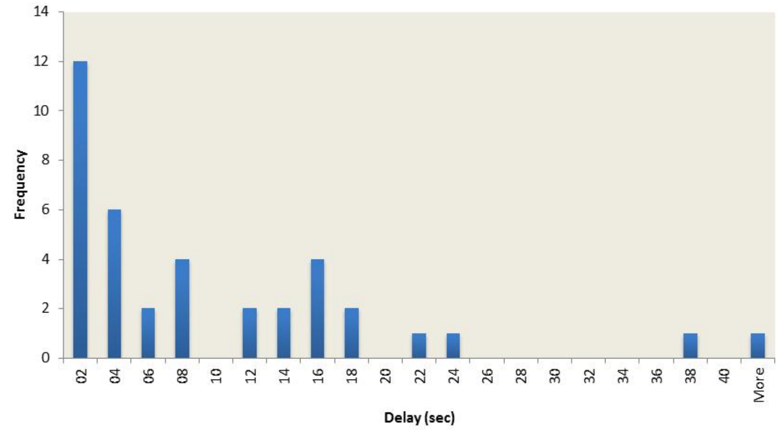


Figure 6.57 Frequency of waiting time – right turn out



6.8.5 Headways

The frequency of total headways (accepted + rejected gaps) for each movement is provided in figures 6.42 and 6.43 following. Making comparisons between the graphs below and those for the accepted gaps taken by drivers in figures 6.54 and 6.55, it can be concluded that the average driver was unlikely to accept a gap of less than 4 seconds.

Figure 6.58 Frequency of headways – right turn in

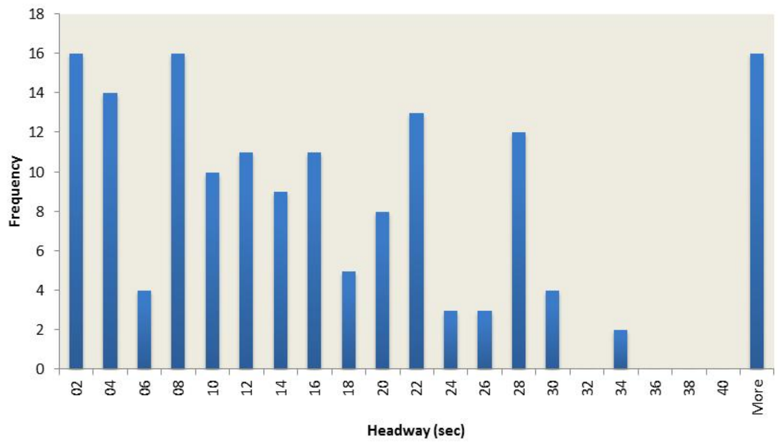
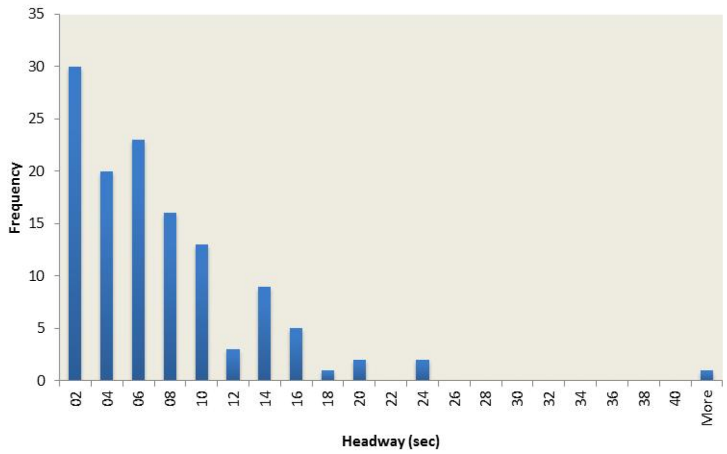


Figure 6.59 Frequency of headways – right turn out



6.9 Conclusions

With reference to the data and brief analysis, it is clear that a correlation between wait time and headway existed – ie as headway increased, wait time decreased. This was, of course, to be expected. However, although the volume of data collected was significant, it was still difficult to generate strong analysis as, especially for the right-turn-out movement, the datasets available were small and only covered the one-hour morning peak period. With further information it would be easier to confirm the conclusions that are suggested from the data above – for example, the question whether an increase in delays means the frequency of drivers accepting smaller gaps increases.

A large amount of research into driver acceptance has previously been undertaken, and incorporated into traffic modelling software packages such as VISSIM and SIDRA. Table 6.1 summarises the default gap acceptance parameters that are used for one-lane priority-controlled intersections in the aforementioned software packages.

