Use of technology to measure and improve freight movements

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Executive summary

Exponential growth of technology means there is an expanse of new data sources being captured. This provides an opportunity to access and use existing, new and real-time data sources to analyse freight patterns and identify solutions to manage network performance and improve the journey predictability for urban freight movements.

This research aimed to develop a better understanding of how the range of available data sets could be used to monitor urban freight flow, and to determine the location and magnitude of network impediments affecting freight movements. Through identifying network inefficiencies, consideration can be given to the types of solutions including intelligent transport system (ITS) technologies that could be applied to support more efficient movement of freight in urban areas.

The specific objectives of this research were to:

- review the availability and current applications of digital data for road network monitoring in New Zealand and overseas
- conduct an assessment of the usefulness of the data for identifying and providing solutions to network bottlenecks and improving journey predictability for urban freight movements
- identify the major freight flow problems and bottlenecks in Auckland and demonstrate their impact using geospatial data
- examine any available case studies to evaluate current best practice use of technology to measure urban freight movements and assess the solutions, including ITS solutions that are being used internationally to identify problems and bottlenecks
- identify potential synergies with other research and ITS initiatives including best practice already being used in New Zealand
- encourage industry involvement with the topic area through stakeholder engagement
- develop possible solutions including innovative and 'thinking outside the box' options in addition to the more traditional ITS-based approaches
- identify the most useful solutions to achieve greater network efficiency and freight journey time predictability in the short-to-medium term
- consider the high-level benefits and costs of potential solutions including documentation of the limitations, considerations and trade-offs in implementing each potential solution.

An extensive review of both national and international research of ITS applications in the freight sector provided examples of innovative ways technology is being applied to measure congestion and manage existing infrastructure more effectively. ITS forms part of a wider urban freight management plan, alongside regulatory measures, infrastructure, urban consolidation centres and off-hour deliveries. The challenges highlighted from international projects include a lack of reliable data collection and availability, high rates of positioning errors due to ITS hardware immaturity, and system integration. By moving towards developing ITSs that are inter-operative with evolving technology, compatible with commercial models and interoperable between cities, technology can be used to its greatest advantage.

The research team reviewed the status of the New Zealand digital data marketplace to determine which technologies are currently being applied, with a specific focus on Auckland City. The technology applications being used in Auckland City for traffic monitoring include Bluetooth, global navigation satellite system data, mobile, weigh-in motion, fibre optic, closed circuit television (CCTV), traffic counts and the Sydney Coordinated Adaptive Traffic System; however, there are no data sources that isolate the movements of urban freight from general traffic.

Stakeholder engagement provided insight into the current urban freight operating environment and informed the identification of challenges facing the freight sector. Frustration at the lack of, or inefficient, Auckland infrastructure was conveyed very strongly. There was also a high level of frustration and a sense of urgency to find solutions to enhance network efficiency and improve operational and financial efficiencies for operators. Stakeholders generally agreed the freight sector could be supported by technology applications that can:

- increase the uptake of public transport
- utilise variable speed technology to improve the flow of corridors and motorways by reducing the speeds before the corridor is congested to improve capacity
- allocate road space better
- improve incident management to clear incidents more quickly
- improve the placement and design of loading zones, including the use of booking systems and sensors to detect availability of loading zones
- educate road users to drive more efficiently and considerately
- utilise emerging connected and automated vehicle technology.

The magnitude and location of congestion on urban freight movements in Auckland was demonstrated through the assembly of several resources using predominately commercial global positioning system data sets. These maps provided snapshots of congestion (based on the quantum of deviation from free-flow speed) at half-hourly intervals during commuter peaks and hourly intervals between 10am and 2pm. The maps demonstrated congestion is widespread in Auckland with only limited periods of relief where traffic is relatively free flowing as the morning peak extends from 5am to 9.30am, and the evening peak from 2pm to 6pm on extensive parts of the network.

These resources were analysed to inform the process of identifying which bottlenecks had the greatest impact on the freight sector, and could benefit most from the application of technology to improve traffic flow and journey time reliability. Analysis also highlighted the greater network-wide impediment to reliable traffic flow.

Locations where the effects of congestion were significant for the freight sector were isolated to carry forward as potential case studies. The research team then proposed several types of technological applications to improve the movement of urban freight in Auckland and worked with the Steering Group to match the technologies with suitable locations that would benefit from these. There was a willingness from stakeholders to see technology improve the level of service on the network for all vehicles.

