Gaining Insights into Public Transport Passenger Satisfaction using Crowdsourced Information

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GLOSSARY

ESRI	Environmental Sciences Research Institute
GI	Geographic Information
GPS	'Global Positioning System', a worldwide satellite system for geographic positioning commonly used by modern smartphones
PT	Public Transport
Ridership	The group of people that use public transport
VGI	Volunteered Geographic Information

1   INTRODUCTION

1.1   CONTEXT

Public transport (PT) networks play an integral role in providing sustainable and accessible transport in urban environments worldwide (Cervero, Suzuki, & Iuchi, 2013). Information about the nature and purpose of trips taken across these networks is often collected to provide insights to public transport operators; into when and where trips take place, as well as demographic groups of passengers (Stradling, Carreno, Rye, & Noble, 2007). Most importantly, information is regularly collected through surveys on how satisfied passengers are when using the provided services, in order to inform operators of service aspects that need improving (Del Castillo & Benitez, 2012).

Passenger satisfaction refers to the experience and perceptions that passengers have as they use public transport (Tyrinopoulos & Antoniou, 2008). Passenger satisfaction is determined by comparing a passenger's overall expectations of a service with their realised experience (Nathanail, 2008). Passenger expectations often relate to factors such as comfort, noise, safety, reliability, and congestion (Tyrinopoulos & Antoniou, 2008). Satisfaction is measured by asking passengers about various aspects of their experience on journeys. Low passenger satisfaction may be the result of resource misallocation that does not align with passenger needs in the above areas of satisfaction. Dissatisfaction may also prevent transport agencies from breaking even on operational costs in a tough financial market when services are underused (Koushki, Al-Saleh, & Al-Lumaia, 2003; Lai & Chen, 2011).

It is important that information regarding passenger satisfaction be accurate, regularly collected and up to date so that the most efficient decisions are made. A clear picture of where services are used, how they are being used and what shortfalls exist allows for decision making to increase patronage and efficiency in delivering services to passengers.

1.2   PROBLEM

The frequency and geographic location of passenger feedback (particularly satisfaction) collected by public transport operators currently does not permit operators to make the most efficient managerial decisions required to improve public transport. The collection of location data establishes a geographic context for identifying trends in passenger satisfaction. For example, issues at specific public transport stops may have significant effects on passenger satisfaction and subsequently passenger willingness to continue to use public transport both at that location and in general. Most

passenger satisfaction surveys collect data on satisfaction measures at network level only, due to a limitation of cost and the number of respondents (New Zealand Transport Agency, 2013). An issue with traditional approaches is that if a route covers a large geographic area, no sub-route observations or trends can be identified in specific locations. Given also that passengers do not traverse the entire route of a given service and instead use smaller parts, more specific location data is a significant omission in existing methods of data collection.

Another significant restriction of existing passenger satisfaction surveys is the frequency of data collection. Many transport operators, such as Environment Canterbury in Christchurch, Auckland Transport in Auckland and the Land Transport Authority in Singapore, conduct annual surveys to provide insights into trends in passenger satisfaction (Environment Canterbury, 2015; Auckland Transport, 2016; Land Transport Authority, 2016). The use of infrequent data may have repercussions for accuracy and usefulness of analysis performed and subsequent decision making (Gaymer, 2010). Increasing survey frequency would provide greater temporal resolution to passenger satisfaction data, revealing market and passenger trends that exist on a monthly or weekly basis (Grigoroudis & Siskos, 2010). Greater frequency also allows transport operators to react to changes and make decisions more quickly using up-to-date data, instead of waiting several months for results of annual surveys. If a new situation arises that impacts satisfaction (for example, regular vandalism of a bus stop), frequently updated data can inform the steps to be taken to resolve the issue quickly. Carrying out existing feedback collection involving surveys and researchers in person at a higher frequency is resource intensive and costly for many organisations (New Zealand Transport Agency, 2013).

1.3 RESEARCH RESPONSE

This research proposes the use of an alternate data collection methodology to collect passenger feedback to address the two key issues outlined above.

Crowdsourcing (also known as Volunteered Geographic Information, or VGI, when there is a spatial component) is a method that allows for dynamic, community-driven data to be contributed by members of the wider public. In recent years, crowdsourcing has been enabled by the rise of internet-connected smartphones capable of collecting a broad range of information. The crowd drives data collection instead of agency personnel. Crowdsourcing often takes place with greater frequency and flexibility in direction than traditional surveys and utilises common technologies such as smartphones and web browsers to collect data (Papadopoulou & Giaoutzi, 2014). Users are also a source of innovative ideas with high customer benefit when given a chance to contribute (Poetz & Schreier, 2012).

Since passengers perceive problems with public transport most clearly, crowdsourcing empowers passengers to contribute meaningful information that improves their public transport experience (Teymurian, Alesheikh, Alimohammadi, & Sadeghi-Niaraki, 2013). Crowdsourcing potentially addresses both data frequency and geographic accuracy by generating passenger feedback datasets using public transport passengers themselves. Detailed passenger feedback can be submitted by passengers using their personal device at any time, including while on board public transport services. Because crowdsourcing is passenger driven and does not require face to face data collection, the resources and cost required for transport operators to collect frequent satisfaction data are reduced. Detailed geographic data in the form of GPS coordinates can be collected alongside satisfaction data using the GPS functionality in modern smartphones.

Crowdsourced datasets allow for more comprehensive spatial analysis to take place. Use of spatial analysis could determine if significant spatial clusters of a given variable exist. For example, analysis could allow for questions to be raised about satisfaction trends in time spent waiting, journey time or safety occurring across specific suburbs, streets or PT stops that were not visible with limited geographic data. Spatial data also allows for other geographical datasets, such as current weather conditions or crash history, to be associated with the crowdsourced dataset and potentially provide context for trends.

Crowdsourcing approach already has benefits for a range of crowd-driven projects such as OpenStreetMap for map databases (Dobson, 2013), and the GeoNet Earthquake Reporting tool for citizen science observations (Geonet, 2016). Such examples utilise frequent, geographically accurate data collection from the crowd to construct a collective picture of phenomena. In much the same way, crowdsourcing has the potential for clearer insights to be gained into the nature of passenger trips and satisfaction of travellers across their transport networks, as well as better-informed decisions on how to best prioritise improvements to public transport.

1.4   RESEARCH OBJECTIVES AND ROADMAP

This research thesis poses the following research question: **How can crowdsourcing methodologies increase the utility of passenger feedback on public transport?**

This research question comprises of four objectives, considered at each stage of this thesis:

1. **To apply crowdsourcing methodologies to collecting more frequent, geographically accurate passenger satisfaction information.** The primary aim of this research will be achieved by

designing a series of questions related to passenger feedback, alongside a crowdsourcing survey tool designed for collecting passenger feedback from bus users. The survey will then be distributed on the Metro Bus network of Christchurch, New Zealand, used as a case study.

2. **To undertake an exploratory analysis of a dataset of passenger feedback to provide insights into passenger satisfaction collected using a crowdsourcing methodology.** A set of crowdsourced passenger feedback gathered during the above case study will be analysed alongside external datasets to increase the value of passenger feedback.

3. **To assess the extent to which passengers are interested in providing feedback on their smartphones during their bus journey.** Given that a crowdsourcing methodology is driven by contributor interest rather than researchers, it will be important to gauge interest in providing crowdsourced feedback from passengers on public transport.

4. **To evaluate the effectiveness of crowdsourced data collection as a useful substitute or supplement to existing methodologies.** This research will identify the role that crowdsourced datasets might play in replacing regular research surveys as a means of collecting passenger feedback, or whether crowdsourced data functions in an alternate role.

In Chapter 2, an exploration of literature surrounding passenger feedback and passenger satisfaction, including factors that affect satisfaction is presented. Existing data collection methodologies are covered, and the research gap in literature identified. A crowdsourced data collection approach is identified using volunteered geographic information (VGI) methodologies, drawing from existing examples of crowdsourcing in other areas of interest. Advantages and disadvantages of crowdsourcing are identified and discussed in their implications for this research.

Chapter 3 outlines the methodological approach of this research implemented in a series of phases, and the context of the case study of the Metro Bus network of Christchurch, New Zealand is provided. Phase 1 outlines development of survey questions that collect information about a passenger's trip and their satisfaction with a range of factors related to their journey. Survey design and the technical implementation of a crowdsourcing tool are described. Phase 2 details processes and methods of promoting the survey across the Metro Bus network in Christchurch and collecting responses. Phase 3

describes the development of a real-time dashboard to display the responses as passengers submit them. Lastly, Phase 4 outlines stages of analysis on the crowdsourced dataset.

In Chapter 4, the results of the survey undertaken on the Metro Bus network are reported. Information on ridership, passenger satisfaction and analysis of external datasets from results are described. Passenger suggested improvements are reviewed and prioritised. Discussion of these results is brought into Chapter 5, where the role and effectiveness of crowdsourced passenger feedback in public transport are evaluated. Practical considerations for undertaking crowdsourcing in PT are given, and suggestions made for future supporting crowdsourcing data collection efforts.

2 LITERATURE REVIEW

2.1 INTRODUCTION

Passenger feedback plays a major role in public transport (PT) operations. This literature chapter details the context and methods by which passenger feedback is collected in public transport. Although there is a wide range of information that can be collected from passengers, this chapter focuses on the role and importance of collecting passenger satisfaction information. Within this area, a research gap is identified in the frequency and geographic accuracy of passenger feedback in the limitations of existing methods. Section 2.3 explores a crowdsourcing approach that takes advantage of increasingly available consumer technologies and web-based platforms to collect Volunteered Geographic Information (VGI). A VGI based methodology for data collection is detailed. Existing VGI projects introduced to serve as a context for the approaches taken and issues faced with this current research, providing direction for this research's approach to effectively crowdsourcing feedback from bus passengers.

2.2 PUBLIC TRANSPORT AND PASSENGER FEEDBACK

2.2.1 Overview

Public transport exists for several social, environmental and economic reasons that need to be managed and prioritised. Public transport operators may be limited by funding requirements or have areas that they are required to service (Walker, 2008). As such, public transport operators require information about their passengers and the services they use to make important decisions about the way they operate, and what should be prioritised or improved in the future. Feedback is collected from passengers across a range of satisfaction factors, as detailed in the following section, that relate to their experience with the operator's services. Feedback may be used in the short term to resolve specific issues of poor service for passengers, while feedback gathered over the long term, (such as annual surveys) assist with the shaping of top-down planning (Stelzer, Englert, Hörold, & Mayas, 2016).

2.2.2 Passenger Satisfaction

Passenger satisfaction refers to passenger experiences and perceptions of public transport, measured by comparing overall expectations of service with experience (Tyrinopoulos & Antoniou, 2008). Public

transport operators widely use satisfaction as a means of measuring perceived service quality (de Oña & de Oña, 2014). Satisfaction makes up the customer component of the quality loop of public transport and is linked to the service provider's performance in effectively delivering services to passengers (Figure 2-1).
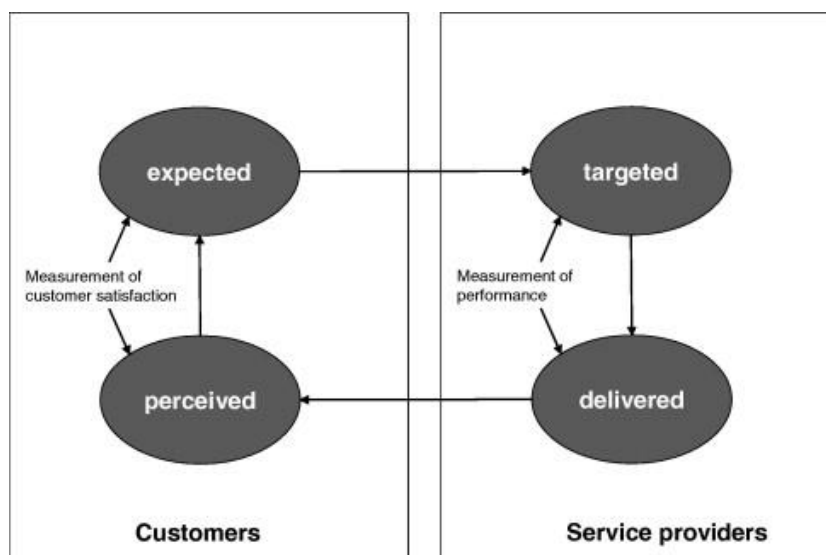
Figure 2-1: The Quality Loop of Public Transport (Nathanail, 2008)

The following section details satisfaction factors used throughout the literature. Satisfaction encompasses the entirety of the passenger experience, from planning, boarding and riding public transport, including the convenience, comfort and safety.

2.2.2.1   Availability

The coverage and frequency of public transport are factors that determine the availability of services to passengers (Del Castillo & Benitez, 2012). Coverage refers to the spatial and temporal extent over which public transport serves users. Improving coverage may include increasing the number of stops along a public transport route or improving a stop's ability to cope with higher passenger numbers using a service. Frequency is how often a service runs along a given route over time and affects the time a passenger waits before boarding (Redman, Friman, Gärling, & Hartig, 2013). When coverage and frequency do not meet passenger expectations or requirements, people become dissatisfied due to the impact on personal mobility and are therefore likely to favour an alternative mode of transport, such as a car (Beirão & Sarsfield Cabral, 2007). Fare pricing may also affect the availability of a public transport service, depending on whether the passenger perceives the value of service at least matches the cost of the fare. The perceived ease of tasks such as getting on, paying a fare, boarding with a bike, disembarking, or making a transfer also impact passenger satisfaction (Redman et al., 2013).

2.2.2.2 Information

The provision of information about the routes and schedules of a public transport network allows passengers to make decisions about where and when they use public transport. In addition to scheduling information, the availability of information on service delays and changes can affect the confidence passengers have in getting to their destination on time. The improvement of passenger information systems has the potential to not only reduce anxiety, but also increase satisfaction and ridership (Ferris, Watkins, & Borning, 2010). Thus, the ease of receiving and understanding relevant schedule information has a substantial impact on satisfaction that should be considered by operators.

2.2.2.3 Reliability

Reliability relates to the difference in arrival time between the scheduled and actual times. As delays in arrival times increase, passengers are more likely to be dissatisfied due to the uncertainty of when the vehicle will arrive at their stop (Beirão & Sarsfield Cabral, 2007). Similarly, the time it takes to cover a given distance also relates to satisfaction with service reliability. However, a passenger's perception of a service's reliability may vary between individuals based on their previous experiences and interactions with public transport.

2.2.2.4 Customer Care

Interactions with public transport personnel, such as the driver, are often inevitable during passenger journeys. Drivers interact with passengers to sell tickets, greet boarding passengers or provide information. The knowledge, helpfulness and friendly attitude of staff in resolving issues is a priority for many businesses and plays a major role in ensuring that customers remain satisfied with their service (Hutchinson, 2011). Therefore, it is important to know if public transport customer service is meeting passenger requirements.

2.2.2.5 Comfort

Passenger comfort may refer to a variety of factors that affect the enjoyment of using public transport, including the interior temperature of the vehicle, the amount of vibration, the amount of noise from the vehicle or nearby sources, and the comfort and availability of seating (Shen, Feng, Li, & Hu, 2016). Comfort has an influence on modal choice; if it does not meet the passenger's expectations, passengers are likely to be dissatisfied and seek an alternate travel option where possible, especially if a vehicle is crowded (Shen et al., 2016).

2.2.2.6 Security and Environment

Passenger safety is a factor of concern for many passengers and has a major role in satisfaction. Safety includes road and traffic safety at stops (Truong & Somenahalli, 2011), or the behaviour of other passengers that could cause concern for personal safety, which may be abusive, frightening or intimidating (Stradling et al., 2007). It is important to know how effectively implemented safety measures are, and whether they address passenger issues (Wallace, Rodriguez, White, & Levine, 1999). The state of public transport environments (such as stops and exchanges), as well as on the vehicles themselves, have an impact on perceived comfort and safety. When issues arise, satisfaction is decreased when PT facilities are degraded through uncleanliness or vandalism (Thompson et al., 2012).

2.2.3 Data Collection Methodologies

The process of obtaining data on passenger satisfaction is driven by the passenger and the operator. For passenger driven feedback, transport operators typically provide a variety of channels in which passengers can provide feedback or register a complaint. On many public transport websites, an online form is provided for feedback, compliments and complaints. Other support mediums include email, phone and customer representatives in person. Increasingly, a social media presence on popular platforms such as Facebook and Twitter are used to interact with passengers.

Agency driven feedback is gathered through regular data collection efforts in the form of passenger surveys. Many public transport operators use annual passenger surveys that are used to inform broader decision making. Environment Canterbury in Christchurch (Environment Canterbury, 2015), Transport For London in the United Kingdom (Transport for London, 2015) and the Metropolitan Transportation Authority in New York, USA (MTA, 2015) all use passenger surveys to collect feedback across PT services on their respective networks. Passenger surveys may be undertaken as an interview, where the participant is asked a series of questions by a researcher face-to-face. In person interviews for annual surveys are generally more time-intensive because they collect large amounts of detailed feedback from participants. A paper or computer assisted survey may be used in place of an interviewer to collect the same information. Web-based surveys are also used that take advantage of rapid digital distribution using internet sites and social media (MTA, 2015).

Until recently, the ability to collect passenger feedback in a sufficient quantity and in a format that permits spatial analysis has been limited (Stelzer et al., 2016). Two primary drawbacks exist regarding existing methods of collecting passenger feedback: geographic accuracy and frequency of collection.

Currently, most passenger satisfaction surveys gather data on passenger feedback and satisfaction measures irrespective of their specific location. Data is typically collected at a network level using routes (New Zealand Transport Agency, 2013). However, if a route covers a large geographic area, sub-route observations or trends in specific locations cannot be identified. Since passengers do not traverse the entire route of a given service and instead travel smaller segments, the omission of precise location information is important to consider. The collection of detailed geographic data in the form of GPS coordinates collected alongside existing satisfaction data allows for more potentially comprehensive spatial analysis to be performed compared to current approaches (Lao & Liu, 2009). The use of spatial analysis can determine if significant clusters of a given variable exist along a route, and allows for questions to be raised about trends that are not visible with limited geographic data.

With many organisations now opening their geographic information through standardised formats, the availability of spatial datasets provides opportunities for new insights into public transportation data. When detailed location information is collected alongside factors which affect satisfaction (for example, factors related to infrastructure at a specific bus stop), other geographic datasets such as traffic congestion or weather can be compared to investigate the cause of low passenger satisfaction. Geographic Information Systems (GIS) and geographic datasets are already used in public transport decision making in other ways; for example, accessibility analysis of underserved areas and accessibility of stops to users (Currie, 2004); (O'Sullivan, Morrison, & Shearer, 2000). The use of spatial analysis for passenger satisfaction may provide a useful addition to an integrated approach to planning and decision making using GIS.

2.2.3.1 Data Frequency

Another restriction is the frequency of existing passenger satisfaction surveys. Many transport operators, such as Environment Canterbury in Christchurch, conduct annual surveys on passenger satisfaction (Environment Canterbury, 2015). While such surveys can provide information about yearly trends, the use of infrequent data for more specific trends may have repercussions for the accuracy and usefulness of analysis performed and upon the decisions made using the data (Gaymer, 2010). Carrying out existing data collection efforts at higher frequencies is resource intensive and costly for many organisations (New Zealand Transport Agency, 2013). However, increasing the survey frequency would provide greater temporal resolution of passenger satisfaction data. Frequent surveys are used in customer satisfaction strategies more broadly to reveal trends in satisfaction that exist on smaller timescales, such as on a monthly or weekly scale (Grigoroudis & Siskos, 2010). Greater frequency also allows transport operators to react to changes and make decisions more quickly using up to date data, instead of waiting several months for the results of the next annual survey.

2.3 DATA COLLECTION USING A VOLUNTEERED GEOGRAPHIC INFORMATION (VGI) APPROACH

Passenger feedback is an important part of the decision-making process for public transport operators and provides a means of evolving their services to fit their users better. Several opportunities exist that could greatly facilitate the process of collecting passenger feedback, and are discussed in the following sections.

2.3.1 Overview of VGI

Until recently, most geographic information (GI, or information that contains a locational or spatial component) was collected and produced primarily by official agencies and organisations, such as national mapping agencies. In contrast, Volunteered Geographic Information (VGI) is geographic information that has been collected from and by the wider public. The individuals that contribute often have little to no formal training in creating the data, yet their engagement has had a dramatic impact on the cost and method of collecting geographic information (Goodchild, 2007). The rise of volunteered geographic data collection has supported the introduction of crowdsourcing tools and technologies. Personal computing and smartphones use has increased data collection from a variety of sensors and people. VGI provides a larger quantity of geographic information to be produced than ever before (Sui, Goodchild, & Elwood, 2013).