Table 6.1 Standard gap acceptance modelling parameters for one-lane priority-controlled intersections

Vehicle movement	CUBE Voyager	SIDRA
Right turn from major road	4.1	4.5
Right turn from minor road	6.2	7.0
Through traffic on minor road	6.5	6.5
Left turn from minor road	7.1	5.0

The analysis of the eight intersections we studied noted on numerous occasions that drivers were unlikely to accept gaps of less than 4 seconds and would, where possible, accept gaps of between 4 and 6 seconds. This ties in with the default parameters outlined in the above table.

7 Crash analysis

Crash data for the 2004–2008 period was extracted from the NZTA Crash Analysis System.

Table 7.1 shows the crash history of each site that we studied, in terms of both injury and non-injury crashes. Separate crash statistics have been reported for the right-turning and crossing crash types (JA, LB and HA), as these movements are directly impacted by drivers' gap acceptance behaviour.

Table 7.1 Crash history, by site

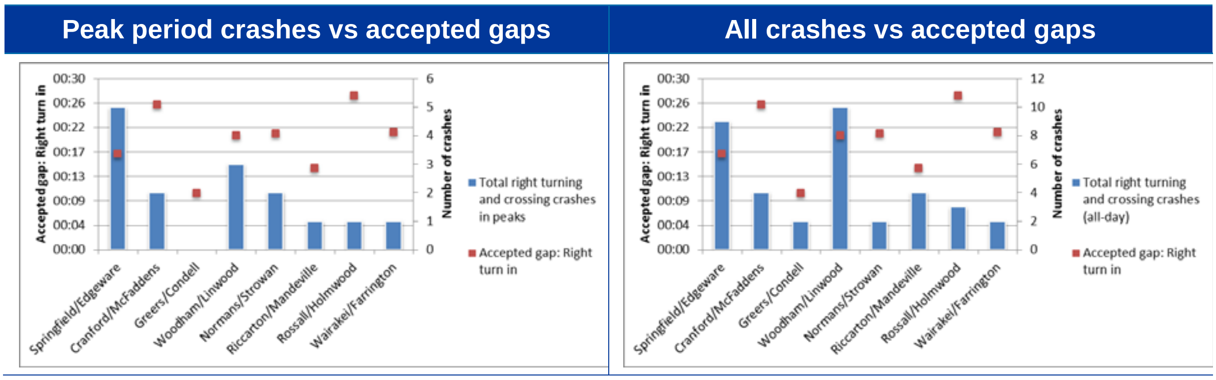
Site	Right-turning and crossing crashes (types JA, LB and HA)					Total intersection crashes (all-day)
	Morning peak (7–9am)	Afternoon peak (4–6pm)	Total crashes in peaks	Total injury crashes	Total crashes (all-day)	
Springfield/Edgeware	2	3	5	2	9	15
Cranford/McFaddens	2	0	2	4	4	7
Greers/Condell	0	0	0	2	2	4
Woodham/Linwood	0	3	3	4	10	17
Normans/Strowan	1	1	2	1	2	10
Riccarton/Mandeville	1	0	1	1	4	15
Rossall/Holmwood	1	0	1	0	3	8
Wairakei/Farrington	0	1	1	1	2	5
Total	**7**	**8**	**15**	**15**	**36**	**81**

A more detailed analysis of crash trends, by site, is presented in the subsections below.

7.1 Crashes vs accepted gaps

Figure 7.1 shows the relationship between right-turning and crossing crashes occurring during peak periods and the whole day, and the average accepted gap taken by drivers turning right into the minor road at each site.

Figure 7.1 Crashes vs accepted gaps



The figures in the above table show that the variability in all-day or peak-period crashes is not sufficiently explained by the accepted gaps taken by right-turning vehicles at the selected sites. The results seem to be skewed by the higher crash numbers observed at the Springfield/Edgeware and Woodham/Linwood intersections, which are not associated with particularly low values of accepted gap for the right turn into the minor road.

On the other hand, larger accepted gaps were observed at the Cranford/McFaddens, Rossall/Holmwood and Wairakei/Farrington intersections, where there were a smaller number of observed peak-period and all-day crashes.

7.2 Conclusions

The lack of a clear trend shown by the above analysis reinforces the need for additional data collection. It should be noted that the figures for accepted gaps shown above are average values for each site, which may be influenced by factors such as the platooning of traffic caused by proximity to a signalised intersection.