The research presents five case studies to demonstrate the application of technological solutions. The priority of freight movements, congestion reduction and increasing the operational efficiency for urban freight operations in the short term are the primary focus. Each case study describes an application of technology, a location within Auckland where benefits will be realised, and the extent of current congestion in the vicinity. The likely benefits and broader considerations are discussed including the challenge of prioritising freight without adverse effects on other modes. Alignment with the Auckland Network Operating Plan and management of the hierarchy of modes on the network is required.

Table ES1 is a summary of the five technology applications and locations.

Table ES1 Summary of technology applications and case study locations

Technology application	Overview	Benefits	Case study location
Freight journey predictability tool	• Combines realtime and historic travel time (two-year rolling average) data to provide travel time and travel time reliability estimates • Hosted on line as a road network application programme interface. Delivered via variable messaging sign and web-based applications • Presents a range of likely travel times based on real-time network conditions in addition to average travel time	• Improved visibility of travel time variability • Improved preplanning, schedule and delivery window adherence • Reduced uncertainty of effect of traffic conditions • Fuel savings and reduced driver frustration	MetroPort to SH1N and SH1S
Freight sector network information tool	• Map-based platform with location specific information relating to accessibility and movement of freight. Including (but not limited to): - road width - loading zones - height restrictions - freight priority ramps - service roads - axle restrictions	• Increased awareness and knowledge sharing • Increased efficiency • Reduced congestion caused by parked or circulating vehicles • Timely and updatable system • Improved safety	Auckland urban area
Intersection freight priority using CCTV video analytics	• The application of video analytics technology to process CCTV footage in real time • Isolate freight vehicles queued in short right turn lanes at signals and extend the green phase to specified movement	• Improve intersection level of service • Improve heavy vehicle throughput • Improve travel times and wait time on right turning vehicles • Increased fuel efficiency	Great South Road and Church Street intersection
Cooperative intelligent transport system freight corridor	• Open communication between trucks and signal infrastructure to provide signal priority • Linking of green phases through advising vehicle of optimum travel speed to pass next signal without stopping	• Improved travel time and journey reliability • Reduced emissions, fuel consumption and noise	Saleyards Rd/Walmsley Rd corridor
Loading zone management tool	• Real-time parking sensors to monitor loading zones and holding areas in large retail complexes • Push out availability of loading zones	• Improved accessibility to loading zones through increased efficiency and turnover • Improved trip planning and delivery efficiency • Reduction in double parked or circulating delivery vehicles	Sylvia Park Shopping Centre

Unpredictable journey times due to congestion are a network wide problem for Auckland. This has significant consequences for the movement of urban freight as well as general traffic. While ITS has a role in improving network performance, this research suggests technology will not provide a 'silver bullet' to resolving the high degree of network wide congestion being experienced in Auckland. ITS can improve the delivery of advanced traveller and network information, freight priority and monitoring overall network performance using available datasets, and is an important part of a wider urban freight and indeed general traffic management strategy.

Abstract

The advance of technology has created several rich sources of data to analyse road network performance and freight patterns. New technology is also driving intelligent transport systems (ITS) designed to improve transport operations. This research used Auckland as a case study to explore how existing and real-time data sources could be used to manage network performance and improve journey predictability for urban freight using ITS solutions.

Drawing on previous research and a wide range of international literature and case studies, the report presents an overview of the role of ITS and the innovative ways technology is being applied to measure congestion and manage infrastructure more effectively.

Extensive industry stakeholder engagement revealed a high level of frustration and urgency to find solutions to improve network efficiency and an acknowledgement of the role of technology alongside infrastructure and regulatory measures to support efficient urban freight movement.

This report proposes five case studies to demonstrate the application of technological solutions to manage and improve network performance with regard to network efficiency, network optimisation and improved journey predictability for urban freight in Auckland.

1 Introduction

Abley Transportation Consultants, supported by Richard Paling Consulting Limited, were engaged to determine how a range of different datasets and technology could be applied to monitor urban freight flows, identify movement impediments and manage network performance to improve journey predictability for urban freight.