2.3.2 Data Collection Approaches to VGI

Widespread use of smartphones equipped with GPS capabilities now allows anybody with a smartphone to collect geographic data, enabling people to be part of a participatory sensor network. VGI might take the form of active contributions, where the participant records and transmits information they see in their environment as a kind of geographic citizen science (Haklay, 2013). Passive forms of indirect VGI contributions are also possible; for example, location information can be used from geotagged sources such as photos uploaded to a photo sharing site like Flickr, or tweets posted on social media websites, even if this was not the original purpose the contributor had in mind when they posted it (Goodchild, 2007). With a large group of participants contributing many observations, it is possible to build a comprehensive 'spatiotemporal view' of phenomena compared to traditional methods of data collection. An example of this is the passive information collected from GPS devices. Information about the user's speed and path are aggregated through passive contributions to provide a picture of traffic congestion (Dobson, 2013). In much the same way, using VGI to crowdsource PT passenger feedback can collectively paint a picture of passenger satisfaction at specific stops across a public transport network, through active passenger reported contributions.

VGI provides a valuable source of geographic data to several companies, agencies and community projects. However, the role and expectations of the contributors of volunteered information should also be considered. For example, commercial spatial map databases such as HERE Maps and (until recently) Google Maps collect crowdsourced geographic information from users that is only available back to users under restrictive terms of use. In comparison, the OpenStreetMap project makes the data freely accessible to all under a Creative Commons license (Dobson, 2013). To ensure that VGI is used in a fair and equitable manner, the benefit of collecting the information between passenger and operator should not be held solely by one side (Sui, Elwood, & Goodchild, 2013).

2.3.3 Public Participation

A key component of VGI are the volunteers themselves. While the individuals that contribute may be part of a community (such as OpenStreetMap), some systems encourage participation from the wider public. Public Participation in GIS (PPGIS) is an area related to VGI that focuses on the use of GIS technologies to enable and support public processes such as decision making and community involvement. VGI aims to create spatial information by allowing people to act as sensor networks (Brown & Kyttä, 2014). Wider public participation in VGI tends to require little to no knowledge or skills, lowering the barrier to entry and allowing for a greater number of people to contribute. The wider public often uses VGI in reporting systems and by citizen science projects used to collect information about a phenomenon. Examples include The Great Kereru Count, which gathers information and locations of native wood pigeon (Kereru) sightings from the public (Great Kereru Count, 2016). GNS Science's Geonet earthquake felt report tool collects and displays information about the shaking characteristics of earthquakes, often within minutes of an event occurring (Geonet, 2016). The Walking Papers project is another example of geographical citizen science that contributes geographic observations of the environment to OpenStreetMap (Haklay, 2013). Public participation in VGI collection also allows for the inclusion of individuals and communities in the design applications and decisions that have the power to improve day to day lives (Kanhere, 2011). For travellers that use public transport every day, crowdsourcing may be a means for the voice of passengers to directly reach operators and have passenger concerns and feedback heard.

2.3.4 Motivation for Participation

Several motivations drive people to contribute VGI data. Structured communities (such as OpenStreetMap or Wikipedia) often facilitate a framework for contributions. The drive to contribute to a greater collective knowledge of a subject of personal importance is a strong motivator (Budhathoki & Haythornthwaite, 2012). Passengers may be motivated to contribute feedback about

their experiences on public transport so that the issues with their experiences can be acknowledged and improved.

However, while this may be effective for some types of data collection, less interesting forms of data collection may not receive the same degree of attention as topics of wider public interest. Gamification has been successfully used to make the process of contributing data more fun and engaging for participants, thereby increasing the quantity of data collected. A location based game that facilitated the collection of data on traffic signs, park benches and bins has previously been used (Davidovic, Medvedeva, Niš, & Stoimenov, 2013). Incentives offered for contribution also increase participation (Composto et al., 2016). Motivators could either take the form of reward incentives, or by providing a service (such as up to date public transport information) that the user requires in exchange (Harris, Smith, O'Neil, & Severinsen, 2016).

2.3.5   Issues Surrounding VGI

Due to the variance in spatial information collected from a range of participants and ability levels regarding the technology used, VGI datasets can sometimes be of lower quality compared to traditional sources of geographic information. VGI is often not accompanied by appropriate metadata about the origin of the information. Metadata is important for determining the usefulness and accuracy of a dataset. The lack of this data may mean there is no way to verify the trust users can place in the information, as is the case for collecting anonymous passenger feedback (Criscuolo et al., 2016).

Some VGI practices also introduce new participation barriers. Technological, social and economic barriers may manifest due to a lack of appropriate technology such as a smartphone; potential participants may not have technical ability to operate a smartphone or cannot afford one (Lin, 2013).

Participation inequalities may also exist, where a concentration of participants will influence the information produced. This phenomenon has been demonstrated in different crowdsourcing projects at various scales; for example, 0.003% of Wikipedia contributors are responsible for two-thirds of the content (Haklay, 2016).

Issues also exist around privacy and the right to access the contributed information. Datasets that are unknowingly provided by passive contributors may be used in a manner that is counter to the original creator's intent. An example of passive contributions is the use of geotagged posts uploaded to social media websites for consumer profiling (Smith, 2014). In such situations where an unequal balance of power exists, one party may receive most or all of the benefits of the data collected (Feick & Roche,

2013). It is important that crowdsourced passenger feedback adopts a role that benefits both the passenger and the operator.

2.4 CONCLUSIONS

The collection of passenger satisfaction plays a major role in passenger feedback but is currently limited in geographic accuracy and frequency of collection. VGI provides an alternate source of information to traditionally collected datasets that can build a useful picture of passenger satisfaction from a wide group of people. Increasingly widespread smartphones use means accurate geographic information can be collected more easily, while a range of software tools and platforms exist to collect and make use of crowdsourced information. Increasingly, VGI is being used for citizen science and collaborative open source projects such as Open Street Map, driven by community contributions. However, it is important to consider issues of data quality, barriers to participation and the benefits gained by both contributor and collector. VGI is a good fit for passenger feedback collection. VGI meets the objectives of this research by being more geographically accurate, allowing frequent passenger feedback to be collected, while also enabling passengers to have a greater and more direct voice in public transport decision making.

3 METHODOLOGY

3.1 INTRODUCTION

This chapter provides an overview of a crowdsourced model for passenger feedback collection and its application to a case study, the Metro Bus network, in the city of Christchurch, New Zealand.

An overview of the crowdsourcing model used in this research is shown in Figure 3-1, and consists of the following phases:

- **Survey Development** – development of survey questions surrounding passenger satisfaction on public transport. A web-based crowdsourcing tool was designed to accept and store passenger responses.

- **Data Collection** – a public facing, location enabled survey was developed that allowed passengers to contribute feedback using their smartphone web browser either on or off the bus. Materials advertising the survey to passengers was distributed across the public bus network and responses collected

- **Real Time Dashboard** – a user-friendly web interface was designed to allow public transport agencies to view and browse passenger responses as they are received quickly. A real-time dashboard allows feedback to be quickly viewed, and for descriptive statistics to be visualised.

- **Data Analysis** – the collected data was downloaded and cleaned for analysis. The analysis included a range of descriptive and statistical tests, spatial analysis and keyword text analysis of text responses, with the aim of drawing conclusions about the spatial, temporal, and statistical characteristics of passenger satisfaction that can inform decision making in public transport.

1. SURVEY DEVELOPMENT

Survey Question Design

◄ Basic Trip Information
◄ Passenger Satisfaction Questions
◄ Suggested Improvements to Service
◄ Demographic Information

TECHNICAL IMPLEMENTATION

Crowdsourcing Tool Development

Feature Layer Design
ArcGIS Online Geoform
Landing Page + Analytics

Pilot Testing

Feedback on questions, UX
Question Iteration

2. DATA COLLECTION

Survey Distrubution

◄ Posters On-Board Buses
◄ Flyers Attached to Bus Stops
Social Media Promotion

DATA VISUALISATION AND ANALYSIS

3. Real Time Dashboard

Live response viewer

Descriptive statistics viewer and explorer

Cloud based analysis and tools

Data editing

4. Data Analysis

Comprehensive desktop based analysis

Spatial Analysis (ArcGIS)

Statistical Analysis (SPSS)

Keyword Analysis

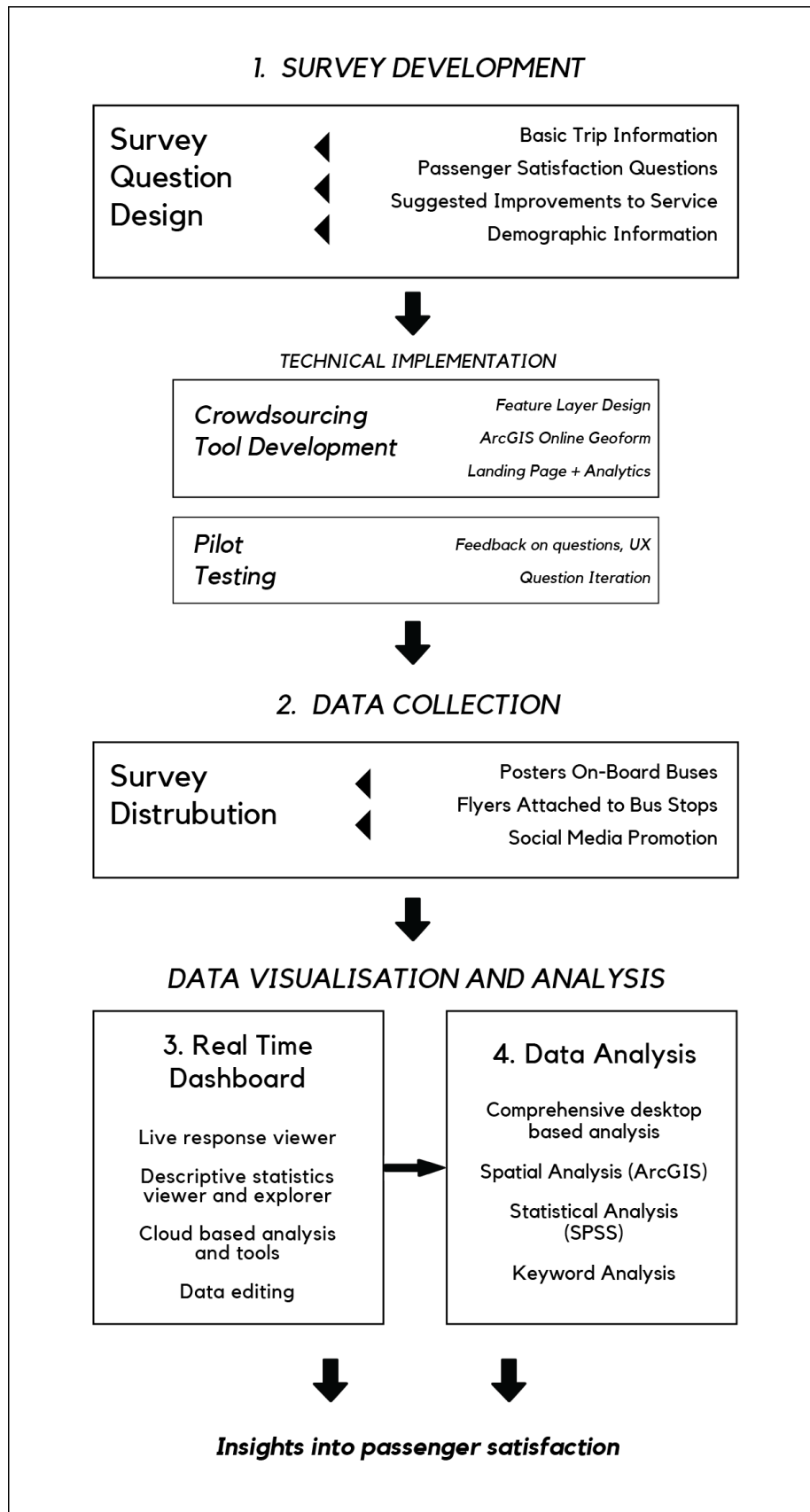***Insights into passenger satisfaction***

Figure 3-1: Crowdsourcing passenger feedback system, as implemented by this study

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3.2 Case Study: Metro Bus Network, Christchurch, New Zealand

This research applied a crowdsourced methodology to the collection of passenger feedback on the Metro network[1], the public bus transportation system in Christchurch, New Zealand. The Metro network consists of twenty-seven bus routes and one ferry route in a hub and spoke transportation model, with five of these routes serving as higher capacity lines connecting Greater Christchurch to the bus interchange in the Central Business District. Metro buses also service the surrounding towns of Rolleston and Lincoln to the south of the city, and Kaiapoi, Woodend, Waikuku and Rangiora to the north (Figure 3-2). Timaru is serviced but was omitted from the study due to the city's distance from Christchurch. The survey excluded Timaru routes from the survey bus route list, and the survey was not distributed there.
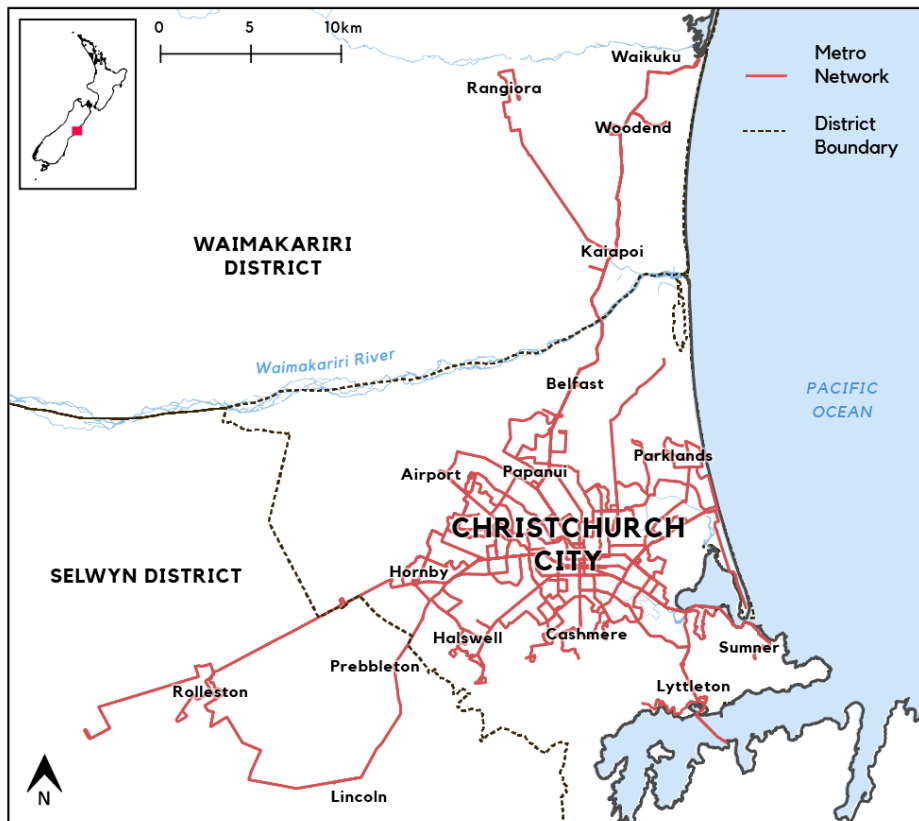

Figure 3-2: Extent of the Metro Bus network across Christchurch City and surrounding districts

Multiple authorities manage the Metro network. Environment Canterbury (Ecan) is the lead agency responsible for coordinating public transport services, including planning, timetabling and marketing

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[1] http://www.metroinfo.co.nz/

activities. The Christchurch City Council is in charge of the public transport infrastructure (bus stops and exchanges) within Christchurch City, with the Waimakariri and Selwyn District Councils responsible for the respective infrastructure in their jurisdictions (shown in Figure 3-2). Two companies – Red Bus and Go Bus – are contracted to operate Metro bus vehicles on services across the network.

The methodology for crowdsourcing passenger feedback was designed and implemented on the Metro network, working with support from Environment Canterbury, Christchurch City Council, Waimakariri District Council and Red Bus. The methodology was developed in the context of a public bus network; however, the method is also intended to apply to other modes of public transport such as rail networks.

3.3 PHASE 1: SURVEY DEVELOPMENT

3.3.1 Survey Design
The questions are made up of the categories below. The full survey used by this study can be found in Appendix 1.

- **Trip Information**: information about the characteristics of the passenger's trip.
- **Passenger Satisfaction:** passenger's satisfaction across a range of factors related to their bus trip.
- **Improvement Information:** open-ended questions that allow for more abstract responses and suggestions for improvements about their journey.
- **Demographic Information:** general information about the participant.
- **Survey Feedback:** Additional questions asked about the process of giving feedback.

The survey was designed to collect anonymous responses. Personal details such as name and contact details were not included to protect the privacy of respondents. The final questions were also subject to ethics approval before being used to collect data.

3.3.1.1 Trip Information

Basic information about the passenger's trip is collected, including whether the survey was filled in while using the bus, to answer the question of whether respondents could respond while using public transport. The time of day and date of the trip was collected to provide a temporal context for the

data and allow satisfaction comparisons over different time periods. For current trips, the date and time were automatically recorded. The bus route used on the trip is asked, allowing survey data to be collated on a route level. At the end of the survey, the location of the stop where the bus trip began is entered on a map by the respondent. Location data allows for spatial analysis of the accompanying collected information and greater integration with other geographic datasets.

3.3.1.2 Passenger Satisfaction

This research's methodology focused on the collection of passenger satisfaction ratings for a trip to test the effectiveness of the crowdsourcing method. The approach has two advantages; a satisfaction rating is straightforward for passengers to complete on mobile phones while also providing a useful insight into passenger perceptions across several aspects of their trip.

A set of questions was developed based on factors likely to have an influence on passenger satisfaction, informed by the literature discussed in Section 2.2.2. These satisfaction factors were then considered for relevance to the Metro Network case study, with feedback from Environment Canterbury on question wording and relevance to ensure that the feedback collected provides utility for improvement of their operations.

Since the survey was primarily intended that participants use smartphones to submit responses, the length and medium of the questions limited the number of satisfaction factors passengers could be asked. A pilot test was undertaken to provide feedback on an initial shortlist of satisfaction questions. Feedback indicated that the survey was too long to complete on a mobile device, so the total number of satisfaction related questions was reduced to 12 satisfaction questions ensure that the survey was an appropriate length. The reduction was achieved by removing the questions deemed least important out of those surveyed in the literature and by passengers in the pilot trial.

The final list of satisfaction factors are as follows:

- Overall Satisfaction of the trip
- Finding bus information (e.g. timetables)
- Getting to the bus stop
- The bus stop's suitability for weather
- The bus stop's cleanliness
- The bus stop's safety
- The time spent waiting for the bus
- Finding a seat on the bus

- The skill of the bus driver

- The bus's cleanliness

- The bus's temperature

- The bus trip's duration

For each of the above, passengers were asked to provide a satisfaction rating between 1 (least satisfied) and 5 (most satisfied). The responses produced satisfaction scores that were then analysed during the analysis phase to provide detail into spatial and temporal trends in satisfaction.

3.3.1.3   Improvement Suggestions

Passengers were asked about the aspect of their trip that could be improved the most. Open-ended questioning was used to collect this data, allowing for a full range of responses. Three questions were asked about improvements in specific areas. However, after pilot and usability testing feedback, the three questions were reduced into a single question that asked respondents for the one thing that would improve their trip the most. The change allowed the survey to be completed more quickly and for the identification of more specific themes in feedback during analysis.

3.3.1.4   Demographic Information

Demographic data provides information into the groups of people that are using public transport. In this survey, two demographic variables were collected: age, and gender. Demographic information provides information about the characteristics of the survey sample (Dillman, Smyth, & Christian, 2008). Demographic data is also important in determining the overall composition of the population. If a demographic makes up a large part of a public transport ridership, this helps provide context to decision making by public transport operators.

3.3.1.5   Survey Feedback

Three questions were asked relating to the survey itself. The first of these questions asked at the beginning of the survey whether the respondent had previously completed the survey. Since crowdsourced information collection can result in frequent observations, this question provides an indication of how likely people are likely to provide multiple responses over time. The second question asked respondents if they would provide feedback about their bus trip again in the future, having now undertaken the survey. Many crowdsourcing systems rely on motivated participants to succeed at their objectives, (Section 2.3.4). Lastly, a free form question at the end of the survey allowed the participants to provide any further feedback.