A reduction in the inherent variability in site characteristics and subsequent identification of trends can only be achieved through collection of data for additional sites. It is suggested that future studies use larger sample sets of around 100–150 sites.

8 Summary of progress, and next steps

An assessment of progress on this research study is set out below, along with commentary on key issues and lessons learnt.

8.1 Identification of suitable sites

The identification of suitable sites was a difficult and time-consuming process. The initial 'desktop' approach to site selection did not identify sufficient Christchurch sites or allow for a process whereby the study team could closely monitor the data collection during the initial stages of the research. This was considered important, as the data collection methodology was innovative and relatively untested. Eight Christchurch sites were subsequently selected for data collection.

8.2 Analysis methods

An innovative data collection methodology was designed to achieve the aims and requirements for this study. While the pilot surveys confirmed the validity and usability of data collected using the developed methods, the time and cost involved proved to be prohibitive. This was one of the key reasons behind selection of a smaller sample set for this pilot study.

The above issue highlights a key future need; namely, the need for quicker video data-processing methods. Automated image-processing technologies do currently exist; however, these are still in nascent stages of development. Discussions between the study team and specialist survey firms indicated that while the current functionality of these automated processes was not adequate for application to this study, ongoing research and development in this area is likely to allow this in the not-so-distant future.

8.3 Data variability

Data on drivers' gap acceptance behaviour, headways, waiting times and crashes at the eight selected sites was processed as part of this pilot study. The results point to the large amount of variability observed within these parameters at the selected sites.

No clear relationships could be identified between crashes and accepted gaps at the study sites. Factors such as the platooning and the volume of opposing traffic have a significant effect on the data requirements of studies looking at gap acceptance behaviour. In the absence of a sufficiently large dataset, these factors are indeed likely to influence the variability observed, which in turn results in a more 'muddled' picture when it comes to identification.

A reduction in the inherent variability in site characteristics, and subsequent identification of trends, can only be achieved through collection of data for additional sites. It is suggested that future studies on gap acceptance behaviour should use larger sample sets of around 100–150 sites.

8.4 Development of crash prediction models

An initial framework for the development of prediction models has been set out as part of this study. Model development to date has included the derivation of a probability distribution function for vehicle headways, and development of an algorithm for identifying the functional relationship between gap acceptances and waiting time. This work is outlined in appendix D.

While the lack of adequate data was a significant limiting factor for this study, it is expected that future studies, by using a more comprehensive sample set of sites, will be able to utilise and build upon the proposed framework for development of prediction models for drivers' gap acceptance behaviour, and subsequently more comprehensive crash prediction models for priority-controlled intersections.

8.5 Need for further research

Further work needs to be undertaken to build upon the methodologies and framework identified as part of this study. This is necessary to improve our understanding of safety issues at priority-controlled intersections and to undertake a more proactive approach towards identification of safety issues. This is especially relevant for making the case for better forms of control at accesses for new developments, which is an issue that is often highlighted during hearings and proceedings of the environment court.

Appendix A List of sites from the first round of analysis

Sites highlighted in grey are rural sites and were included as possible alternative sites if there were insufficient sites within the three main urban cities.

Table A.1 Sites suggested in the first round of analysis

Site no.	Location	Road 1	Road 2
1	Whangarei	KENSINGTON AVENUE	SH1N
2	Rodney	SH17	COATESVILLE-RIVERHEAD HIG
3	Rodney	SH16	TAUPAKI RD
4	North Shore	WAIRAU ROAD	ELLICE ROAD
5	Auckland	GREAT NORTH ROAD	BULLOCK TRACK
6	Auckland	BLOCKHOUSE BAY ROAD	ROSEBANK ROAD
7	Auckland	PAH ROAD	SELWYN ROAD
8	Papakura	GROVE ROAD	OLD WAIROA ROAD
9	Papakura	BEACH ROAD	PAPAKURA OFF SBD
10	Franklin	HARRIS ST	EDINBURGH ST
11	Franklin	GLENBROOK ROAD	KINGSEAT ROAD
12	Manukau	MOORE ST	VINCENT ST
13	Manukau	KERRS ROAD	DRUCES ROAD
14	Manukau	BROWNS ROAD	ROWANDALE AVENUE
15	Manukau	ALFRISTON ROAD	FLEMING ST
16	Manukau	RUSSELL ROAD	SWALLOW DRIVE
17	Manukau	HOLLYFORD DRIVE	ASPIRING AVENUE
18	Manukau	BAIRDS ROAD	KELPIE LANE
19	Manakau	SH20	PLUNKET AVENUE
20	Western Bay of Plenty	SH2	MINDEN ROAD
21	Matamata-Piako	SH26	SH27
22	Waikato	SH1B	HOLLAND ROAD
23	Hamilton	SH1N	KAHIKATEA DRIVE
24	Hamilton	CLARENCE ST	PEMBROKE ST
25	Hamilton	RUAKIWI ROAD	LAKE DOMAIN DRIVE
26	Waipa	SH1N	SH1B
27	Rotorua	ARAWA ST	TUTANEKAI ST
28	Rotorua	BENNETTS ROAD	LAKE ROAD
29	Taupo	SH1N	SH5
30	Taupo	SH5	KIDDLE DRIVE
31	Taupo	HEUHEU ST	TITIRAUPENGA ST
32	New Plymouth	SH3	PRINCESS ST