The objectives of this research were to:

- review the availability, and current applications of digital data for road network monitoring in New Zealand and overseas
- conduct an assessment of the usefulness of the data for identifying and providing solutions to network bottlenecks and improving journey predictability for urban freight movements
- identify the major freight flow problems and bottlenecks in Auckland and demonstrate their impact using geospatial data
- examine any available case studies to evaluate current best practice use of technology to measure urban freight movements and assess the solutions, including intelligent transport systems (ITS) solutions that are being used internationally to identify problems and bottlenecks
- identify potential synergies with other research and ITS initiatives including best practice already being used in New Zealand
- encourage industry involvement with the topic area through stakeholder engagement
- develop possible solutions including innovative and 'thinking outside the box' options in addition to the more traditional ITS-based approaches
- identify the most useful solutions to achieve greater network efficiency and freight journey time predictability in the short to medium term
- consider the high-level benefits and costs of potential solutions including documentation of the limitations, considerations and trade-offs in implementing each potential solution.

This aligns with the New Zealand Government's *Intelligent transport systems technology action plan 2014–2018* (MoT 2014) which emphasises the Government's aspiration for the use of ITS technologies to increase freight productivity in New Zealand.

The research underpinning this report was undertaken during 2016/17 and involved seven phases of work, starting from an initial technology and literature review and finishing with the analysis of potential solutions. This report therefore presents both an overview of the research process as it was developed, and the outputs and conclusions that were generated.

1.1 Report structure

The report is organised as follows:

- Chapter 2 provides a brief overview of the strategic direction of freight in New Zealand.
- Chapter 3 presents the findings of a review of international literature on current use of technology to measure urban freight movements, including the application of ITS to identify problems and relieve bottlenecks on transport networks.

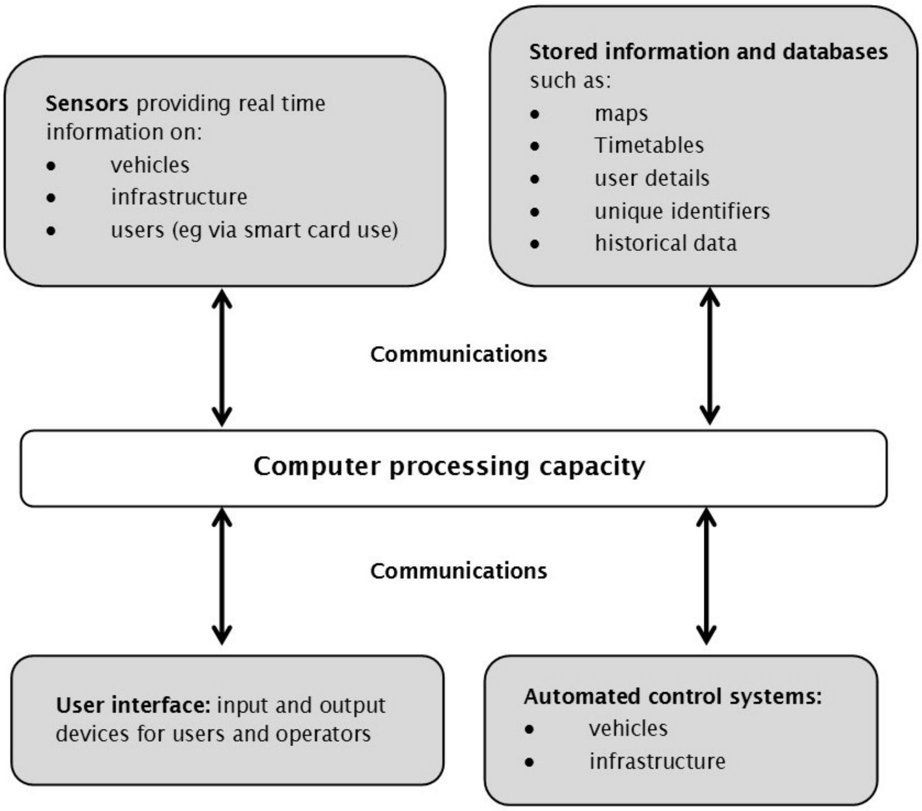
- Chapter 4 provides a summary of key existing New Zealand data sources.
- Chapter 5 summarises feedback from engagement with transport industry stakeholders.
- Chapter 6 details the most useful data sources available to demonstrate the extent and location of congestion on the Auckland network.
- Chapter 7 discusses potential ITS applications of technology to improve urban freight movements
- Chapter 8 describes the application of technological solutions to improve the movement of freight in five Auckland case studies.
- Chapter 9 presents a summary of research outcomes.