For passengers interested in providing additional and specific feedback about the survey, a separate optional survey was provided after the main survey. The additional questions were included to provide further information on public interest in the crowdsourced approach; it also reduced the burden of adding too many questions to the main survey. Because of the reduced uptake of this additional survey, additional response bias needs to be taken into consideration.

3.3.2   Technical Implementation

3.3.2.1   Overview

ArcGIS Online[2] is a cloud software platform created by ESRI that allows for the creation, management, analysis and sharing of spatial information and apps. The platform was chosen in this research due to:

- Its ability to work with, store and visualise spatial information, a core component of this study.
- Its ability to collect spatially enabled crowdsourced information using included templates such as the GeoForm, which uses a web form and map combination to collect data.
- The platform's ability to collect and display crowdsourced information in real time.
- The platform's ability to accommodate potential future development for greater customisation or interoperability using ArcGIS tools and APIs. The flexibility of the platform leaves the door open for any potential tools to be developed in the future to suit the various requirements of public transport agencies.
- Environment Canterbury, the agency in this case study already uses ArcGIS in some areas within the organisation (Eagle Technology, 2015) and the software is also widely used in New Zealand.

Other crowdsourcing tools can collect crowdsourced feedback, such as Maptionnaire[3]. ArcGIS was chosen over other alternatives as the software was available to the research project at no cost and was better suited to the case study used. However, the methodology for crowdsourcing employed by this research would be easily adapted for use in Maptionnaire and similar tools.

3.3.2.2   Implementation
Once the survey questions were developed and software platform selected, a geographic feature layer was created to store responses using ArcGIS Pro, a desktop GIS software package. A feature layer is a table designed to record the responses of the participants as they are collected. Unlike typical

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[2] http://www.esri.com/software/arcgis/arcgisonline
[3] https://maptionnaire.com/

databases, feature layers also contain spatial geometry; in this case, the coordinate points provided by respondents. The feature layer was designed to ensure that only valid data was collected for the type of question asked. Questions that required a numerical value (such as a satisfaction rating) could only accept integers, while text-based questions accepted text strings. Ranges were defined to ensure that only a satisfaction value between one and five was accepted, bus routes were limited to a drop-down selection of bus routes and numbers. Age, gender and binary questions used coded value ranges. To ensure that, at a minimum, required information on the bus service and overall satisfaction was collected (even if all the questions were not answered), the fields for these questions were set to prohibit a NULL value from being entered. Such measures ensured that the data collected was valid for analysis.

The feature layer was connected to a GeoForm (an excerpt is shown in Figure 3-3, the full survey can be found in Appendix 1) using ArcGIS Online. GeoForms are a crowdsourcing tool provided on the ArcGIS Online platform for the creation of web based, location enabled surveys. The advantage of using a GeoForm over a traditional web form survey tools such as Qualtrics is that a GeoForm facilitates the analysis of the spatial aspect of the crowdsourced data analysis by collating the responses on a map (Figure 3-4). GeoForms are compatible with smartphone browsers so that passengers can fill surveys out on their mobile devices while they ride or wait for a bus without needing to install an app. When feature layers are hosted on ArcGIS Online, other maps and applications to connect to and display the crowdsourced information as soon as responses are submitted through the form.

While GeoForms work with a broad range of smartphones, the large number of different browsers, operating systems and phone makes and models available means that it is possible the GeoForm will not work on every single device. In rare instances where the GeoForm did not work for passengers, a reduced, basic web form was created and provided. While the basic web form does not capture location (and therefore spatial analysis was limited to routes as directly input by users), the form ensured that passengers were still able to rate their satisfaction.

The GeoForm was configured to use the appropriate input method for each question; for example, yes/no questions were represented as radio buttons, ranged values as drop downs and the date question utilising a time and date picker. To ensure that the extensive list of the various bus services was navigable on a mobile device, a hybrid search bar and drop down was used, allowing the user to start typing the service name or number to jump to the appropriate route name.

Christchurch Metro Satisfaction Survey

Thanks for taking the survey! It will take less than 5 minutes to complete.

You will be asked to provide some details about your bus trip, and give a satisfaction rating (1-5) for several aspects of your trip.

You will then be asked to provide **the location of your starting bus stop** using the map provided (either allow access to your location, or select a point manually)

Optional: What do you think about this method of providing feedback about your bus trips? Let us know how we did here.

If you have any questions regarding this survey, please contact the Researcher.

1. Enter Information

Have you given feedback using this survey before?

○ Yes
○ No

Bus service used for this trip: (required)

| Select ▾ |

Start typing the service name/number

Overall, how satisfied are you with the bus trip that you are taking today? (required)

| Select… ▾ |

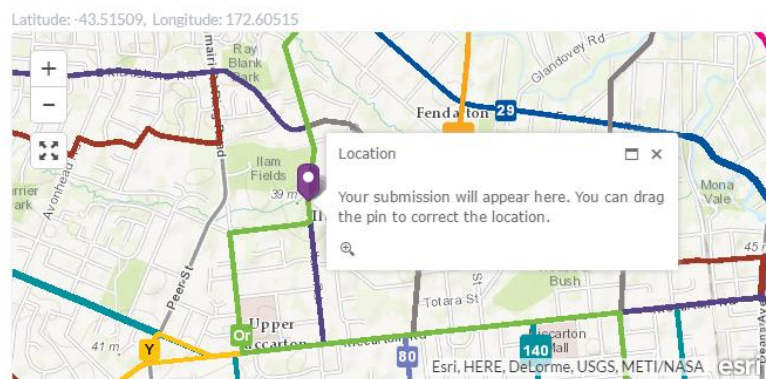*Figure 3-3: A partial screenshot of the GeoForm used in the survey*

Figure 3-4: The GeoForm's map component which allows the user to specify the trip's starting location

To inform passengers about the purpose and content of the survey before undertaking it, a mobile optimised web landing page was developed. The landing page served the function of providing details about the motive of the survey and provided contact information where required. Embedded analytics allowed for information to be collected about device types and models that accessed the survey for troubleshooting purposes, and to gauge the number of users that arrived at the landing page versus those that clicked through to the survey. The first question of the survey ('Are you currently on the bus?') was asked before the survey began, to direct respondents to GeoForm questions that used the correct tense (Figure 3-5). Social media sharing buttons were also placed on the landing page, to facilitate ease of sharing the survey with others and to maximise responses.

Figure 3-5: The first page of the web survey, which directed respondents to the correct survey

3.4   PHASE 2: DATA COLLECTION

Once the survey was developed and ready to collect data, pilot testing was undertaken with friends, colleagues and bus users; Environment Canterbury was also consulted. The feedback provided useful direction on final changes to the number of and wording of questions.

The data collection period for the survey ran for two months, from the beginning of November to the end of December 2016. During this time, advertising material linking the web survey was distributed across the Metro network through posters located on buses, at bus stops, shared on social media and at bus exchanges. These promotional materials provided information about the survey and contained a shortened bit.ly web link to access the survey. A phone readable QR code was also included for users with QR scanning apps to be taken directly to the survey without typing in the address.

3.4.1   On Board Bus Advertising

In conjunction with Environment Canterbury and Red Bus, 35 A4 posters were placed at the front of buses operated by Red Bus, operating across both the more popular metro lines as well as several smaller suburban routes. An example of the advertising can be seen in Figure 3-6. It was hoped that posters could also be placed on Go Bus operated services (Go Bus operates roughly half of the routes run across the Metro Network) as well. However, this was not possible at the time of data collection because Go Bus could not be reached.

3.4.2   Bus Stop Advertising

To increase response rates and cover routes not operated by Red Bus, advertising material (Figure 3-7) was distributed to bus stops and exchanges across Christchurch City and the Waimakariri district. Since the public transport infrastructure is owned and managed by the respective local councils, permission was sought and gained from the Christchurch City Council and the Waimakariri District Council to attach posters to bus stops, shelters and signs; on the condition that shelters with advertising displays were excluded. The posters were printed on A5 sized weather resistant paper to ensure longevity in rainy conditions and attached using tape to poles, bus signs and council owned bus shelters.

Figure 3-6: Posters used inside the front of Red Bus services

Figure 3-7: Posters attached to bus stops and signage

Due to time limitations and the many bus stops in Christchurch, a first round of bus stop advertising was focused on high passenger volume bus stop locations known as 'super stops'; interchanges where several routes pass through a single location. Super stops are found near popular suburban malls, shopping areas and the University of Canterbury. A second round of posters focused on stops along the main metro routes and suburban routes but was restricted by the availability of appropriate and permitted public transport infrastructure. A map showing the distribution of posters at bus stops over the survey period can be seen in Figure 3-8.

Figure 3-8: Locations with bus stop survey advertising.

3.4.3   Social Media

The link to the survey was shared once by the official Metro Facebook page to promote the survey to those that follow the page. A low budget Facebook advertisement targeting commuters in Christchurch was also placed to test whether this was an effective means of getting responses. Unlike print advertising, less effort is required for participants to click a link already online instead of typing a web link in manually (even if shortened).

3.5   PHASE 3: REAL TIME DASHBOARD FOR OPERATORS

To enable interaction with real-time data, ArcGIS WebAppBuilder was used to create an interface designed with public transport operators in mind, to visualise and display the crowdsourced responses spatially (Figure 3-9). Real-time viewing is possible by connecting the map to the same feature layer

that the GeoForm uses, so that submitted responses are instantly available. A variety of standard spatial tools such as individual survey responses browsing and measurements can be used. Additional spatial layers can also be added by public transport operators for quick comparisons.

Most importantly, the interface can be configured to display graphs and descriptive counts of the latest data; for example, the overall satisfaction score of the network or an area by using the spatial filter. In this way, the dashboard tool provides a useful overview that allows for issues or trends to be identified and flagged for further analysis if required, all within the browser. The dashboard also allowed performing basic cleaning of the spatial data to be carried out, such as correcting offset points or deleting spatial outliers entirely.
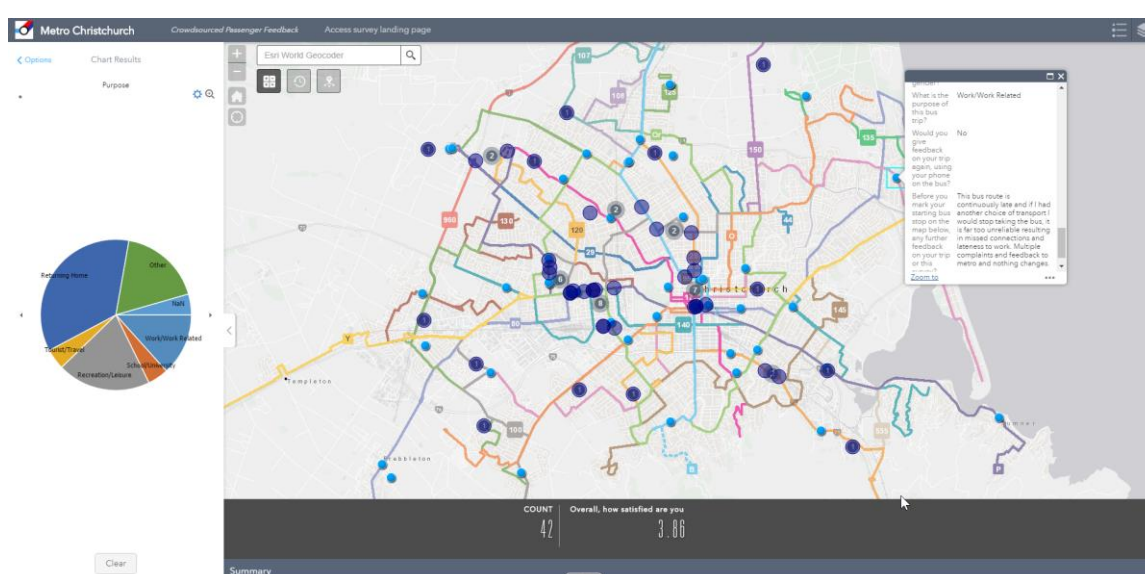
Figure 3-9: Real time viewer for crowdsourced passenger feedback designed for operators of public transport to browse responses and summaries of collected data

3.6 PHASE 4: DATA ANALYSIS

Much of the comprehensive spatial analysis during this research was performed using desktop ArcGIS software. If licences for this software are unavailable, it is possible to undertake many analysis operations in the cloud using ArcGIS Online using service credits at a small cost or by using other, potentially free and open source, software, such as QGIS.

3.6.1 Data Preparation

The crowdsourced data layers were downloaded from ArcGIS Online in shapefile and CSV formats. Edits were made in Microsoft Excel to format the date and time fields for use with processing scripts.

3.6.2   Spatial Analysis and Additional Datasets

Spatial analysis of responses was carried out using the Spatial Analyst and Data Management tools in ArcMap and ArcGIS Pro. Firstly, a spatial dataset was obtained for Christchurch's average street traffic intensity (Christchurch City Council) to provide a measure of expected congestion around the bus stop. The Crash Analysis System dataset (New Zealand Transport Agency) that provided estimates of historical crash incidents that could point to unsafe stretches of road for pedestrians waiting at bus stops (Truong & Somenahalli, 2011). Both datasets were both used to provide measures which could then be compared to safety satisfaction scores at bus stops. The Dark Sky Weather API was used to gather weather information that was historically available for each trip using a custom Python script. The information queried the weather condition, temperature and hourly precipitation at the time, day and location of the trip.

3.6.3   Statistical Analysis

The SPSS software package (version 21) was used for statistical analysis. The data set was exported from ArcGIS Pro to Excel format, which could then be read by SPSS. Descriptive statistics were generated from the dataset for bus routes, demographic variables and satisfaction factors. To determine whether the relationship between weather conditions and bus stop satisfaction is significant, a Pearson Chi-Square test was used with weather conditions, and Logistic Regression used on the continuous weather variables of temperature and rainfall; Logistic Regression was also used to explore the relationship between bus temperature satisfaction and outside temperature.

3.6.4   Keyword Analysis

For the text-based responses to the "What is one thing about your trip that could be improved?" question, thematic groupings were assigned to the types of feedback given based upon their frequency; example of categories included reliability, price and driving behaviour. Asking this question allowed for the identification of prevalent themes across all responses and helped to identify areas where improvements to the bus service would have a positive impact on the most passengers. The full list of groupings identified are found listed in the results section (4.5).

3.7   SUMMARY

This chapter outlined a model for the development of a system to collect crowdsourced passenger feedback. In Phase 1 of this model, a set of questions around passenger satisfaction were designed and implemented into a location based crowdsourcing survey to test this model. In Phase 2, the

survey was distributed across the Metro network in Christchurch, and a sample of crowdsourced data was collected using the system and analysed. Phase 3 saw the development of a real-time dashboard that allows operators to interact with the collected data. Lastly, Phase 4 outlined the approaches to analysing the crowdsourced information using spatial and statistical analysis.

4 RESULTS

4.1 INTRODUCTION

This chapter reports on the results of the crowdsourced survey. The spatial, temporal and demographic characteristics of the datasets are summarised; the spatial accuracy of the responses is also evaluated. Passenger satisfaction is evaluated spatially and temporally, and conclusions are drawn about the differing patterns of satisfaction in across time and space. The utility of the external geographic datasets used by this case study is evaluated. Improvements to bus services suggested by passengers are surmised, as well as the feedback from passengers provided about the survey itself.

4.2 INFORMATION ON RIDERSHIP

4.2.1 Geographic Spread

Location information is important in determining where bus trips take place across the public transport network. This research sought to increase the geographic accuracy of passenger feedback reported using Volunteered Geographic Information (VGI) methodologies from passenger smartphones. This section describes the geographic characteristics of the dataset collected during this study.

Ninety-six responses were collected over the survey period. The crowdsourced dataset successfully collected accurate geographic information of the replies from across Christchurch City. The spatial distribution of GPS tagged responses collected over the survey period is shown in Figure 4-1. Responses followed roads with a high number of bus routes, with higher concentrations along the busy routes and interchanges of Westfield Riccarton and the University of Canterbury in the west and in the central city where the Bus Exchange is located.

The eastern part of Christchurch saw a lower number of responses; only seven responses were collected in North-eastern part of the city. Despite prominent advertising at popular eastern bus hubs, no responses were collected in these locations. The low number of responses from this area might be attributed to the decline in this area's population because of damage caused by the 2011 Christchurch earthquake sequence. Eastern suburbs such as Avondale, Bexley, Dallington and Burwood experienced population declines of between 42-63% between the 2006 and 2013 censuses (Statistics New Zealand,

2013), after many dwellings in these suburbs (an area labelled as the Residential Red Zone) were demolished.

Additionally, four responses were collected from the Waimakariri District to the north of Christchurch, and three responses in Lincoln to the south-west of the city.
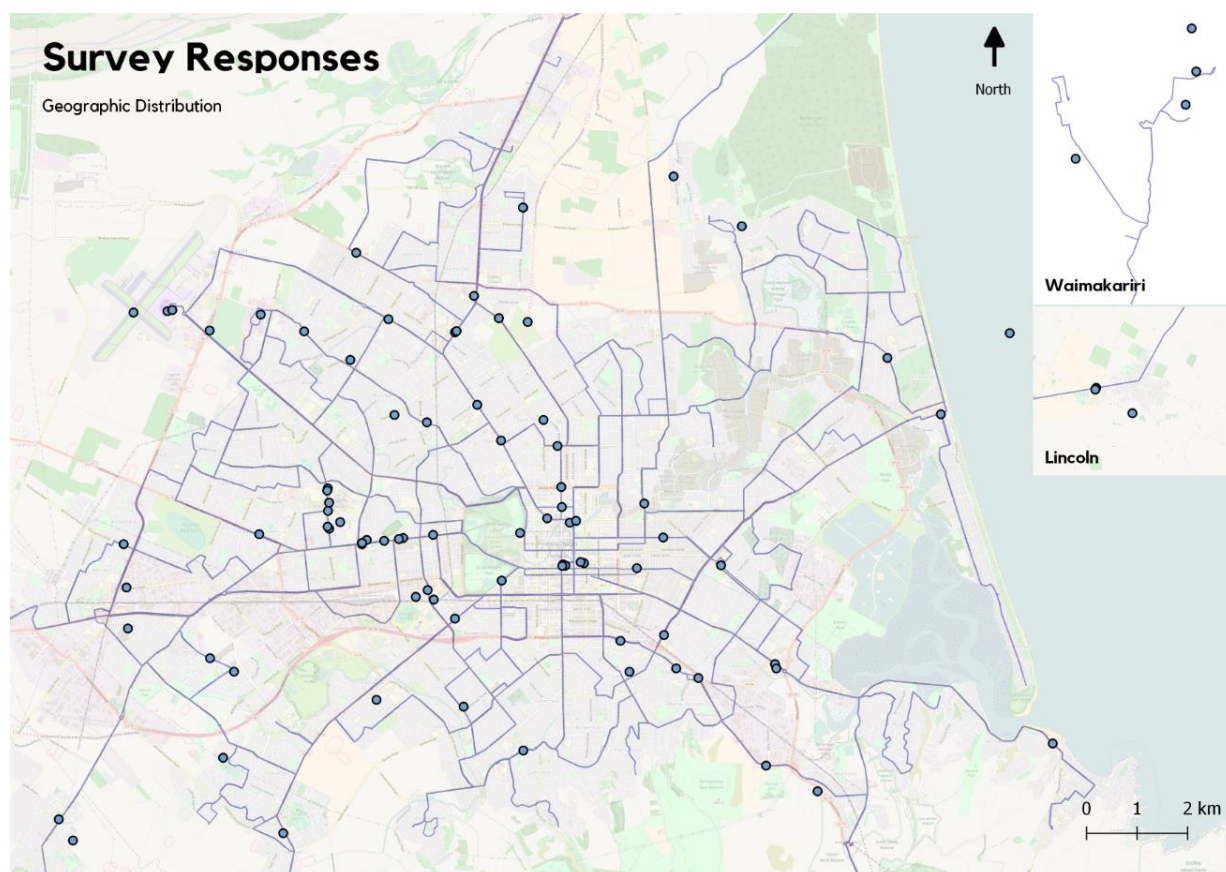
Figure 4-1: Geographic distribution of survey responses collected