Site no.	Location	Road 1	Road 2
33	New Plymouth	SH3	MANGATI ROAD
34	New Plymouth	SH3	LEMON ST
35	New Plymouth	SH45 LEACH	GOVER ST
36	New Plymouth	SH45	VIVIAN ST
37	Napier	SH2B	WATCHMAN ROAD
38	Hastings	SH50	SH50A
39	Hastings	SH 50A MARAEKAKAHO	YORK ROAD
40	Hastings	FARNDON ROAD	PAKOWHAI ROAD
41	Hastings	KARAMU ROAD SOUTH	MURDOCH ROAD EAST
42	Manawatu	SH3	KAIRANGA BUNNYTHORPE ROAD
43	Manawatu	SH54 MILSON	KAIRANGA BUNNYTHORPE ROAD
44	Palmerston North	GREY ST	ALBERT ST
45	Auckland	GAUNT ST	DALDY ST
46	Auckland	MOUNT ALBERT ROAD	EUSTON ROAD
47	Auckland	WHITE SWAN ROAD	HILLSBOROUGH ROAD
48	Auckland	SELWYN STREET	TRAFALGAR STREET
49	Auckland	WOODWARD ROAD	CARRINGTON ROAD
50	Auckland	BLOCKHOUSE BAY ROAD	NEW WINDSOR ROAD
51	Auckland	ERIMA AVENUE	ANDERSON AVENUE
52	Wellington	SH1N RUAHINE	WELLINGTON ROAD
53	Wellington	TAKAPU ROAD	TAWA OFF SBD
54	Ashburton	SH1S	EAST ST
55	Christchurch	SH73	POUND ROAD
56	Christchurch	SAWYERS ARMS ROAD	GARDINERS ROAD
57	Christchurch	HAREWOOD ROAD	WOOLDRIDGE ROAD

Appendix B Survey work instruction

B.1 Scope of work

The work involves intersection survey work for 'Gap acceptance crash prediction models' for NZ Transport Agency research project TAR 08/29.

B.2 General

The survey involves the collection of vehicle movements at an intersection, using a video camera and manual observations. Traffic profile data using tube counters may be collected at some sites. One surveyor will be involved. The surveyor's task will be to set up the video camera, confirm intersection layout measurements as per the instructions for each intersection, and record addition information specified on a survey sheet.

All data collected shall be clear and legible. The following information will be provided on a pre-printed intersection layout video survey sheet and manual data collection sheet:

- Intersection layout video survey sheet:
  - intersection location
  - proposed location of video camera
  - measurements to be undertaken.
- Manual data collection sheet:
  - site information.

B.3 Equipment

The following equipment is required to undertake the survey, and will be provided:

- video camera
- cover for video camera
- tripod for video camera
- clipboard and data entry sheets
- writing equipment.

B.4 Safety

Company personnel must also comply with all company health and safety procedures. Surveyors will be briefed, as required by company health and safety procedures.

B.5 Data collection procedure

Pre-survey preparation:

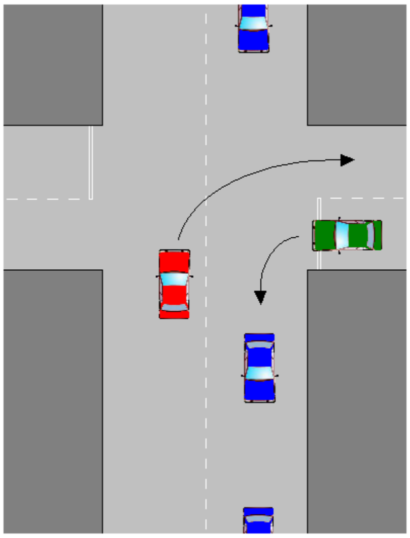
- charge up camera the night before

- ensure camera SD card is prepared for video
- measure site
- locate position for camera safety – refer to site survey layout
- set up video camera on kerbside with tripod – ensure turning vehicles are in the frame of the video
- once video camera is set up, start recording and do not move camera until survey is complete
- video intersection for one hour in AM peak (07:30–08:30).