4.2.2 Location Error

For crowdsourced information to match the accuracy of existing methods, it is important that any potential error is identified in the collected location data. The survey collected two types of location data – a route, and a more accurate GPS location of the starting bus stop used. Ideally, the GPS location would be expected to be positioned accurately along the bus route given. Figure 4-2 indicates the extent to which the response's coordinates differed from their closest estimated position based on the specified bus route. Most responses (70.8%) were within 250 metres of the specified route, with 84.3% responses falling within 1000 metres. However, several responses were up to several kilometres away. Examples with the highest amount of error included a location off the coast of New Brighton to the east, and an outlier located in the southern part of the North Island over 300 km away.
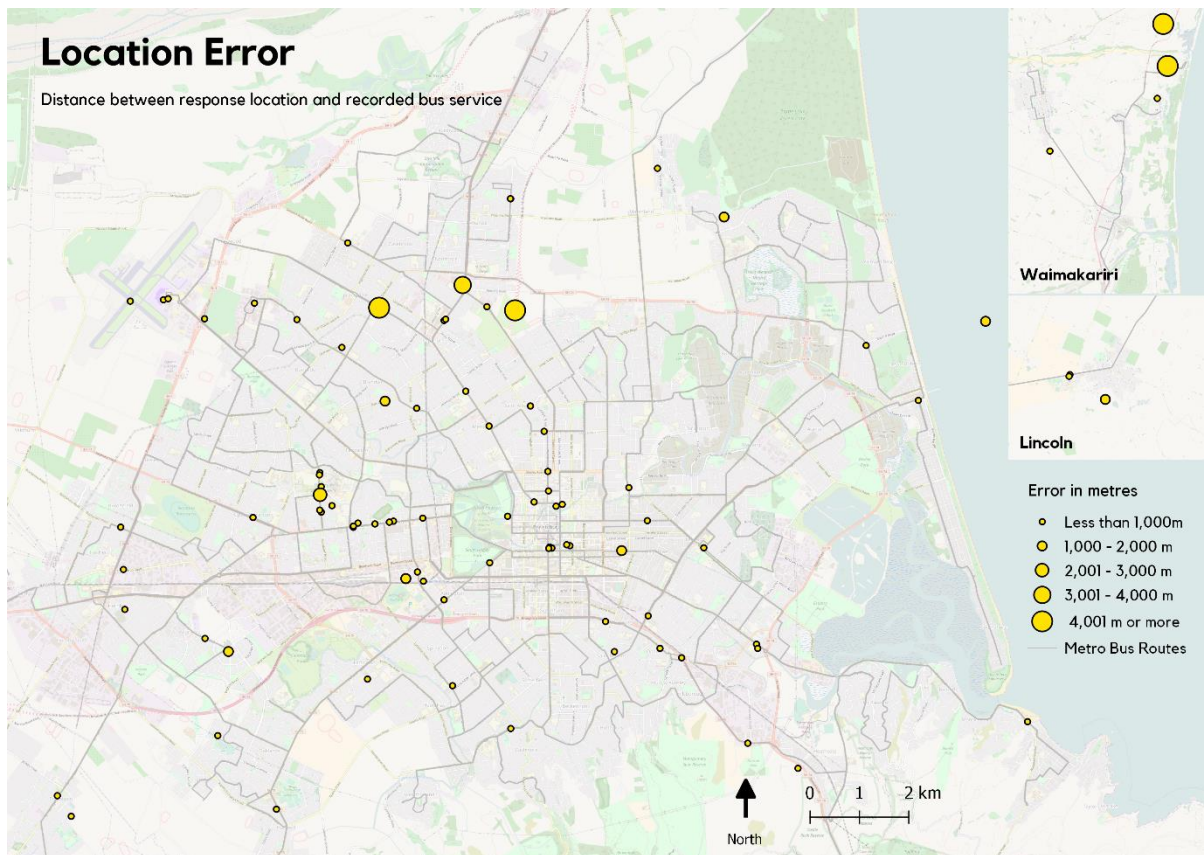
Figure 4-2: Estimated location error in metres

Location error might exist in the results for several reasons:

- The location on the map was not correctly selected by the respondent if the location was chosen manually, or the instructions for selecting the starting bus stop location on the map was not understood correctly.
- GPS measurement error produced by the smartphone used. Factors influencing GPS accuracy include the make and model of smartphone (some devices have more accurate sensors than others), or the surrounding environment having an impact on the signal's accuracy.
- If the survey were undertaken in a location other than on board the bus or at their bus stop, the use of the GeoForm's automatic request for the device's location would have provided their current location instead of the intended location. If the respondent did not correct this location manually, the automatic location would have been submitted as the response's location.

The spatial accuracy of survey data will be discussed in further in Chapter 5.

4.2.3   Temporal Spread

The survey ran for just over two months, during which the survey was promoted across the Metro network. Most trips recorded fall inside this period. Two responses predate this period, a result of passengers manually setting the date when giving feedback on a trip that took place in the past.
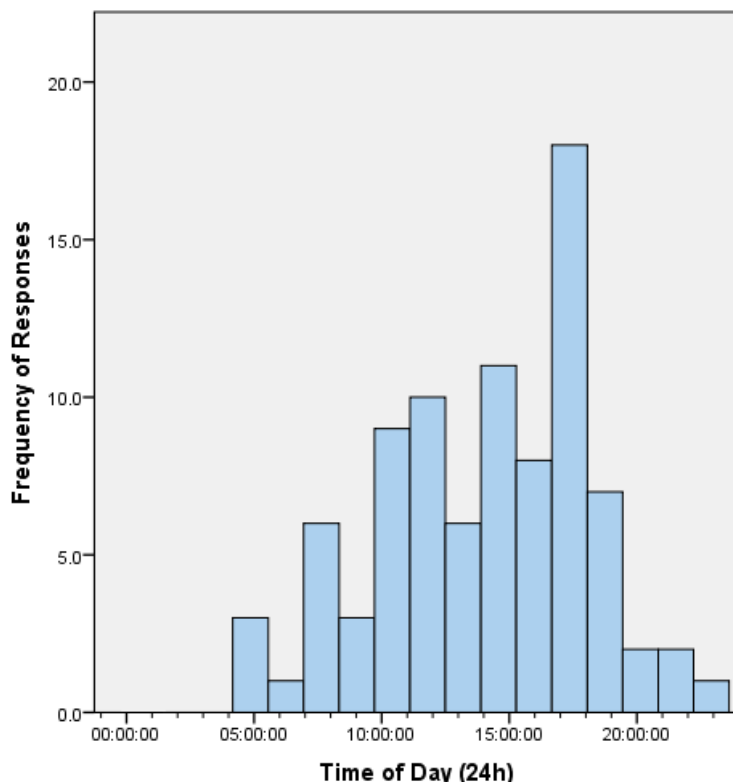
Figure 4-3: Temporal distribution of responses, by time of day

Figure 4-3 provides a breakdown of responses received by the time of day. An increased rate can be seen around 15:00, which is then doubled by 17:00 during the afternoon peak of traffic. Of note is a seemingly standalone higher rate of responses at midnight. It was found that all nine of the responses marked at midnight are marked exactly to the minute, and were all made by passengers reporting on past trips. This anomaly can be attributed to data entry error, where respondents may have forgotten the exact time the trip was taken and recorded a default time of 00:00 instead. The outliers were removed from the results.

4.2.4 Bus Route Spread

Responses were collected across twenty-two different bus services, out of the total twenty-eight services across the Metro network. The distribution of responses is in Figure 4-4.
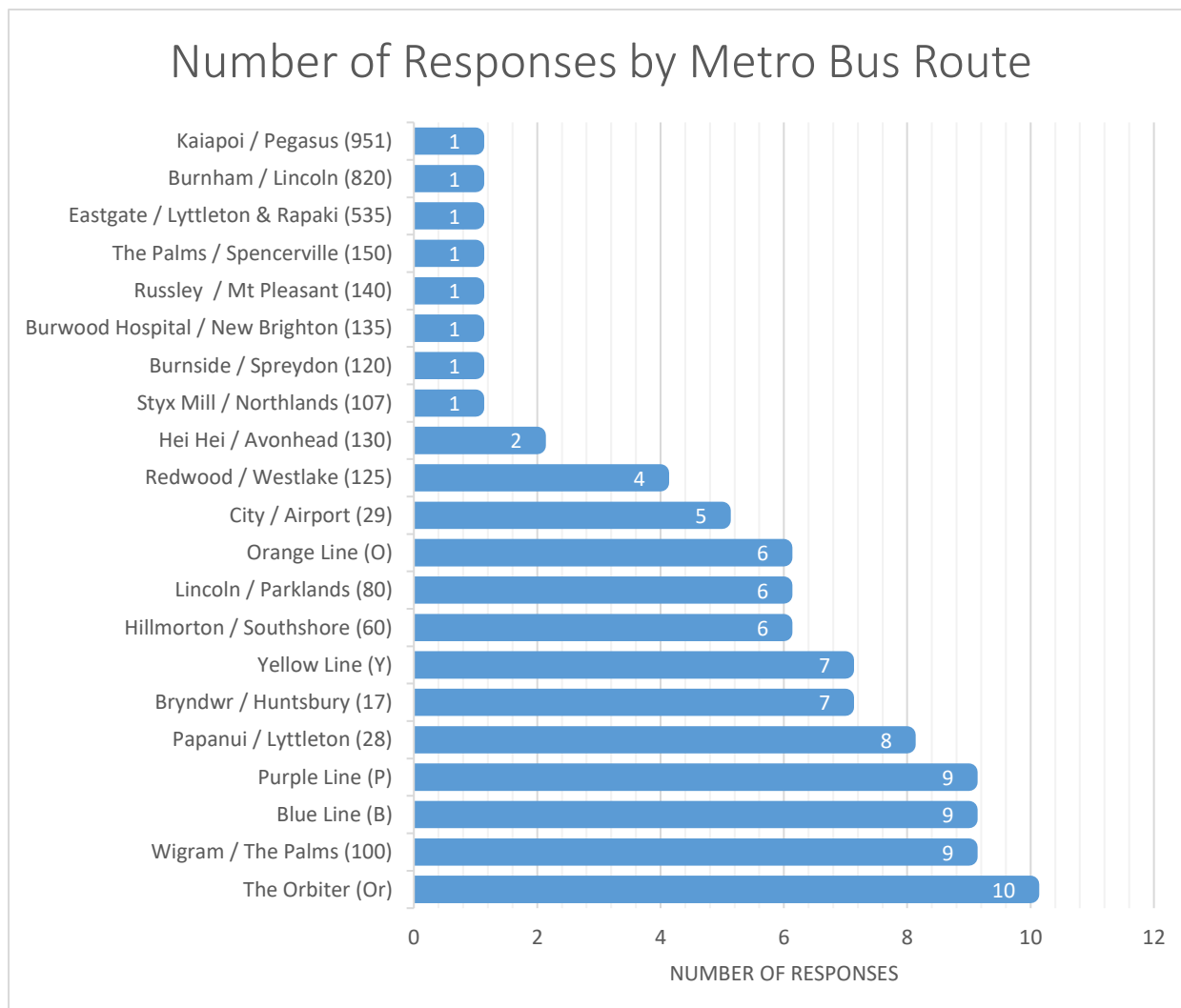
Figure 4-4: Number of responses collected grouped by bus route.

Participants were asked whether or not they were using the bus when they undertook the survey. The proportion of responses is shown in Figure 4-5. Forty-five out of the ninety-six total responses were completed on board the bus. As expected, a greater (but not significant) number of responses were received from passengers while on board Red Bus services that used advertising (twenty-eight responses). Seventeen results were collected from passengers on board Go Bus services which had no such on-board advertising. This distinction is important because the question is an indicator of the effectiveness of onboard advertising compared to other methods. The result suggests that passengers

would load the web link from advertising at bus stops and complete the survey on the bus, or access the survey directly via social media, even if onboard posters were not present.
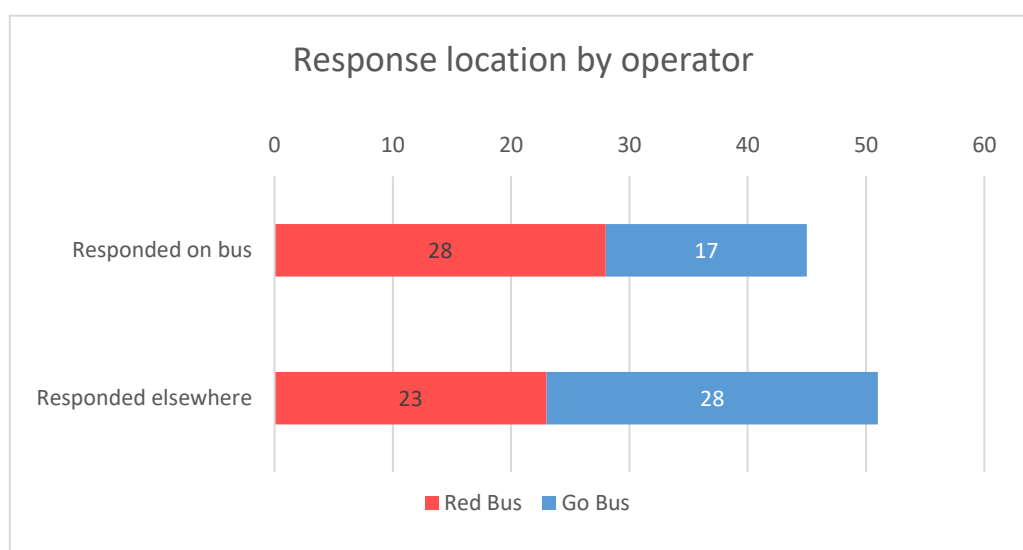
Figure 4-5: Number of responses on-board or elsewhere by bus operator

The survey was designed with the primary goal of being completed on board the bus. In the additional survey, a question asked respondents to identify the situation in which they filled out the main survey. Of the seventeen responses collected, seven people completed the survey while using the bus, five filled the survey out at home, two at work/school/university and one at a bus stop or exchange. Two people did not provide an answer. The presence of responses completed elsewhere suggests that there is still passenger interest in providing feedback when no longer aboard. Therefore, it is important that similar survey questions be flexible for a range of situational contexts, to ensure that the survey is appropriate and accessible enabling as wide a group of people as possible to contribute.

4.2.5   Demographic Information

To gain a better perspective of how well this survey represented demographic groups, comparisons are made with existing research data. Figure 4-6 shows the age breakdown of survey respondents by age category. The 18 to 24 age group represented a third of responses. This spread can possibly be attributed to high smartphone and technology use by this age group. When compared to the age breakdown of Environment Canterbury's 2015 Metro Users report, the percentage of respondents by age category show a roughly similar distribution and reasonably represents the makeup of the bus user population. This research took an approach of using a 14 to 17 age category that encouraged younger technologically adept passengers to give feedback, instead of the 16 to 17 age groups used by

Environment Canterbury. Despite this, the use of a larger youth category did not appear to attract a larger number of users in this group.
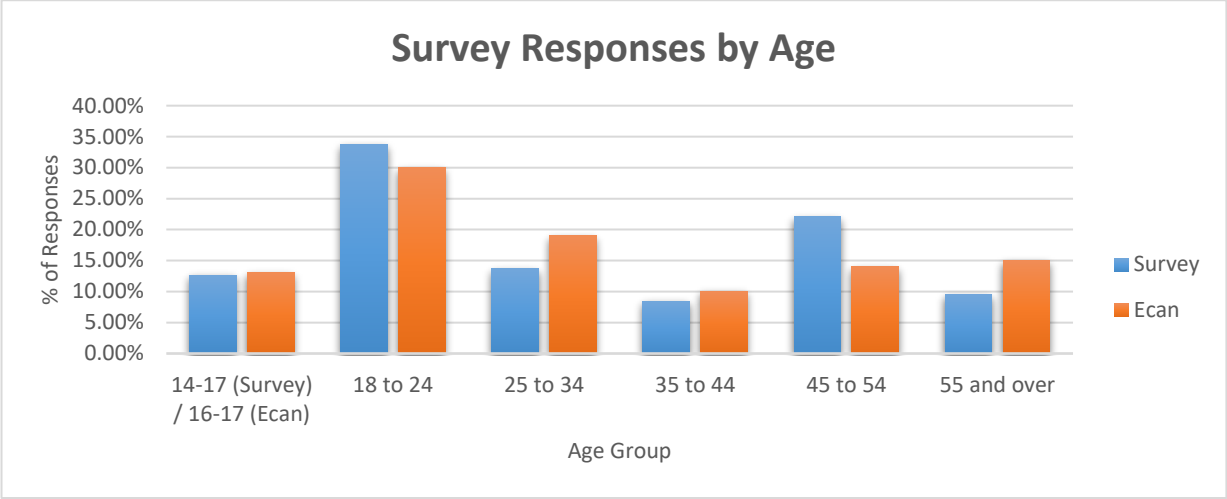
Figure 4-6: Survey responses by age, comparing survey and Environment Canterbury (Ecan)'s 2015 survey
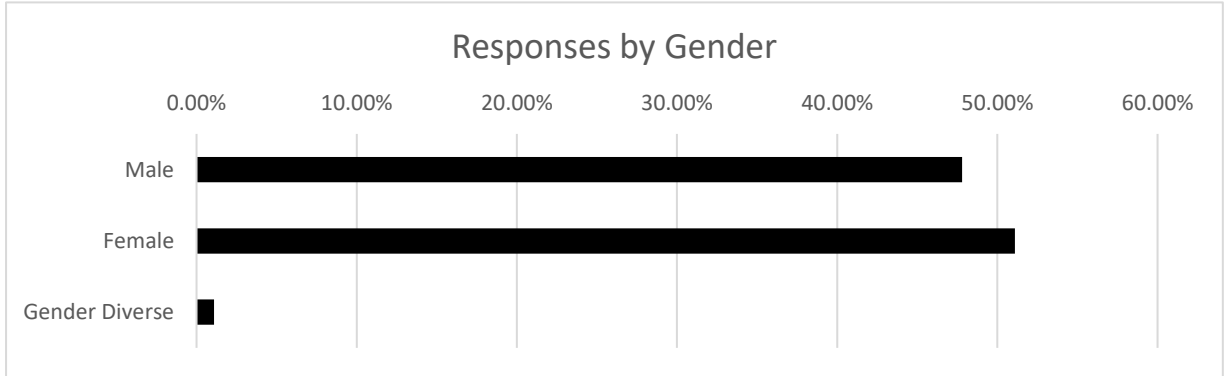
Figure 4-7: Survey responses by gender

Figure 4-7 shows the gender distribution of responses. Male respondents made up 47.8%, with Female respondents making up a 51.1% proportion. The survey's gender percentages are close to Environment Canterbury's 2015 percentage of 50% Male and Female each, and even closer to Greater Christchurch's population make up of 49% Male and 51% Female as of the 2013 census (Statistics New Zealand, 2013). The Environment Canterbury report did not offer Gender Diverse as an option.

4.2.6   Trip Purpose

Figure 4-9 shows the breakdown of the respondent's purpose for their trip. The beginning of the school and university summer holidays coincided with the start of the survey period, resulting in fewer students using public buses at the time. Thus, only 11.7% of respondents were using the bus for educational purposes. This figure is likely to be higher at a different time of year during term time when public transport is more frequently used for school travel, and therefore increase the total number of responses collected. While these categories for trip purpose are used throughout literature, issues exist with this approach as it is possible for trips to serve multiple purposes.
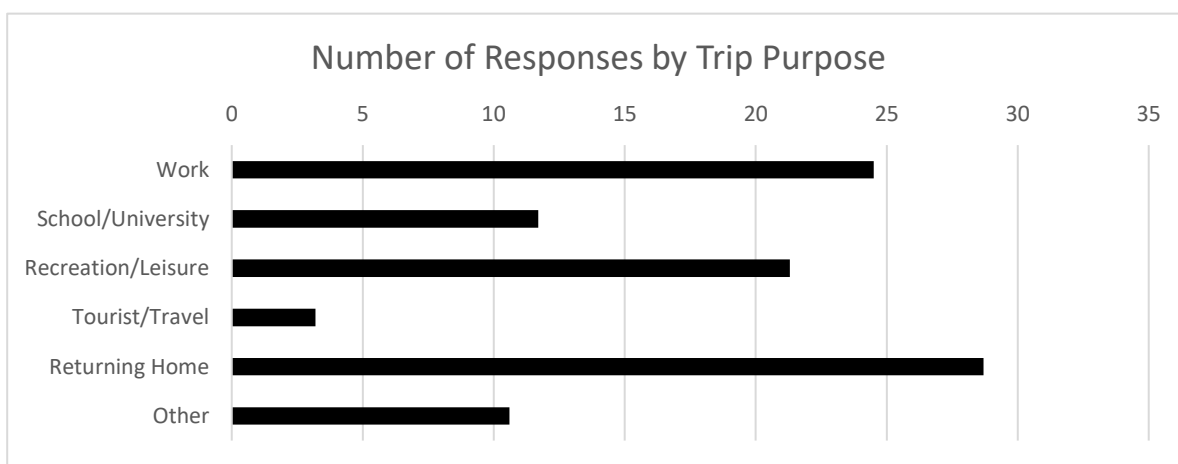
Figure 4-8: Survey responses by trip purpose

4.3   PASSENGER SATISFACTION

The following section outlines the satisfaction ratings respondents gave to various aspects of the passenger's trip. Satisfaction was measured on a scale of 1 (least satisfied) to 5 (most satisfied).

4.3.1   By Area

The collection of spatially enabled feedback easily allows satisfaction scores for specific areas to be compared with each other. The city was divided up into five areas for analysis, made up of four cardinal sectors and Christchurch's Central Business District (CBD) inside the main four avenues that surround the centre of Christchurch. The mean satisfaction values of these areas are summarised in Figure 4-9. Broader areas were used because the density and quantity of survey responses were not sufficient to draw meaningful conclusions about more detailed areas.

Satisfaction values averaged 3.69 across Christchurch. Christchurch CBD (consisting of the central business district) scored higher than the city average at 4.46. However, there were only seven

responses for north-eastern Christchurch, producing a mean score of 2.69. As the large error at the 95% confidence level shows, Figure 4-9 shows it is unlikely this result is accurate.

Due to the low number of responses from Lincoln and the Waimakariri District, the average satisfaction values for these locations is not sufficiently representative for useful analysis.
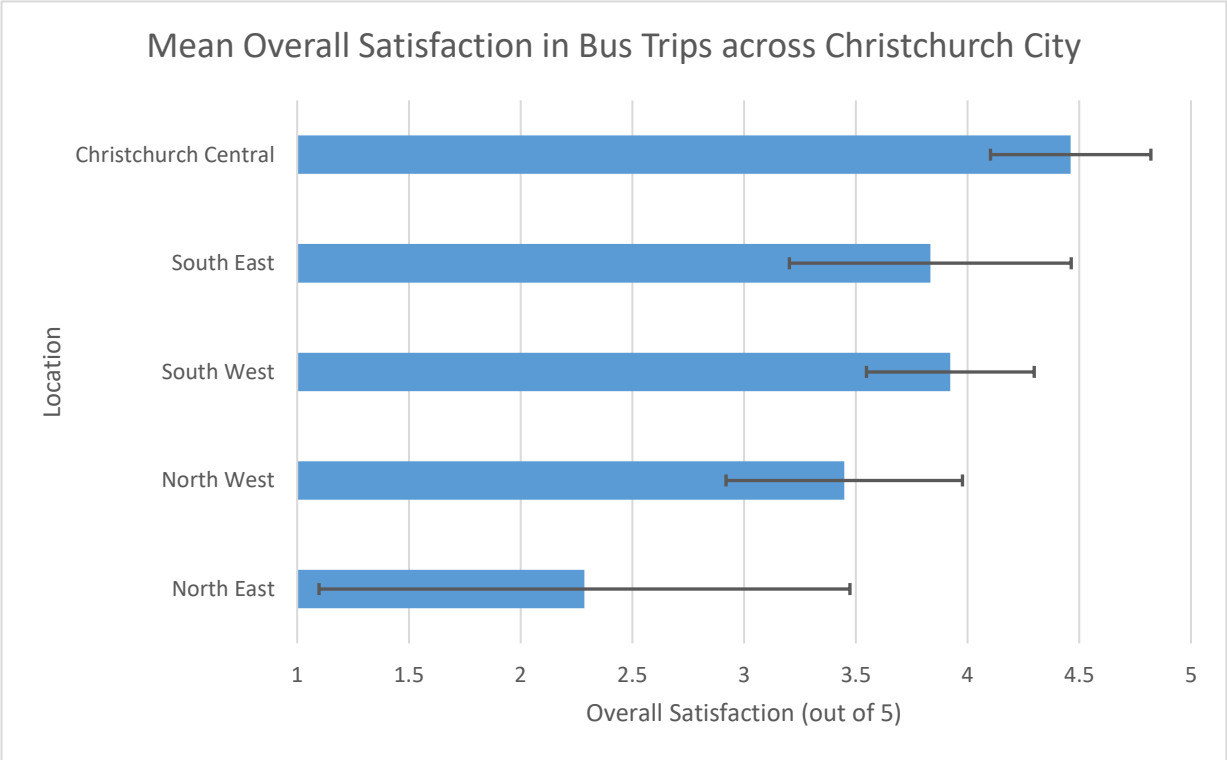
Figure 4-9: Mean overall satisfaction in bus trips across Christchurch City, at a 95% confidence interval

Table 4-1 lists the average satisfaction score for each of the answers for all responses collected. Finding a seat was ranked the highest with a score of 4.23 out of 5, while bus journey time was ranked the lowest with a score of 3.54. Journey time was among the top suggestions for improvements by passengers, as outlined in Section 4.5.

Table 4-1: Breakdown of average passenger satisfaction averages by question on a 1-5 scale (1 = least satisfied, 5 = most satisfied)

	Mean	Std. Deviation
Overall Satisfaction of Trip	***3.71***	***1.247***
Finding seat	4.23	1.102
Stop's safety	4.1	1.073
Bus Information	4.02	1.199
Driver's skill	3.97	1.192
Bus cleanliness	3.96	1.026
Getting to Stop	3.86	1.232
Stop's cleanliness	3.75	1.211
Stop's suitability for weather	3.57	1.318
Bus temperature	3.57	1.252
Bus journey time	3.54	1.301
Waiting for bus	3.44	1.358

Figure 4-11 shows an area breakdown of mean satisfaction for bus stop related variables. On average, passengers in the North-Eastern part of Christchurch were less satisfied with the time spent waiting for the bus (2.2/5), their bus stop's suitability for weather (2.5/5) and their bus's journey time (2.5/5), scoring much lower compared to the same factors in other areas of the city. The low satisfaction figures in this area may indicate that improvements need to be targeted more specifically to this area to improve service reliability and public transport infrastructure.

Figure 4-10 shows mean satisfaction by area, this time for factors related to the onboard experience. Bus cleanliness remained geographically consistent across all areas (around 3.5/5), with Christchurch Central averaging 4/5. In comparison, bus journey time varied greatly between areas, with North Eastern Christchurch's satisfaction score of 2.5/5 ranked the lowest compared to Christchurch Central's 4.38/5.
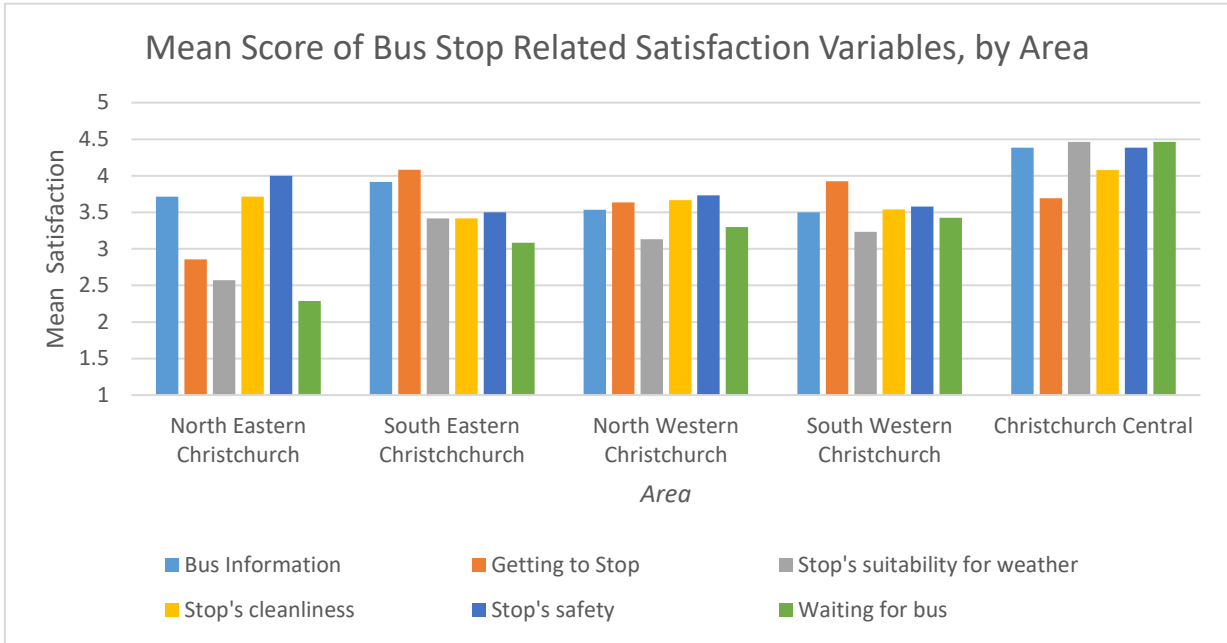
Figure 4-11: Mean Satisfaction Scores of Bus Stop Related Satisfaction Variables in Christchurch City
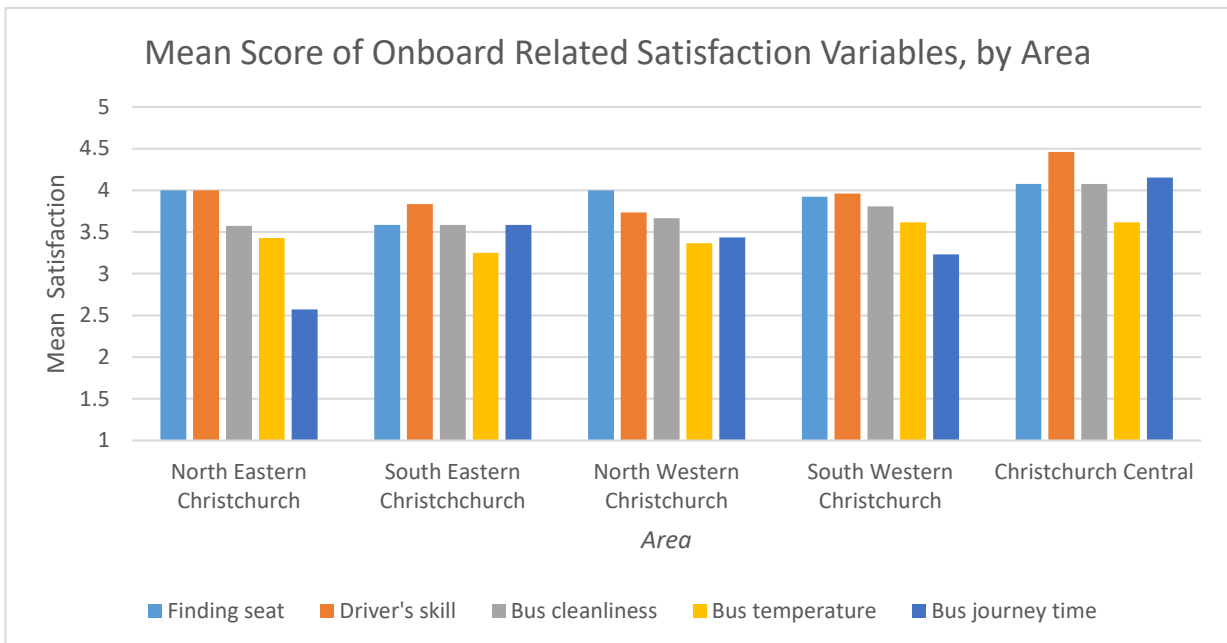
Figure 4-10: Mean Satisfaction Scores of Onboard Related Satisfaction Variables in Christchurch City

4.3.2   By Time of Day
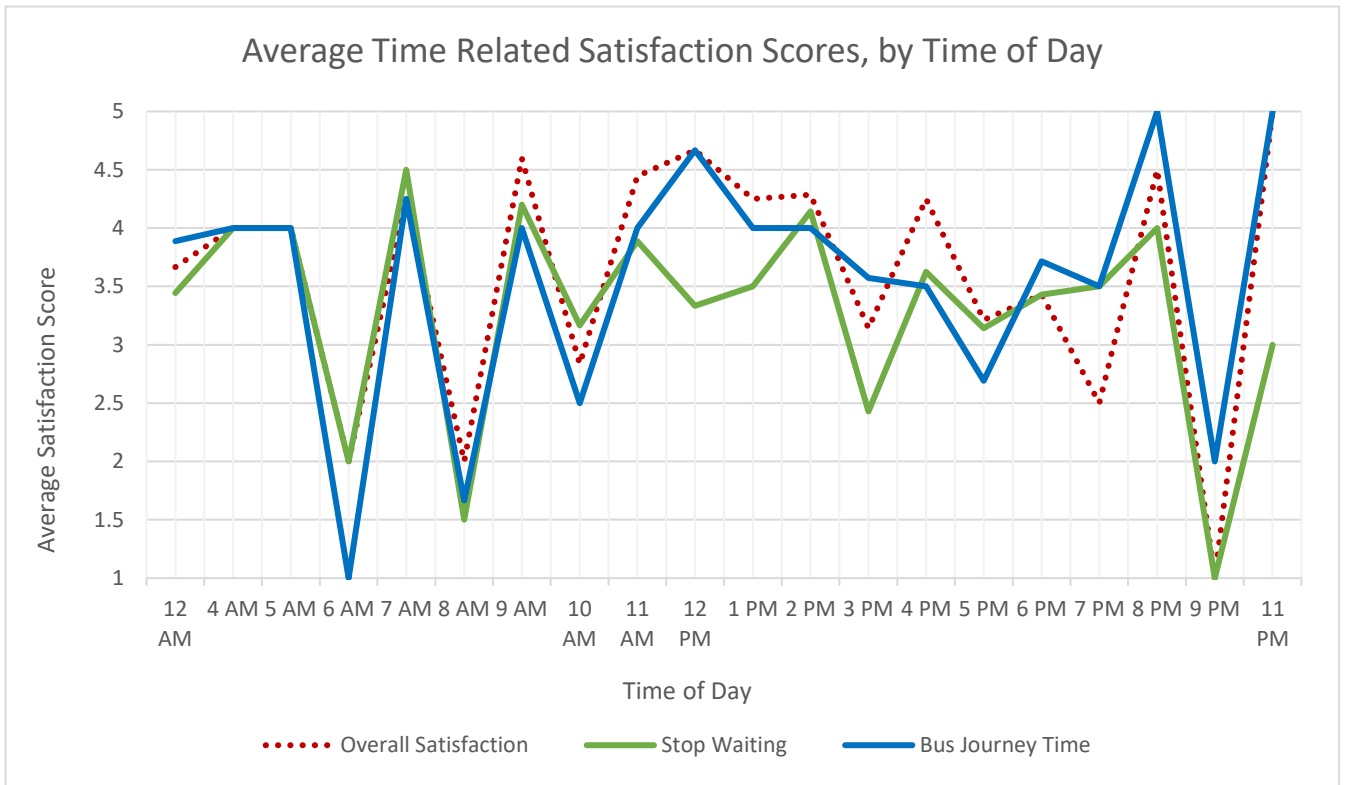
Figure 4-12: Average satisfaction scores of time related factors, by time of day

Satisfaction was found to vary by time of day, both in overall satisfaction and in satisfaction factors likely to be time-related, such as time spent waiting for the bus and journey time. Changes in satisfaction scores are shown as hourly averages in Figure 4-12. A large dip in mean satisfaction is seen during the period of increased commuter traffic at 8 am (with an overall satisfaction score of 2), and again to a lesser extent during the evening traffic surge. Of note is that satisfaction with waiting for the bus dropped independently of satisfaction with the bus journey time during the 12 pm to 1 pm period. This decrease in satisfaction could be attributed to bus services running behind schedule but maintaining a consistent journey time. The sharp dips that occur at 6 am and 9 pm respectively can be attributed to the low number of responses collected during this period, which had the effect of skewing the average.

4.3.3   By Route
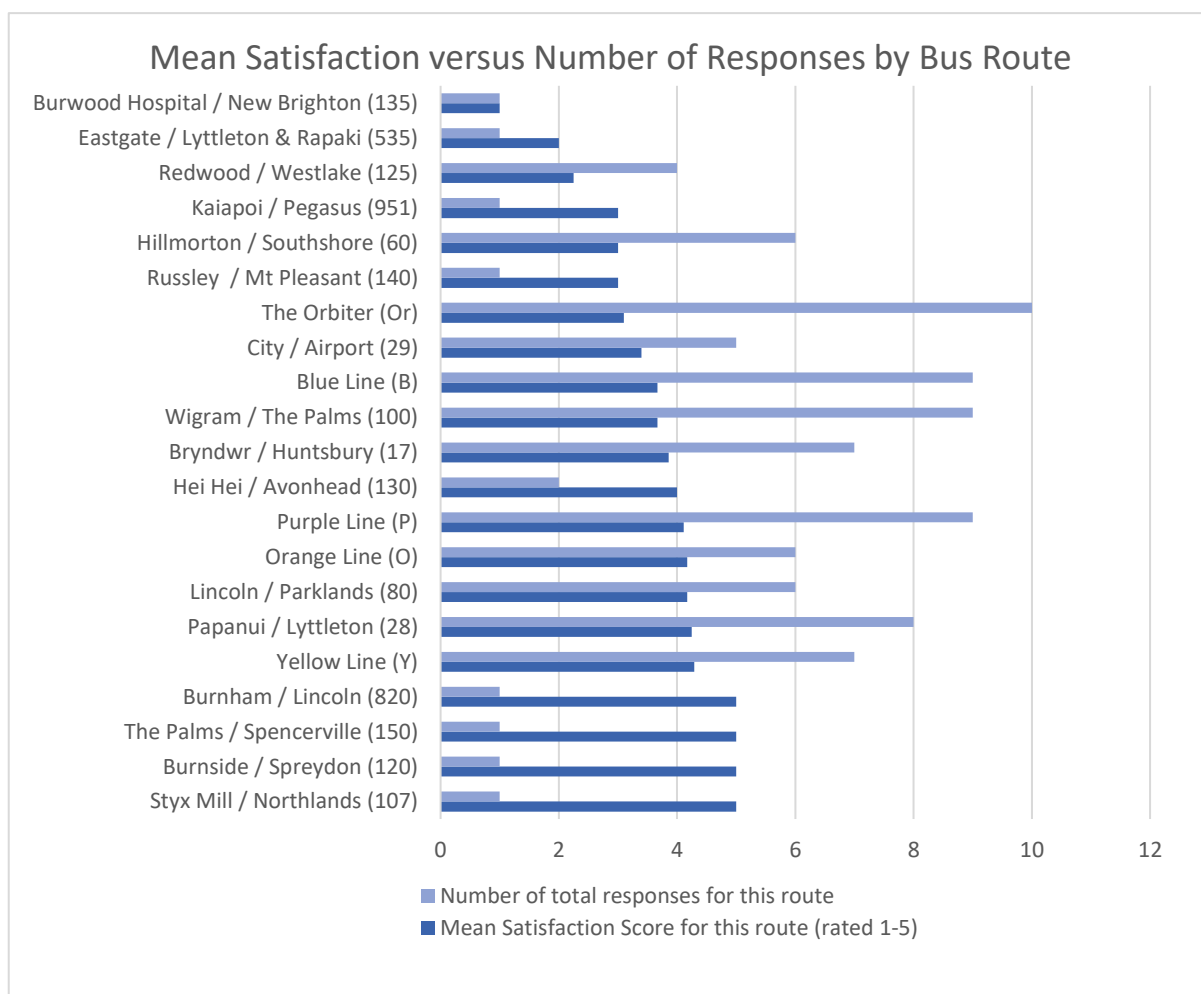
Figure 4-13: Mean satisfaction compared to the number of responses received, by bus route

Figure 4-13 shows the mean satisfaction for each of the bus routes respondents used and compares the mean with the total number of responses received on that route. For routes where the number of responses was less than three, it was concluded that the available data was unlikely to provide a valid representation of the actual mean satisfaction. The Yellow Line scored the highest valid mean satisfaction score across the network, followed by routes 28 and 80.