Appendix C Measurement definitions and data collection procedure

Definitions for measurements are outlined below. Refer to the diagrams for reference to vehicle locations and explanations.

1 Turning vehicle curvilinear distance



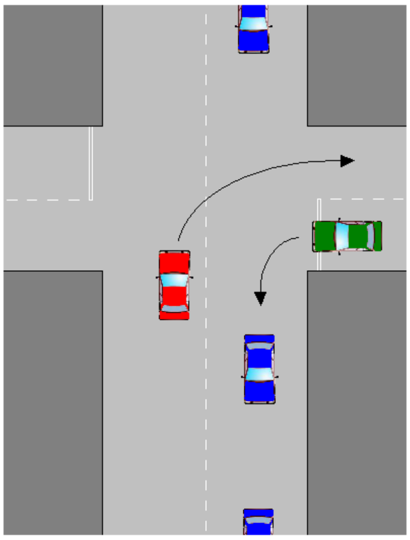
Definition:

The distance measured from the front of the vehicle at the point where the turning vehicle has to stop (red and green cars in diagram), to the point on the road where the rear of the vehicle clears the lane it has turned out of. Both measurements taken from the centre point of the vehicle.

Measurement:

The distance is measured from the location of the turning vehicle's stationary position and the point where it clears the give way line (from major to minor road) or has fully completed the turning movement (minor to major road). Measure in metres.

2 Time of passing of each straight-through vehicle



Definition:

The time of passing is based on the place where the turning vehicle stops. The timing location for the straight-through traffic is the location on the through line directly opposite the front of the stationary turning vehicle.

Measurement:

The timing starts when the first straight-through vehicle passes the stationary (red or green) turning vehicle timing location (timing point shown on diagram). After the turning vehicle has completed its turn, the final timing point is when the next straight-through vehicle reaches the timing location. Measure in seconds.

3 Right movement (red vehicle) time of arrival

Definition:

The time of arrival starts when the red vehicle is stationary, waiting to make the right turn out of the major road. Include any time in a queue. Measure in hrs:mins:secs.

4 Right movement (green vehicle on minor road) time of arrival

Definition:

The time of arrival starts when the green vehicle is stationary, waiting to make the right turn out of the minor road. Include any time in a queue. Measure in hrs:mins:secs.

5 Major road through-traffic headway

Definition:

The difference between the time when the front of a vehicle arrives at a point (timing location in point 2 above) on the road and the time the front of the next vehicle arrives at the same point. Measured in seconds.

Measurement:

Obtained from analysing the video with marks on the road, street or computer screen as reference points to measure the time between vehicles.

Appendix D Framework for crash prediction modelling

D.1 Introduction

The first two tasks (see section 3.1.3 in the report) in the model development component of this research were completed prior to the data collection commencing. They are the:

1. derivation of the probability distribution function for vehicle headways
2. development of an algorithm for identifying the functional relationship between gap acceptance and waiting time.

Summaries of these two tasks are given in the following subsections.

D.2 Distributions of headways

A three-parameter probability distribution function for representing headways has been derived, based on the following two main assumptions:

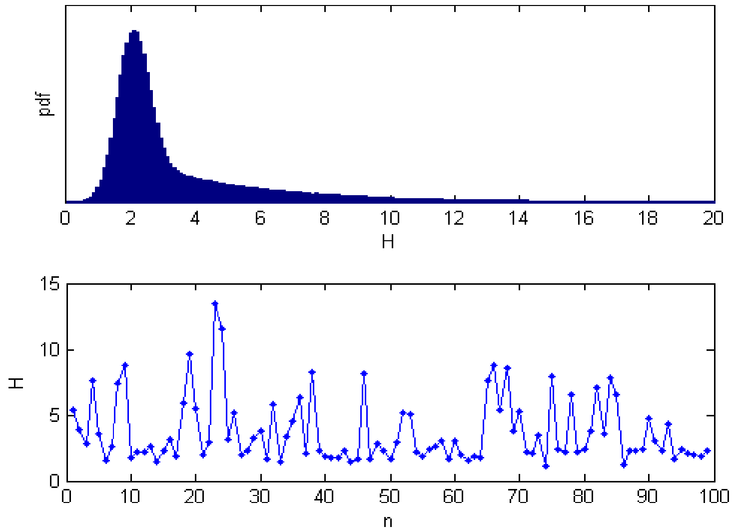
- We first adopt a prior distribution according to the independent-vehicle scenario, in which vehicles are Poisson-distributed spatially, such that the headways between them are negative exponentially distributed.
- Secondly, we assume that vehicles adjust their following distances to a safe level, which varies among drivers and follows a Normal distribution.