4.3.4   Route Level versus Coordinate Level Satisfaction
Figure 4-14 demonstrates the difference between the spatial visualisation of passenger satisfaction at a route level and a more accurate geographic coordinate level. Because bus routes often cover large geographical areas, satisfaction aggregated by route cannot provide useful insights into more detailed

geographic areas of the network. The mapping of coordinate level satisfaction in comparison provides a much more accurate view of geographic distribution.
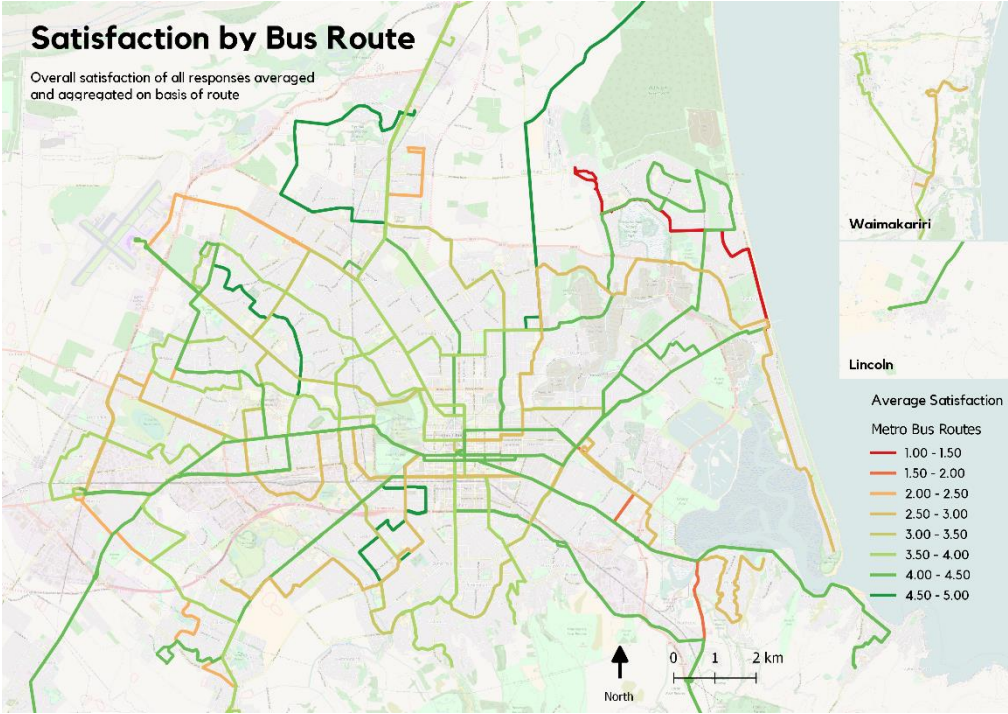
Figure 4-14: Spatial distribution of satisfaction by bus route (top) and by specific geographic location (bottom
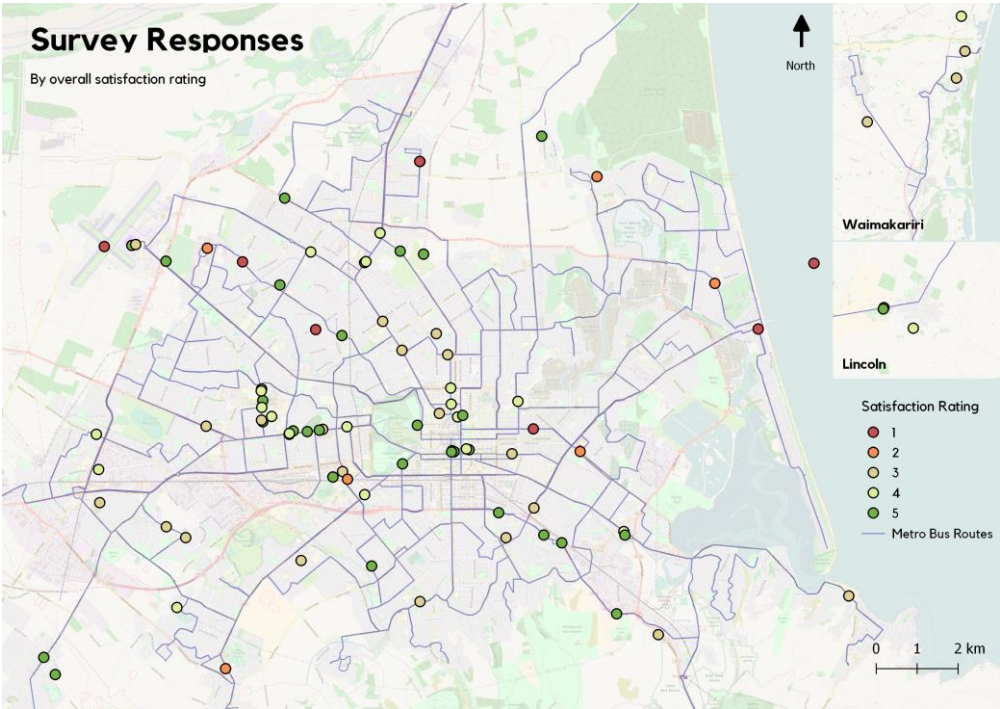
4.4   RELATIONSHIPS WITH OTHER DATASETS

By capturing GPS coordinates of the passengers' journeys, other spatial datasets can be used in conjunction with the passenger satisfaction measures to uncover the influence of external factors, such as weather, traffic and crash safety. This section explores the relationships of three external datasets used by this research with the crowdsourced data collected in this survey (as outlined in Section 3.6.2).

4.4.1   Weather

The Dark Sky Weather API[4] was used to obtain weather information for the time and place that each survey response was recorded. It was expected that rainy weather conditions would have a negative impact on passenger satisfaction. Most weather conditions (clear, cloudy, drizzle, etc.) during the passenger's recorded trips were clear and seldom varied across the survey period, (Figure 4-15); and therefore, not able to provide any useful insights. Likewise, the overall lack of precipitation during the survey period meant that the role of weather conditions in passenger satisfaction during this research's case study could not be assessed. A longer survey period would have allowed a greater variance in conditions to take place.
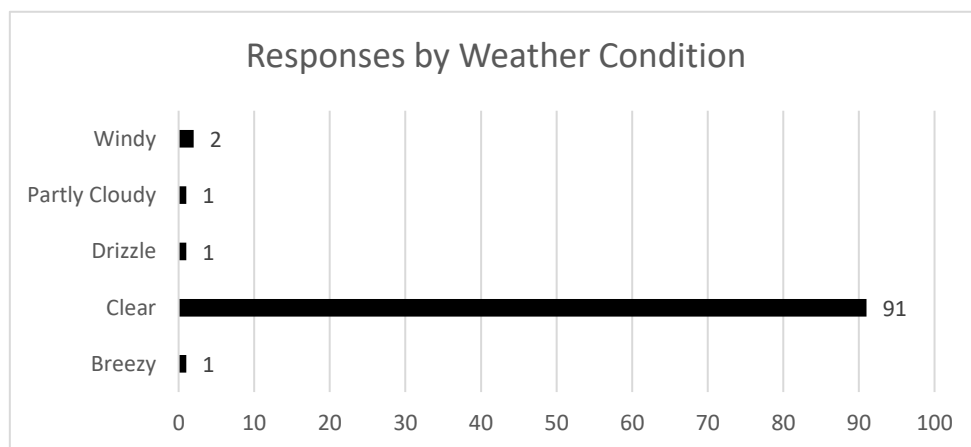
Figure 4-15: Frequency of associated weather conditions at the time and place of the response

Outdoor temperature was compared with temperature related satisfaction variables. Figure 4-16 shows the spatial distribution of bus stops that respondents ranked two or lower for weather suitability, ranked by temperature. Mapping temperature spatially against satisfaction allows for bus stops to be identified that provide inadequate shade for passengers waiting on hot days; for example, in Addington (shown in dark red). While higher temperatures were useful to consider during the

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[4] https://darksky.net/dev/

summer months over which this survey was conducted, the comparison could also consider the effects of cold on exposed bus stops during winter months.
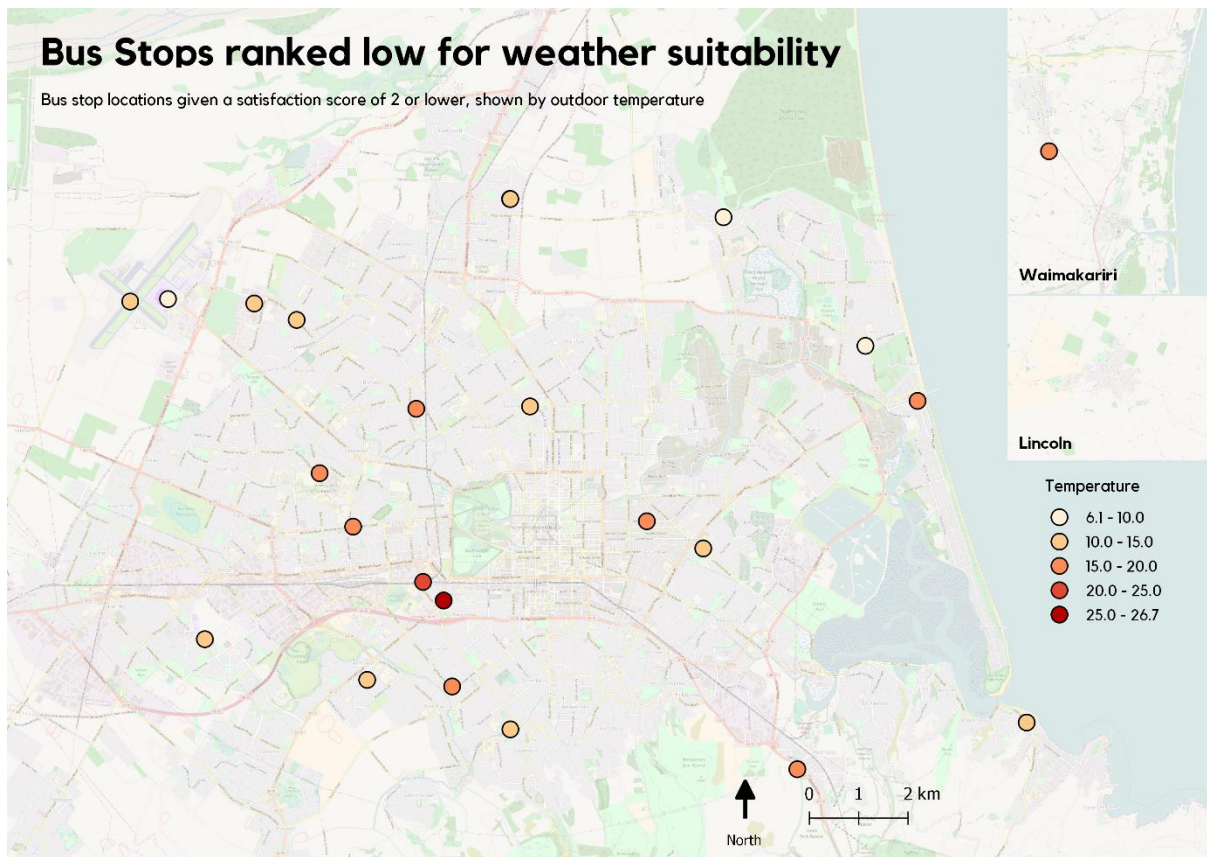
Figure 4-16: Bus stops ranked low for weather suitability, compared with temperature

Next, the outdoor temperature was compared with the reported satisfaction with interior bus temperature, plotted in Figure 4-17. In theory, if the interior climate controls of the bus across the Metro network were not being appropriately used for passenger comfort, satisfaction with interior temperature could be expected to correlate negatively with outdoor temperature. However, a non-significant Pearson's Correlation coefficient of -0.061 determined that was not the case. Despite this finding, this finding does not preclude individual instances where interior temperatures are inappropriate for passenger comfort, evidenced by specific comments discussed in the improvements section of this chapter.
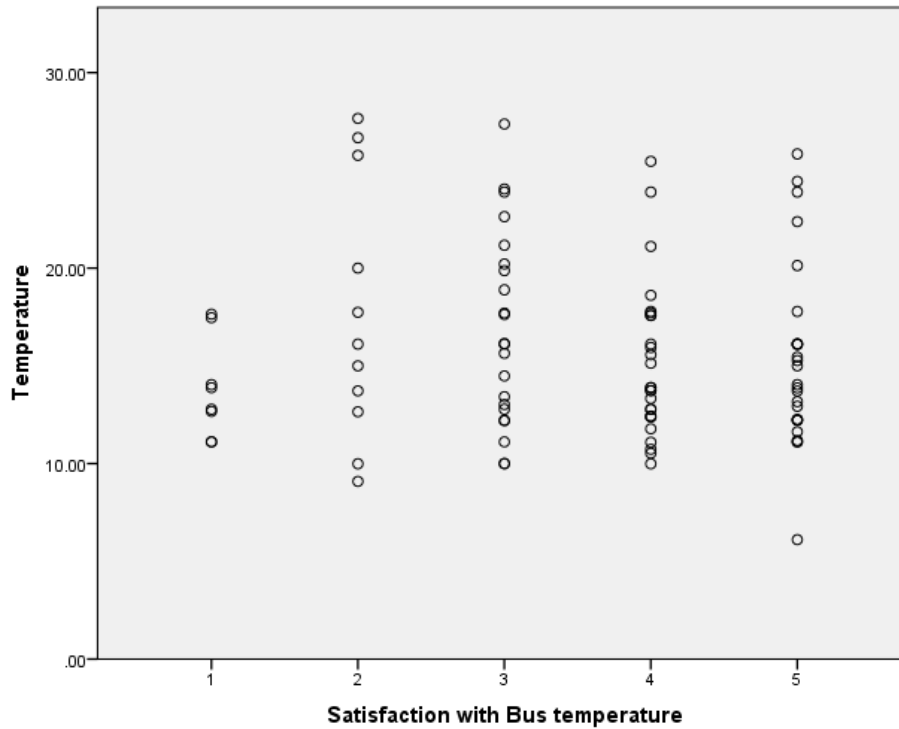
Figure 4-17: Satisfaction with interior bus temperature, compared with outside temperature (in Celsius) at the time

4.4.2 Safety

Crash data has previously been used to determine the safety of bus stops (Truong & Somenahalli, 2011), so are expected to have an adverse impact on satisfaction with bus stop safety. Historical crashes recorded within the previous two years within 150 metres (where some impact on pedestrian safety can be expected) of each survey response were counted, obtained from the New Zealand Transport Agency's Crash Analysis System (CAS). CAS data was then compared with respondent's perception of their bus stop's safety. The number of fatal accidents within 150 metres was found to have a statistically significant correlation with passenger satisfaction of safety at bus stops (-.312 at the 0.01 level, Table 4-2). However, areas with a high fatal crash history are only able to account for 9.7% of the variability in passenger perception of safety at bus stops. Additionally, average traffic intensity of the road was compared with bus stop safety and was found to not play a statistically significant role in perceived bus stop safety (Table 4-2).

Table 4-2: Pearson correlation coefficient tests for bus stop safety satisfaction, compared with historical crash data and average traffic intensity of adjacent road

	Bus Stop Satisfaction with Safety Score
Fatal Accidents	-.312**
Average Traffic Intensity	-0.016

**. Correlation is significant at the 0.01 level (2-tailed).

4.5 PASSENGER SUGGESTED IMPROVEMENTS

In the survey, passengers were asked to provide suggestions on the single thing that would most improve their trip. This open-ended question was important in giving passengers the freedom to express the issues they had with the bus services used. The results of this question were grouped into categories based on recurring themes identified across all responses, and are shown in Table 4-3. Relevant comments in the open-ended 'Further Comments' section were also included in this analysis where appropriate.

4.5.1 Journey

Eight respondents indicated that a faster journey time was important to them:

"It took 84 mins to get from my house to work. It was far too long. I cycle to work normally and it takes me just over 1 hr. How can the bus take longer? That's crazy."

Respondent 37

Four respondents expressed a preference for more bus lanes to facilitate a faster journey time:

"Massively increased incidence of bus priority lanes esp. through major (& wellknown) traffic chokepoints to improve travel time & driver wellbeing, as well as increasing uptake of service by reducing timekeeping delays"

Respondent 56

Table 4-3: Passenger suggested improvement summary overview

Journey	
Faster journey time	8
More bus lanes	4
Improved road quality	3
Better Information on delays	1
TOTAL:	26

Driver	
Driver behaviour	8
Less time spent at stops	1
Driver changeover at end of line	1
TOTAL:	10

Bus Service	
Increased service frequency	9
More reliable arrival times	6
Improved route coverage	3
Cheaper ticket price	4
More appropriate route	1
Upgrade bus fleet	1
TOTAL:	23

Making Transfers	
Making transfers on time	4
Making transfers easier	2
Less dependence on transfers	1
TOTAL:	7

On board Improvements	
Air conditioning	7
Bus Temperature	6
Electronic bus information/next stop alerts	2
Music/radio	2
Onboard Wi-Fi	3
TOTAL:	20

Bus Stop/Hub	
Fixes/improvements to PT infrastructure	4
Improved shade	1
Wifi/Charging ports	1
TOTAL:	5

Overall Total Comments: 91

Three respondents preferred a less bumpy journey. Christchurch's roads are still in the process of being repaired following the damage caused to infrastructure by the 2011 Christchurch Earthquake. However, there was an awareness that this was beyond the driver's control:

"The road needs repair; the driver is making the best of an awkward situation"

Respondent 96

4.5.2 Bus Service

More frequent bus services were a priority for nine respondents, with several stating that existing frequency of services did not meet their needs. Six comments made were from passengers dissatisfied with the reliability of the bus's arrival against the published timetable:

> *"This bus route is continuously late and if I had another choice of transport I would*
> *stop taking the bus, it is far too unreliable resulting in missed connections and lateness*
> *to work. Multiple complaints and feedback to metro and nothing changes."*

Respondent 35

Three respondents said that existing bus routes were not convenient enough for their needs. One respondent believed some streets were too narrow for the vehicles to pass through and therefore not appropriate for a bus route.

4.5.3 On Board Improvements

Air conditioning inside the buses was cited as being the biggest improvement that could be made for passengers on board. It should be noted that this survey was undertaken during the late spring and early summer, during warmer temperatures. It is possible that if the survey was conducted in winter, improved heating might be requested instead.

> *"In hot weather actually use air conditioning if the bus doesn't have windows"*

Respondent 25

Suggestions were made for the inclusion of electronic information displays inside the bus, as well as information on the upcoming stop, a feature used in many public transport systems around the world. As a means of making the online survey easier to complete, on board WiFi was also suggested.

4.5.4 Bus Driver

Eight respondents were not satisfied with the standard of driving exhibited by the bus's driver, for example:

> *"The driving skills. A bit aggressive. Uses the horn at cars, heavy on brakes and stops*
> *suddenly etc."*

Respondent 85

> *"The bus driver did not wait until all passengers were seated. So some of them went flying nearly onto the floor!!"*

<div align="right">

Respondent 9

</div>

However, positive comments were also made, indicating that a helpful and friendly relationship with the driver played a major role in providing an enjoyable trip:

> *"…I was in a relatively bad mood but the bus driver was very friendly and polite when I got on the bus and made me a lot happier."*

<div align="right">

Respondent 74

</div>

> *"…Red Bus customer service is excellent! It is really good when you get regular drivers too.*

<div align="right">

Respondent 65

</div>

4.5.5   Making Transfers

Seven respondents indicated that the experience of transfers between services could be improved, something that was not specifically asked in the survey. Of these, the biggest concern was that passengers found it difficult to make connections between various services promptly, often due to buses arriving late:

> *"Connecting to services into the city - B and 28 - often they miss by less than a minute!"*

<div align="right">

Respondent 65

</div>

> *"The Redwood bus being able to talk to the orbiter so I didn't miss it by 30 seconds"*

<div align="right">

Respondent 61

</div>

4.5.6   Bus Stop/Hub

Lastly, suggestions were made for improvements at bus stops and hubs. Four complaints were made about specific problems with the on-street public transport infrastructure.

4.5.7 Summary of Open-ended Responses

Overall, respondents felt that the biggest improvements could be made to the bus journey itself, with an improved journey time considered to be the important factor in achieving this. Improving the level of service provided was also highly recommended, through improved service frequency and reliable arrival times. Themes in the suggestions are reflected in observations made by the Environment Canterbury report (Environment Canterbury, 2015) and local news reports (Small, 2016), suggesting that better journey times, increased service frequency and reliable arrival times continue to be important to passengers using the Metro Network.

4.6 FEEDBACK ON SURVEY

This section summarises the respondent's perception and engagement with the survey.

4.6.1 Interest in Providing Repeated Feedback

Two survey questions gauged interest in providing repeated feedback. 83% of respondents answered they had not undertaken this survey for a previous trip, with the remaining 16.7% indicating they had taken the survey before. Near the end of the survey, respondents were asked if they would be likely to provide feedback again on their bus trip, using their smartphone. 76.8% of respondents saying they would be willing to do so, while 23.2% stated they would not.

The difference between the two sets of results appears to indicate that while most people are interested in providing feedback again, not many have done so using this survey. The survey period of 2 months may not have been sufficiently lengthy, meaning that there was not enough time for repeat responses. The limited accessibility and visibility of the survey advertising across the Metro bus network may also have reduced opportunities for passengers to access the survey again.

4.6.2 Engagement in Feedback Process

Of the 17 respondents in the additional survey that was used to gather perceptions of the main survey, 56% stated that they had provided feedback on their bus experience to Metro and Environment Canterbury in the past (including feedback submitted online, over the phone and in person), and 44% had not. While there were not many responses to this question (and therefore the role of response bias should be acknowledged), this result may indicate that a crowdsourcing methodology increases engagement in the feedback process.

4.6.3 Public Response

In the optional survey, respondents were asked to rate how easy it was to complete the main survey from 1 (very difficult) to 5 (very easy). Of the 17 responses, the average rating of was 4.18 out of 5, suggesting that the Geoform user interface is well suited to the process of giving feedback.

Comments were received from open-ended questions about the process of giving feedback using the crowdsourced methodology. Some were positive:

"I'm delighted this initiative has been developed"

Respondent 96

"Great survey tool - assume it informs Evan (Ecan) or Metroinfo "

Respondent 65

A comment indicated that the survey would be easier and more convenient to complete on board the bus if WiFi was installed, especially for those with limited cellular data connections:

"Happy to use smart phone, but would need wifi on bus…"

Respondent 24

One comment felt that the survey was not suitable for a smartphone, and reiterates the requirement to consider the length of survey questions asked of passengers:

"Filling out a survey on a smart phone would just be a hassle. There are already hundreds of apps we need to use and filling out a survey isn't something many people would bother doing on their phones."

Respondent 17

4.7 SUMMARY

This chapter outlined the results of a range of analyses performed on the crowdsourced passenger satisfaction dataset collected during this research's case study of the Metro Bus network in Christchurch, New Zealand. Observations were made about the spatial, temporal and demographic characteristics of the dataset, trends in passenger satisfaction analysis explored and limitations identified of the external datasets used. Lastly, passenger suggestions for improving services were shared alongside perceptions of the survey used in this case study.

5 DISCUSSION

This chapter examines the role of crowdsourcing in public transport (PT) passenger feedback, and the comparisons drawn with traditional collection methods. The case study of the Metro Bus network is discussed, and lessons learned about passenger satisfaction on public transport in Christchurch, New Zealand over the survey period are detailed. Several practical recommendations are made for public transport operators that intend to crowdsource passenger feedback in their operations. Finally, the ways in which crowdsourcing can be supported to increase effectiveness and value of data going forward are explored.

5.1 ROLE OF CROWDSOURCING IN PASSENGER FEEDBACK

Two primary drawbacks of existing passenger feedback collection methods were identified by this research: the limited geographic accuracy and frequency of collected feedback. The literature indicated that crowdsourcing had the ability to improve geographic accuracy and frequency of passenger feedback in a cost-effective manner. The following section will discuss the extent to which crowdsourcing addressed these limitations during this case study.

5.1.1 Geographic Accuracy

Crowdsourcing greatly increased the geographic accuracy of passenger feedback from public transport. Traditional approaches to passenger feedback typically collected a bus route level approximation of trip locations (Environment Canterbury, 2015; New Zealand Transport Agency, 2013). The crowdsourced survey form collected precise geographic point locations representing start locations of reported bus journeys. The precise location points were made possible through the included map functionality, which a respondent could use to either select the starting location themselves or use GPS to collect a location automatically. All ninety-six responses collected during case study using the crowdsourced form had a location attached. As detailed in Section 4.3.4, accurate geographic data had the clear benefit of providing a detailed view of where bus journeys across the network took place compared to the route level. However, there is room to increase spatial accuracy further.

In this survey, passengers were asked to provide the location of the bus stop at the beginning of their trip. Due to the variable data sources involved in crowdsourcing, a small amount of error was expected in collected data. As described in Section 4.2.2, some responses were not geographically precise when compared to bus stop locations. Error was determined by comparing the survey's location to the closest expected location along a specified route. Most responses (70.8%) were within

250 metres of the route specified by the respondent. However, some outliers were also present. Error may be present in the location data for the reasons shown in Table 5-1.

Table 5-1: Sources of spatial error and potential solutions

Reason	Explanation	Potential Solution
User Error	Location was not correctly selected on the map by the respondent, who may have misunderstood the location to select, or just defaulted to automatic GPS location	Ensure instructions on survey are clear and easy to understand to minimise confusion
Measurement Error	Accuracy of Smartphone GPS sensors can vary between different makes and models (Bauer, 2013)	Take this into account when performing analysis

In situations where a response with low spatial accuracy is received, data points can be corrected manually if the error is small, or excluded entirely as an outlier from spatial analysis. Other information, such as bus route, can instead be used as a fallback. Data quality of crowdsourced datasets and possible methods for improvement is discussed further in Section 5.4.

5.1.2 Frequency of Feedback

A total of ninety-six responses were collected during the case study over a two-month period. The crowdsourced survey demonstrated that passenger satisfaction feedback could be collected quickly and frequently. The process was faster and cheaper than traditional methods as the data was collected and displayed on a map in near real time. The survey collected responses across a diverse spread of measures, such as location, time of day and demographic factors. The quantity of data was sufficient for a higher level of analysis ascertaining broader spatial and temporal trends across the city, on a suburban scale more accurate than passenger feedback collected on a route basis.

Environment Canterbury's 2015 Annual Report had a sample size of 2,077, which is the equivalent of collecting 173 responses per month (Environment Canterbury, 2015). This research aimed to collect a greater quantity of responses. This greater quantity could then be used for a more detailed analysis of satisfaction on the individual bus stop or trip level. Unfortunately, only 96 responses were collected over two months, meaning that the overall number of data points collected during the survey period lacked the spatial and temporal resolution required to paint a highly detailed picture of passenger satisfaction across the network. While this level of detail was not possible to demonstrate in this study

due to the survey response, a higher density of data points borne from more frequent responses would have made this possible.

A possible reason for the low response rate may lie with passenger awareness. The Metro Bus Network consists of over 2000 bus stops and 28 different routes in the greater Christchurch area, meaning that it was impossible to promote the survey's existence at most locations with the resources available. Likewise, advertising promotional material was not possible on all buses on these routes, resulting in many passengers not being exposed to the survey. Strategies for improving passenger awareness and accessibility of the survey are discussed in Section 5.3.

Motivation may also be a factor in the low response rate. The survey was promoted on the premise that the passenger's feedback was sought and valued, allowing them to have a voice in improving their bus journeys; no further reward incentive was offered. While this incentive was evidently ample for the actual respondents, more frequent responses might have been collected with increased use of reward incentives for completion (Dillman et al., 2008). However, in situations where data collection is ongoing, reward incentives may not always be feasible (Harris et al., 2016). The use of small financial incentives, such as fare discounts, may boost response numbers. Fare reduction strategies were shown to be effective in increasing uptake in new travel systems in Auckland (Harris et al., 2016). An alternate strategy that turns the survey process into a more direct feedback loop between passenger and operator could increase passenger engagement and responses. Strategies that could be employed include communicating the benefits of completing the survey to passengers or providing a summary of completed responses to see what other passengers have already said (Dillman et al., 2008). These approaches are discussed further in Section 5.4.3. It should be noted that the survey was a student survey, and passengers may have felt that responses were less likely to feed into improvements compared to an operator feedback survey.

Overall, the quantity of responses collected demonstrates that increasing and supporting participation in crowdsourcing remains vital for success; without a critical mass of responses, the value of crowd-driven insights cannot be fully realised.

5.1.3   Where does Crowdsourcing fit in?

This case study demonstrated the collection of passenger feedback using a crowdsourcing methodology. One aim of this research was to determine whether a crowdsourced passenger feedback dataset could serve as a substitute or supplement to existing methods of feedback collection.

In the current implementation of this survey, crowdsourced information is unlikely to match the quantity of information collected by traditional surveys equally. The large amount of data gathered during research surveys cannot simply be translated to a smartphone-based survey for a range of practical and usability reasons, including length, the survey medium and the attention span of users. Therefore, it was necessary to use a smaller subset of more important questions. User testing also indicated that shorter surveys were preferred by users, further placing restrictions on length. Because of these limitations, a crowdsourced methodology for collecting passenger feedback is not able to serve as a full replacement data source.

However, crowdsourcing shows promise as a supplementary source of passenger feedback information for several reasons. The data is collected in near real time, meaning that information can be reported a lot quicker than more comprehensive approaches. Crowdsourcing allows for a more detailed picture of passenger satisfaction to be constructed in a much shorter time, which can then be complemented by a more detailed annual report. As the flow of information between passenger and operator becomes increasingly bi-directional and inclusive, crowdsourcing is likely to play an important future role in the passenger feedback loop of public transport.

5.2 PASSENGER SATISFACTION AND FEEDBACK

Passenger satisfaction plays an important role in decision making for agencies that operate public transport (Del Castillo & Benitez, 2012). Measures of passenger satisfaction are used as a means of collecting information about perceived service quality across a range of aspects relating to their experiences using public transport; for example, reliability, comfort and safety (de Oña & de Oña, 2014). If a trip aspect scores poorly, operators can prioritise steps to improve their service in that area. This section discusses the approach of crowdsourcing passenger satisfaction information and passenger feedback more broadly, with observations made on survey design, usability, data quality and value.

5.2.1 Quantitative Scoring of Trip Aspects

This research took the approach of using scores for all areas of satisfaction. A standard measure made comparisons between different areas of passenger satisfaction easier, allowed comparison of satisfaction spatially and temporally, and was deemed to be the simplest and most consistent approach for passengers using smartphones on board buses.

The use of satisfaction scores may not be appropriate for every question a passenger survey asks. Because of the subjective nature of satisfaction, it sometimes may be difficult to draw objective

conclusions from scores that are useful for analysis. For example, respondents were asked about how satisfied they were with their perceived safety at bus stops. Analysis using the Crash Analysis System (CAS) dataset indicated a statistically significant relationship between perceived bus stop safety and nearby fatal crash history, but this relationship only accounted for 9.7% of the variability in passenger perception of safety (Results chapter, section 3.5.2). 'Safety' has a wider range of implications for passengers beyond standing on the side of high-risk stretches of road; respondents may perceive safety from different (or potentially unidentified) perspectives which should be considered, such as environmental design (Wallace et al., 1999).

5.2.2   Open-ended Questions

In addition to questions that collected quantitative passenger satisfaction scores, a qualitative open-ended question was also used that asked passengers for suggested improvements to public transport services. Many of the suggestions provided valuable and interesting information into what passengers felt were the biggest problems with the services used, and provide important insights on what improvements public transport operators should prioritise. The flexibility of the question allowed for a range of responses that would not have been possible had the survey only contained predetermined answers. An observation of the collected responses revealed that feedback was related more to general improvements to the system rather than the trip specifically. An interpretation of this observation is that passengers are more concerned about larger, overall problems with the bus service that are likely to impact multiple trips, in addition to issues that only affected a single bus vehicle or service.

While the data provided by this question provided valuable insights, analysis with the qualitative data was limited and could not easily be compared with the other information in the survey or additional datasets. Additionally, while the qualitative data can be viewed individually in the real-time dashboard, the text responses cannot be automatically aggregated or summarised like quantitative variables. Real-time analysis of text might be possible in the future through appropriate tools designed to process and analyse text.

Overall, the use of open-ended questions was a valuable addition and allowed for a greater range of expression from respondents. However, the use of this data requires more manual analysis and effort than the rest of the survey for identification of larger trends. It is therefore not as useful in real time for identifying specific issues, a point further discussed in Section 4.2.1.

5.2.3 External Datasets

One of the benefits of location-based feedback is that other geographic datasets can be joined to the crowdsourced dataset so that additional relationships with passenger satisfaction can be explored. Three external datasets were tested in this research.

A traffic intensity dataset was used to determine whether traffic congestion had an impact on journey and wait time satisfaction. Traffic congestion is known to affect satisfaction in a number of ways, as it has impacts on waiting, reliability to the scheduled timetable and journey time (Edvardsson, 1998). An average traffic intensity dataset was used as an approximate measure of traffic congestion. In Section 4.3.2, passenger satisfaction with time spent waiting and journey length was found to decrease during times of increased commuter traffic in the morning and evening. Given that the impact that increased volumes of traffic has on journey times on the main roads and thoroughfares during this time, it is highly likely that bus journey and waiting times are also affected. Additionally, passenger behavioural patterns around commuting should be considered. Regular bus commuters may not experience large declines in satisfaction because of the expectation that waiting and journey times will be increased during increased traffic, and therefore make plans that may reduce the gap between the passenger's expectation and the service provided.

However, the limited temporal resolution of the traffic dataset proved to be a limiting factor in the analysis, as the analysis was not able to consider the detailed traffic variation that takes place throughout the day or differentiate between weekdays and weekend traffic patterns. A more comprehensive traffic dataset should be used in future feedback analysis taking into account time sensitive variation in traffic flows. For example, traffic counts at an hourly occurrence over the day should be used.

Weather has previously been linked to dissatisfaction with public transport (Edvardsson, 1998). For weather information, a dataset was compiled from the Dark Sky Weather API using a custom python script to query historical conditions for each survey response. However, due to weather remaining homogenous across the survey period, the lack of variance meant that the usefulness of weather data could not be tested in this case study. Seasonal trends in weather-related satisfaction are more likely to become apparent when data is collected over several months when contrasts in conditions, temperature and rainfall are more pronounced.

Historical incident data from NZTA's Crash Analysis System (CAS) was used identify survey locations with a recent history of crashes, aggregated using a 150m buffer surrounding the location. There is greater potential for more specific analysis using variables that distinguish between the type of vehicle

involved in the accidents so that incidents specifically involving pedestrians or buses can be identified in line with literature (Truong & Somenahalli, 2011). This more detailed information was available until recently as part of the standard CAS dataset but is no longer provided publicly by NZTA (NZTA, 2016). Public transport operators may be able to access this information through data agreements with NZTA.

Overall, the value of external datasets in enhancing crowdsourced depends greatly upon their quality and availability. It was clear that the datasets used in this case study did not prove to be as useful as envisioned because the data was of insufficient detail for the required analysis. However, it does not preclude the use of higher quality geographic datasets to achieve this value in future use cases. Trends in passenger satisfaction may also exist on different time scales, such as at an hourly, daily, weekly or even monthly level. The temporal extent and resolution of both the crowdsourced data (for example, the period over which data is collected) and external datasets used should be considered during analysis, as relationships between satisfaction and variables such as weather and traffic may appear at micro and macro time scales.

5.3   PRACTICAL CONSIDERATIONS FOR CROWDSOURCING IN PT

This section discusses the effectiveness of the approach to crowdsourcing passenger feedback during this case study. Observations are made on how survey design, crowdsourcing tools and survey distribution methods shaped the resulting dataset. These observations are discussed in relation to research objectives of increased data collection frequency, improved geographic data and passenger engagement in crowdsourced data collection.

5.3.1   Survey Design

5.3.1.1   Survey Purpose
The survey was primarily developed to be completed on a mobile device, while on the bus, giving feedback on a specific trip. While 46.8% of respondents fell into this category, respondents also answered the survey by:

- Completing the survey at bus stops and home
- Completing on a variety of devices, including mobiles, tablets and desktops
- Making broad suggestions for improvement and not necessarily specific to a single trip

The high number of respondents filling in the survey at alternate locations indicated a wider context of engagement beyond the original purpose of a mobile first on board experience. Therefore, it is

important to consider how the survey can be better designed to suit contexts both on and off the bus. The survey was not designed for efficient issue reporting, but reports were received such as broken bus stop displays were received. One possibility is that instead of a single survey with the same questions, two purpose specific location-based surveys are used instead:

- A survey designed to have a greater focus on trip specific feedback, which incorporates fewer but more specific questions about the journey.
- A complaints/report a problem form, so that issues can quickly be separated from general feedback during a processing workflow and acted upon more quickly. Christchurch City Council currently offers a mobile-based application titled 'Snap, Send, Solve'[5] which is a tool designed for the public to submit crowdsourced issue reports to the responsible local authority. These reports contain details of the issue to be fixed, alongside a photo and the location of the issue. A similar reporting format to 'Snap, Send, Solve' could be adopted for issues related to public transport infrastructure and services. Because there may be specific details required to follow up a complaint, such as contact information or precise details about the situation, separation of the information from general feedback is important.

Separating out the survey makes the task of using the data for the intended purpose, while still retaining the ability to combine datasets in analysis.

5.3.1.2   Survey Distribution

Promotional material containing the survey's shortened link and QR code was used to invite passengers to respond to the survey on board buses, at bus stops and on social media. Observations are made in this section about the effectiveness of the approaches.

The research provided an opportunity to assess the effectiveness of social media in promoting responses to the survey. Analytics indicated that just over half of all visits to the survey landing page came from the social networking site Facebook. Both overall visits to the landing page and survey responses collected peaked in early December when the survey was shared with users of the official Christchurch Metro Facebook page. The page is typically used by passengers to stay up to date with service changes to the Metro network and is therefore likely to provide the most relevant exposure of the survey to the people most interested in providing feedback on their journey. 57.3% of social media traffic to the survey came from mobile devices. A possible interpretation of this is that the traffic came from passengers waiting for or on the bus, who took the survey while checking up on trip information.

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[5] https://www.ccc.govt.nz/report/snap-send-solve/

In the future, it may be possible to leverage social media user engagement using online advertising, such as Facebook's sponsored posts feature to target promotion to bus users.

For consistency across printed material, the same shortened web link to the survey's landing page (http://bit.ly/chchmetro) was used during the case study. However, this approach meant that it was not possible to identify whether a person found the survey through the onboard bus posters or via the flyers at bus stops. Variants in the shortened web link to the survey (for example *chchmetro-bus* for on board posters and *chchmetro-stops* for bus stop material) could allow analytics to identify the most effective physical advertising. Alternatively, this information could be requested in the survey.

In comparison to other approaches, the effectiveness of using of poster flyers at bus stops was less certain. Permission was given to advertise the survey on board Red Bus services and at bus stops, and use the Metro logo in a support role. However, for the purposes of this survey it was only possible to tape non-permanent poster flyers to the public transport on-street infrastructure. Because of this approach, some passengers might possibly perceive the survey promotional material as unprofessional and therefore unimportant, resulting in fewer overall responses. The time flyers remained in place remained in place varied from several days right through to the entire survey period due to environmental factors. It was unclear how successful this approach to survey promotion was. However, the inclusion of survey promotion within more durable and official agency marketing materials in future will make survey promotion completely successful.

5.3.1.3   Repeat Responses

The survey was designed to collect trip specific feedback and repeat responses were encouraged from passengers for each trip taken to increase the overall frequency of feedback received. Only 16.7% of responses indicated they had submitted feedback at least once before, but there was high interest in providing feedback again another time at the end of the survey. In the OpenStreetMap community, crowdsourced contributions of geographic information can be separated into groups by motivational level; between the 'crowd' (large numbers of people contributing infrequently) and the 'community' (repeat contributors) (Budhathoki & Haythornthwaite, 2012). The low proportion of repeat responses indicates that respondents in this case study primarily fall into the 'crowd' category, where repeat responses are not commonly collected. Because the 'crowd' requires a lot of contributions to build a collective dataset, a greater effort is required to collect new responses. Repeat responses can be encouraged by keeping the survey widely accessible and available to those wishing to provide feedback again; strategies for improving accessibility are further discussed in Section 5.4.2. To facilitate sustained and repeated engagement however, efforts need to be made to develop a

community level of motivation that comes with participatory engagement in public transport (PT) decision making (Johnson & Sieber, 2013).

5.3.2   Crowdsourcing Tools Used

Crowdsourcing research and tools are continually being developed and improved. Current tools are likely to improve going forward as crowdsourcing tools and methodologies are increasingly adapted. The following sections will share observations about the tools used at the time of this study, as the technology of crowdsourcing continues to evolve.

5.3.2.1   Location Survey Building

The survey used the ArcGIS Online platform to collect responses using the GeoForm template and store data with spatial locations attached to the survey answers. The process of creating a new survey, or updating a survey first required the authoring of a feature layer built using the survey questions. Creating the feature layer was straightforward, but required more experience than typical online survey building software, such as Qualtrics and Typeform, because familiarity with more complex GIS software was required. However, it is expected that location based crowdsourcing tools will soon remove the requirement for specialist knowledge, with tools, such as Survey123[6], beginning to simplify the process of building location-based surveys using a drag and drop interface.