This adjustment can in turn affect the vehicle behind, requiring a larger adjustment. Depending on parameters, headways then become significantly interdependent and vehicle clusters form. The parameters required for this distribution are:

- traffic volume (vph)
- mean of following distance
- standard deviation of following distance.

Figure D.1 shows the resultant distribution and dynamics of headways given example values for these parameters. Traffic volume here is 100 vehicles per hour, in a single-lane flow, and following distances have a mean of 2 seconds, with a standard deviation of 0.5 seconds. The first plot is the probability density function (pdf) of *H*, the headway. The second plot is a sample of *H* in its natural sequence; that is, against *n*, the vehicle number.

Figure D1 Vehicle headways



D.3 Gap acceptance vs waiting time

An algorithm has been developed which, given data in the form {*W*,*H*,*A*}, where *W* is waiting time, *H* is the headway, and *A* is the (binary) acceptance of that headway (gap), calculates the relationship between headways and waiting time.

We assume first that the probability of gap acceptance given a particular waiting time is a logit function with respect to headway:

$$P = \frac{1}{1+e^{-a(H-H_0)}}.$$

(Equation D.1)

When $H=H_0$, P=0.5, so if we allow H_0 to vary with W, H_0 vs W is the function to be calculated. As an initial estimate we assume H_0 varies linearly with W, with slope *b* and intercept *c*. In this way we can express P as a three-parameter function of both W and H:

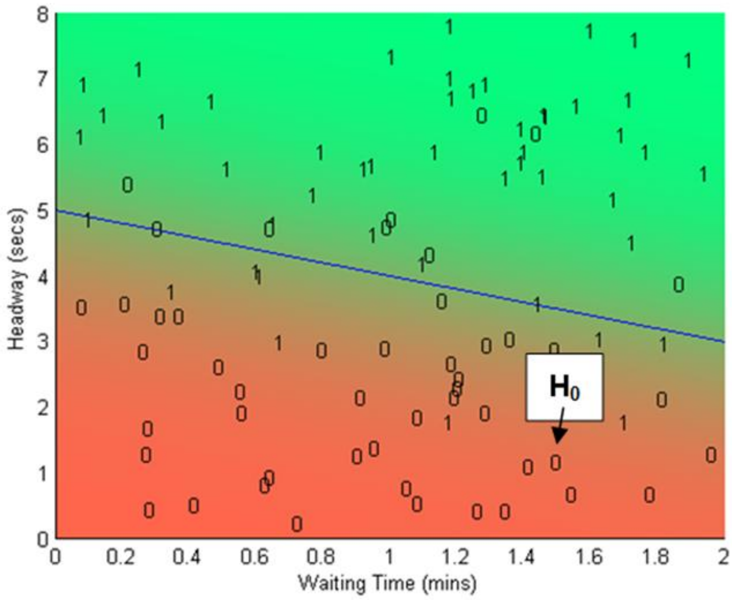
$$P = \frac{1}{1+e^{-a(H-(bW+c))}}.$$

(Equation D.2)

The variable *A* is assigned 0 where the gap is rejected and 1 where it is accepted. By varying the parameters of P to minimise the total squared error between *P* and *A* (Numerical Software Matlab has efficient minimisation capabilities), *P* becomes the best-fit surface for *A* given *W* and *H*. Then H_0 as a function of *W* is known.

Figure D.2 shows this approach graphically. Values of *A* are plotted against *W* and *H* as zeros or ones, representing rejection and acceptance of headways. The optimised function *P* is plotted in colour, where zero is red and one is green. Finally, the linear relationship between H_0 and W is identified.

Figure D2 Gap acceptance vs headways



This tool will be applied to gap acceptance data in order to identify the relationship between gap acceptance and waiting time. Of particular interest will be the slope between the critical headway, H_0, and W, quantifying the change in gap acceptance with increased waiting time.