5.3.2.2   Survey Technology Reliability

The GeoForm functioned as intended on nearly all passenger devices that took the survey. Analytics taken from the survey's landing page indicated that the survey was accessed primarily by mobile devices, with 44.4% of visits from Android devices and 28.0% visits from iOS devices. Desktop visits were made up of 22.7% from Windows devices and 2.9% from Macs, the remainder were undetermined. There were rare exceptions where the GeoForm had issues being accessed. A support link was provided on the survey's landing page to record whether any issues arose. A total of three people reported having issues that prevented them from accessing or completing the survey; these people were redirected to a reduced version of the survey that did not include the location component. These three responses could not be analysed spatially but were instead incorporated into later non-spatial statistical analysis to ensure all responses were included. The importance of accessibility is discussed further in Section 5.4.2.

To streamline the process of tagging a GPS location on the survey response, the automatic GPS location feature of the GeoForm was used. For some users, this tagging may have resulted in an automatic incorrect location in the event a manual location was not selected, while other participants

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[6] http://survey123.arcgis.com/

stated that they would prefer that the form did not automatically ask for a location. In future approaches, information about how the location process works and why it is requested should be made clear to respondents.

5.3.2.3   Real Time Dashboard

In addition to tools for crowdsourced data collection, a web dashboard was created to display and browse survey responses on a map in real time. Crowdsourced passenger feedback collection functions effectively in a real-time context, increasing utility by allowing trends in satisfaction to quickly be discerned by operators as they happen. The dashboard allowed for the responses to be visually explored and individually viewed, and for descriptive statistics, such as satisfaction averages, to be displayed for specified areas. ArcGIS Online's WebAppBuilder tool was used successfully to build the dashboard, requiring little configuration. Since public transport agencies are likely to have varied requirements for the visualisation and dissemination of their data, the tool provides extensibility allowing for specific needs to be developed for their own transport systems and organisational workflows.

5.4   HOW CAN CROWDSOURCING BE SUPPORTED IN PT?

For the value of crowdsourced passenger feedback to be realised in future public transport agency efforts, several considerations need to be made by planners and operators. The following sections will discuss the ways that crowdsourcing from passengers on public transport can be supported and enhanced in the context of the literature. The experiences gained during the case study are considered, alongside literature surrounding effective crowdsourcing practice.

5.4.1   Integration into Public Transport Agencies

It is recommended that if a crowdsourced approach is adopted, it needs to be well integrated into existing organisational workflows that deal with passenger feedback. Workflow integration is necessary for ensuring that feedback is being received and dealt with appropriately (especially if a complaint is submitted through the system). Integration also helps to reassure passengers that the feedback they provide is meaningful and is being considered, which provides an important motivator for contribution (Dillman et al., 2008). This approach includes integration of the survey promotional material into standard agency marketing materials on board buses, at bus stops and exchanges and online/social media, providing a unified promotional approach.

To this end, it is important for organisational policy makers to be aware of the benefits, drawbacks, costs and challenges of collecting and analysing crowdsourced information (Johnson and Sieber,

2013). For example, new costs that arise from the learning curve of new GIS software tools for spatial analysis should be considered. Crowdsourced datasets also may not have the same completeness or structure of traditionally utilised authoritative datasets (Johnson and Sieber, 2013). To provide a common benchmark for comparison, it is recommended that standards be developed to fit crowdsourced data into a common structured format. NZTA is investigating the role that crowdsourcing plays in planning and supporting New Zealand transport, so future crowdsourcing standards could be directed through a national crowdsourcing framework (Harris et al, 2016). Currently, NZTA has a reporting requirement for regional public transport agencies to collect passenger feedback using a common set of survey questions. This requirement as it stands may hinder smartphone-driven crowdsourced data collection as a full data source replacement, as the format and quantity of these questions are not suitable for smartphone based entry (NZTA, 2016).

5.4.2 Accessibility

The survey should be implemented with the lowest barrier of entry to passengers as possible. The accessibility of smartphones remains a barrier to mobile device based crowdsourcing. Smartphone use is steadily increasing (Sui, Goodchild, et al., 2013); however, some socioeconomic groups such as lower income earners and older adults are less likely to be exposed to newer technology that enables crowdsourcing to take place (Research New Zealand, 2014).

It is therefore important to ensure that the survey remains accessible to people that do not own smartphones. A quarter of respondents undertook the survey on a desktop computer, allowing responses to be submitted without this requirement; however, this may be limiting for those wishing to submit feedback while not at home or work, or that do not have an internet connection. A suggestion could be to install kiosk-based tablets (an approach like 'Happy or Not'[7] service rating kiosks but with more flexibility) at bus exchanges that allow passengers that do not own a smartphone to provide feedback about their trips while passengers wait. Kiosks may also facilitate longer form questions that would otherwise be tedious on the small screen of a smartphone, but without the requirement of a researcher to be present.

5.4.3 Motivation to Contribute

Motivation to participate remains an important issue for the viability of a crowdsourced dataset. Without motivated people that are interested in contributing, the value of the collective crowd is not realised. Several strategies for increasing participation could be employed.

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[7] https://www.happy-or-not.com/en/

Reward incentives: provide a reward for undertaking the survey. The extent of the reward will depend on available resources, but small reward amounts have proven to be effective at increasing survey responses (Dillman et al, 2014). Bus passes or top up credit for fares are an interesting option that benefits both passenger (who receive benefit for services passengers regularly use) and operator (who gets up to date data plus passenger's continued patronage and may encourage additional usage) (Harris et al., 2016).

Gamification: add engaging elements to the survey that encourages contributions, through point systems or scoreboard that make giving feedback more interesting and competitive (Antoniou and Schlieder, 2014; Dillman et al., 2008). For example, statistics of passenger responses could be compared with other passengers in a scoreboard system.

Pair with value: provide an arrangement where the passenger receives a benefit in return. Unlike a reward incentive, pairing the survey with something that the passenger is interested in using and depends on regularly, such as an app that provides up to date travel information, or through social media can draw more attention towards the survey on a regular basis, prompting regular responses (O'Malley, 2017). In contrast to active crowdsourcing contributions, public transport travel cards have been used to produce data on passenger journeys in a passive manner (Bagchi & White, 2005). Pairing the benefits of travel cards with active crowdsourced contributions could provide incentives for survey completion, while also enhancing trip information datasets. However, this approach is only possible for travel systems that use a tag on and tag off system, which the Metro network does not (Bagchi & White, 2005).

Government agencies, including public transport agencies, are increasingly making the data that they generate and collect freely open to access through Open Data portals. The release of open data bolsters economic innovation and promotes participation, but also provides transparency and accountability to public organisations (Open Data Handbook, 2017). Open data provides confidence to passengers that their collective voices are being heard and responded to appropriately. In turn, this ensures that passengers see the value in providing feedback demonstrated. Making crowdsourced data on passenger feedback publicly available provides an important means of ensuring that agencies are meeting their goals in making meaningful improvements to public transport systems.

5.4.4   Privacy and Trust

It is important to ensure that respondents' anonymity is respected. Anonymity allows people to have a safe space to give the feedback they think is important without judgement. More importantly, anonymity prevents sensitive location data from being collected about individuals that could be used

unethically to reveal information about where respondents live and travel. However, these issues are not necessarily unique to this study. It should be considered that travel cards may already provide this information to operators through tag on and tag off records (Bagchi & White, 2005).

Not only is it important for people to understand how the geographic data is used, but the benefits of contributing the data should be well communicated to respondents. Research undertaken by Transport for London on the Underground tube network indicated that people were initially wary about the use of geographic location tracking, but were more accepting of the data collection activity once people understood how the collection of the information had personal and positive impacts on their journeys (O'Malley, 2017).

5.4.5   Data Quality

This research focused specifically on the spatial accuracy of responses rather than data quality more broadly. As stated in Section 3.1.1, most responses were accurate to their stated located, but there is room for improvement. In some cases, manual correction of location data was required. Techniques exist for the automatic classification (and therefore exclusion) of inaccurate spatial data based on accuracy criteria (in this case, proximity to stated bus route) that can assist in maintaining high-quality crowdsourced datasets (Ali & Schmid, 2004). Ensuring that all questions and instructions are clear in intent and easy to understand also plays an important role in data quality. Clear communication reduces the potential for confusion about the information required (and therefore user error) in the location provided can be minimised (Dillman et al., 2008).

Crowdsourcing trust models that assess the accuracy of overall collected data were outside the scope of the study. However, for the accuracy of survey data more broadly, crowdsourcing validation models can be used to compare similar or conflicting reports (Bordogna et. al 2014).

5.5   SUMMARY

The methodology used by this research sought to allow for passenger feedback to be fed into analysis and decision making activities carried out by public transport operators. This in turn would allow for improvements to public transport services that benefit passengers (Figure 5-1).
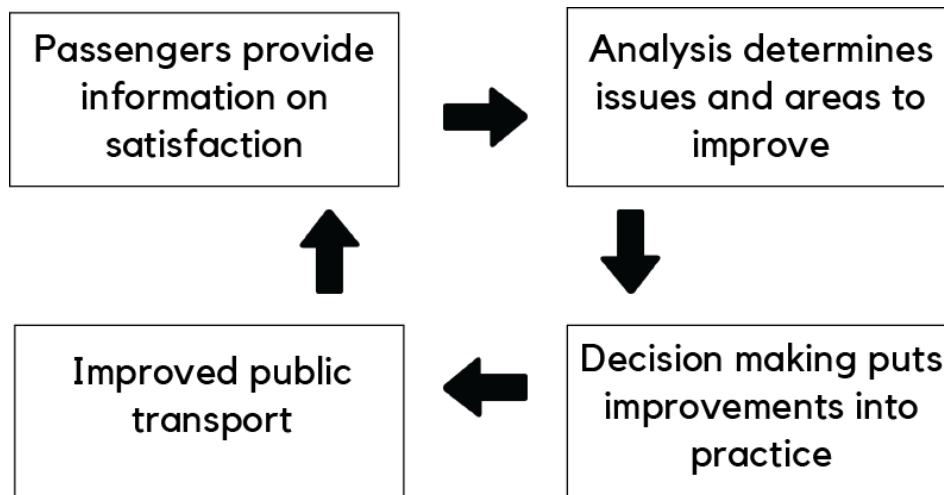
Figure 5-1: The cycle of improvement with the use of a passenger feedback system, derived from the quality loop of public transport (Nathanail, 2008)

Overall, a crowdsourced methodology for the collection of passenger feedback is successful at increasing the utility of passenger satisfaction. The research demonstrated that crowdsourcing could be applied to collecting more geographically accurate and more frequent data using tools designed for mobile data collection, with the additional benefit of receiving and displaying responses in real time. However, while crowdsourcing is more than capable of playing a supplementary role in passenger feedback collection, many hurdles exist that prevent this methodology from becoming a full replacement to existing methodologies. The facilitation of increased passenger motivation was identified as a key driving force in the utility of crowdsourced information, as the quantity of responses collected played an important role in determining the analysis that could be undertaken. Important considerations for public transport operators were discussed, such as the need for well-integrated organisational workflows around crowdsourcing, increasing survey accessibility, motivating a higher number of responses and respecting privacy and trust of respondents.

6 CONCLUSION

6.1 OVERVIEW

Public transport plays a major role in urban transport, and for many is relied upon every day. It is therefore important that public transport agencies continue to improve their services to meet the needs of their passengers best. With increased geographic accuracy and frequency of passenger feedback, this research found that it was possible to leverage crowdsourced data collection to provide a means of ascertaining a wider picture of passenger satisfaction in real time.

The use of geographically accurate feedback showed trends in satisfaction across broad geographic areas, an improvement over coarse route based locations. However, while the speed at which feedback is received far surpasses traditional methods, the low number of responses signifies that greater support for crowdsourcing methodologies is needed to match the quantity of data collected using existing methods. Increasing motivation, adopting crowdsourcing frameworks and making surveys accessible to all will be key in future for developing this methodology further. These are important factors to consider should the model be adapted as an improved (or replacement) data source of passenger satisfaction for decision making.

6.2 RESEARCH OBJECTIVES AND FINDINGS

This research posed the following question: **How can crowdsourcing methodologies increase the utility of passenger feedback on public transport?** The question was addressed through four research objectives. A summary of the findings pertaining to each of these research objectives are provided below.

1. **To apply crowdsourcing methodologies to collecting more frequent, geographically accurate passenger satisfaction information**

   A sample of passenger feedback was collected on the Metro Bus network in Christchurch, New Zealand using a crowdsourcing approach. A total of ninety-six responses were collected over a period of two months, containing a comparable demographic spread to existing passenger figures (Environment Canterbury, 2015).

   Crowdsourcing was found to increase the speed at which feedback was collected and made available for analysis in near real time. However, while crowdsourcing permitted responses to

be collected more frequently, a lower number of responses was collected when compared to existing approaches.

Crowdsourcing was also successfully able to increase the geographic accuracy of passenger feedback. The use of location-enabled web form allowed for the collection of precise geographic coordinates to be collected about where bus journeys began, either using smartphone GPS or through manually selected on a map. The spatial accuracy of collected locations was estimated by comparing the difference of the point from the specified bus service. Most responses were placed near or on the expected route, with few responses inaccurately located.

2. **To undertake an exploratory analysis of a dataset of passenger feedback to provide insights into passenger satisfaction collected using a crowdsourcing methodology**

The sample of passenger feedback collected on the Metro Bus network was analysed to investigate patterns in passenger satisfaction. Spatial and temporal patterns were identified using spatial and statistical analysis to identify differences in passenger satisfaction in different areas of the city. While broader spatial analysis was possible, limitations in the ability to perform more detailed spatial analysis at the bus stop level were identified due to the low number of responses received. External geographic datasets, i.e. weather, traffic intensity and nearby crash history, were also incorporated into the crowdsourced dataset to increase the value of the data. Homogenous weather conditions during the survey period meant that weather's relationship with passenger satisfaction could not be tested, and limitations were encountered in the temporal resolution of the traffic dataset. However, crash history was found to have a statistically significant relationship with passenger satisfaction with bus stop safety (Section 4.4.2). Lastly, passengers also provided open-ended suggestions for improving bus services. The answers were categorised into common themes to aid in the identification of key issues.

3. **To assess the extent to which passengers are interested in providing feedback on their smartphones during their bus journey.**

A total of ninety-six responses were collected during the survey period of two months, which was a lower amount compared to the equivalent amount collected by traditional annual surveys. This result indicated the need to facilitate further motivation for passengers to

contribute and to ensure that the survey was accessible as possible to users through widespread promotional material across the bus network. The survey used in this case study was smartphone orientated to facilitate users on public transport to determine the interest in completing surveys on board. Seventy-two percent of respondents accessed the survey from a mobile device, while less than half of responses were completed on board the bus; this indicated a broader context of use beyond smartphones on buses that is important to consider when designing future smartphone orientated surveys.

Comments from passengers that undertook the survey were supportive of the crowdsourcing approach (Section 4.6.3). When undertaking the survey, passengers were asked whether they had completed the survey previously and whether they would be interested in giving feedback on their trip in future using their smartphone. A high proportion of responses indicated that they had not completed the survey before but would do so in the future. Thus, it is likely that material promoting the survey needs to become more accessible to passengers using the public transport network, to ensure that passengers can provide repeat responses about their bus journeys.

4. **To evaluate the effectiveness of crowdsourced data collection as a useful substitute or supplement to existing methodologies.**

During the survey design and pilot testing phase of this research, limitations imposed on question content and survey length by the smartphone medium became apparent. It was not possible to collect detailed information on the full range of questions used in existing annual surveys. Crowdsourced data collection in its current form does not meet the requirements to completely replace existing surveys. However, crowdsourcing instead shows promise as a supplementary source of information, collected at low cost and in real time, that can reveal trends on sub-annual time scales.

Overall, crowdsourced methodologies show great potential in increasing the utility of passenger feedback, through increased geographic accuracy and frequency, real time data gathering and at a lower cost to existing methods. However, maintaining passenger motivation to respond remains an important barrier to success.

6.3   SUPPORTING CROWDSOURCING

As detailed in Section 5.4, several steps can be taken to support crowdsourced passenger feedback on public transport. The integration of crowdsourcing into organisational workflows dealing with

passenger feedback is important to consider, from promotional marketing materials through to customer service and higher level decision making. Integration ensures that passenger feedback continues to be dealt with appropriately, while also reassuring passengers that their suggestions and experiences are being listened to and acted on. Accessibility of the survey also needs to be supported to ensure that all who wish to provide feedback can do so. To reach passengers without a smartphone, crowdsourcing tools need to facilitate other devices, such as desktop computers or public transport terminal based kiosks. Lastly, facilitating approaches for increasing passenger engagement and motivation to contribute is key to collecting sufficient quantities of crowdsourced information. To that end, small reward incentives, gamification and/or the utilisation of paired benefit systems that encourage a two-way exchange of beneficial information between passenger and operator.

6.4 FURTHER RESEARCH

This research demonstrated the use of crowdsourcing to improve the utility of passenger feedback. To increase the benefit of crowdsourcing methodologies further, suggestions for future research in the area are made below.

Rewards such as cash or discounts have been used to incentivise survey completion in the past. Specifically, smaller reward amounts have been shown to be more successful than larger amounts (Dillman et al., 2008). Given that this research's crowdsourcing methodology would benefit from increased contribution, more research into the effect of various reward amounts on the frequency of passenger feedback contributions would be valuable. For example, the effectiveness of small fare discounts could be compared to cash and non-financial rewards, such as valuable travel information. Such research would aid public transport operators in identifying the most cost-effective approach to increasing passenger engagement and responses, in turn allowing for a more complete picture of passenger satisfaction to be constructed.

This research used locations of the beginning of bus journeys for the spatial component of the analysis undertaken, as the crowdsourcing tool used only permitted a point location to be recorded. As crowdsourcing tools evolve and develop, collection of different forms of spatial information may become possible (such as start and end journey points or trip segments) to be easily recorded by passengers in surveys. This is important to consider when recording journeys that involve multiple trips and transfers. More comprehensive spatial information about the exact paths of trips may provide greater detail into spatial patterns in passenger satisfaction.

6.5   Concluding Remarks

It is important that public transport best serves the needs of users to attract new users and maintain existing patrons. To that effect, the collection of passenger satisfaction information remains crucial to the success and effectiveness of public transport operations. This research has demonstrated an alternate crowdsourcing methodology for the collection of more frequent and geographically accurate passenger feedback. Crowdsourced information can serve to provide additional context to decisions making, while also encouraging public participation of users to have a say in how public transport services are run for the better.

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APPENDIX 1: SURVEY QUESTIONS

Christchurch Metro Satisfaction Survey

Thanks for taking the survey! It will take less than 5 minutes to complete.

You will be asked to provide some details about your bus trip, and give a satisfaction rating (1-5) for several aspects of your trip.

You will then be asked to provide **the location of your starting bus stop** using the map provided (either allow access to your location, or select a point manually)

Optional: What do you think about this method of providing feedback about your bus trips? Let us know how we did here (https://andrewdc.typeform.com/to/gf32p1).

If you have any questions regarding this survey, please contact the Researcher.

1. Enter Information

Have you given feedback using this survey before?

○ Yes
○ No

Bus service used for this trip: (required)

| Select | ▾ |

Start typing the service name/number

Overall, how satisfied are you with the bus trip that you are taking today? (required)

| Select... | ▾ |

How satisfied are you with finding information about this bus trip?

| Select... | ▾ |

How satisfied are you with getting to your starting bus stop?

| Select... | ▾ |

Are you satisfied with the starting stop's suitability for the trip's weather?

| Select... | ▾ |

What about the cleanliness of the starting bus stop?

| Select... | ▾ |

How safe you felt at the starting bus stop?

| Select... | ▾ |

How satisfied are you with how long you waited for your bus?

| Select... | ▾ |

What about finding a seat onboard the bus?

| Select... | ▾ |

The driver's skill in driving the bus?

| Select... | ▾ |

The bus's cleanliness?

| Select... | ▾ |

The temperature inside the bus?

| Select... | ▾ |

How long the journey is taking?

| Select... | ▾ |

What is one thing that could be improved about your trip?

| |

What age catagory do you belong to?

| Select... | ▾ |

What is your gender?

○ Male
○ Female

○ Gender Diverse

What is the purpose of this bus trip?

Select...   ▾

Would you give feedback on your trips again, using your phone on the bus?

○ Yes

○ No

Optional: What do you think about using your smartphone to give feedback on you bus trip? Use this quick form to tell us! (opens in new window)
(https://andrewdc.typeform.com/to/gf32p1)

Before you mark your starting bus stop on the map below, any further feedback on your trip or this survey?

255 characters remaining

2. Select Location

Specify the location for this entry by clicking/tapping the map or by using one of the following options.

Search   Lat/Lon

Find address or place   🔍

⏶ Locate Me

Latitude: -43.52717, Longitude: 172.63870

3. Complete Form

Add this information to the map.

Submit Feedback and Finish

Back to top

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