1.2 Intelligent transport systems

The term 'intelligent transport systems' has evolved from telematics, the integrated use of telecommunications and informatics. The origin of ITS stems from the use of emerging technologies in a variety of practical applications. ITS apply modern computing processing capabilities and modern advances in technology (such as automated control systems, sensors, transportation databases and other input/output devices) to help solve transportation problems, as shown schematically in figure 1.1 (adapted from MoT 2013). ITS support the better utilisation of existing road network assets. Hence, ITS can be a cost-effective approach to monitoring, understanding and managing transportation problems (Smith et al 2014).

Digital data to support ITS is collected by a range of technologies including in-road traffic detectors, global positioning system (GPS) and Bluetooth. As well as data collection, ITS incorporate the provision of timely travel information to transport authorities to support network management, and to road users though media such as variable messaging signs (VMS), web-based services and in-vehicle communication systems. Wider benefits of ITS include economic, safety and environmental benefits and improvements in travel experience though reduced congestion, improved road safety and reduced fuel consumption.

Figure 1.1 Components of a typical intelligent transport system



1.3 Urban freight

Urban freight refers to the movement of freight vehicles whose primary purpose is to carry goods into, out of and within urban areas and are critical to the basic functioning of a city. Urban freight distribution is very diverse and has a significant impact on the economic, commercial, social and environmental operation of a city. This creates a need to identify the most suitable types of vehicles for urban freight or last mile deliveries. Servicing the requirements of a city encompasses a wide range of urban freight activities including:

- the strategic movement of inter- and intra-regional freight
- consumer goods including e-commerce
- inputs and outputs from manufacturing processes
- courier and postal services
- construction/building materials
- waste
- hospitality.

Auckland is a key centre managing the distribution, collection and through movement of freight on its road network. Urban freight movements incorporate Auckland Port and MetroPort's substantial role in the export of primary products as well as a significant number of through trips to Northland and other provincial freight trip generators.

Each of these urban freight activities has quite different characteristics including utilising different size vehicles, and different delivery patterns, frequency, times of day and spatial coverage (Taylor nd). In addition, city residents and administrators are also key stakeholders in the city's freight transport movements. Balancing the different demands, interactions and points of view of each of these groups increases the complexity of finding solutions to manage urban freight efficiency and journey time predictability (Faccio and Gamberi 2015).

The demand for freight transport is largely determined by the private sector and is highly competitive. This sector is also growing at an exponential rate largely as a result of changes to society purchasing patterns including embracing e-commerce, just-in-time manufacturing and technology advancement (Taylor nd).

While urban freight has an important function to support the economic well-being of a city, there are a number of associated negative effects including congestion, air quality, greenhouse gas emission, noise pollution, safety and intimidation (MDS Transmodal Limited 2012).

This research focused on identifying the impacts of congestion on and accessibility for urban freight movements in Auckland City, New Zealand and the role of technology to manage network performance and journey reliability.

2 New Zealand strategic context

The Ministry of Transport (MoT) and NZ Transport Agency (the Transport Agency) set the national strategic direction for road transport in New Zealand. The primary drivers for both organisations are to improve the performance for all users of the transport network, including freight, and deliver value for money from transport investment by the government. Both MoT and the Transport Agency acknowledge the role of ITS technologies to support their strategic objectives (MoT 2014; NZ Transport Agency 2014).

2.1 Strategic direction for freight in Auckland

In Auckland, the issues and policy direction for regional freight movements are captured in the *Auckland regional land transport plan 2015–2025* (Auckland Transport 2015), *Auckland integrated transport programme* (Auckland Transport 2013) and are supported through initiatives such as the *Upper North Island freight accord* (NZ Transport Agency 2015).

Across all these strategic documents, the key priorities that have an impact on urban freight reliability can be summarised as:

- reducing congestion, especially on key freight links
- demand management, including ‘just in time at port’ (smart logistics), and engaging with the freight industry to improve efficiency
- investment in public transport, walking and cycling networks to free up road space for freight traffic
- increasing the productivity of arterial roads by prioritising public transport, freight and high-occupancy vehicles.

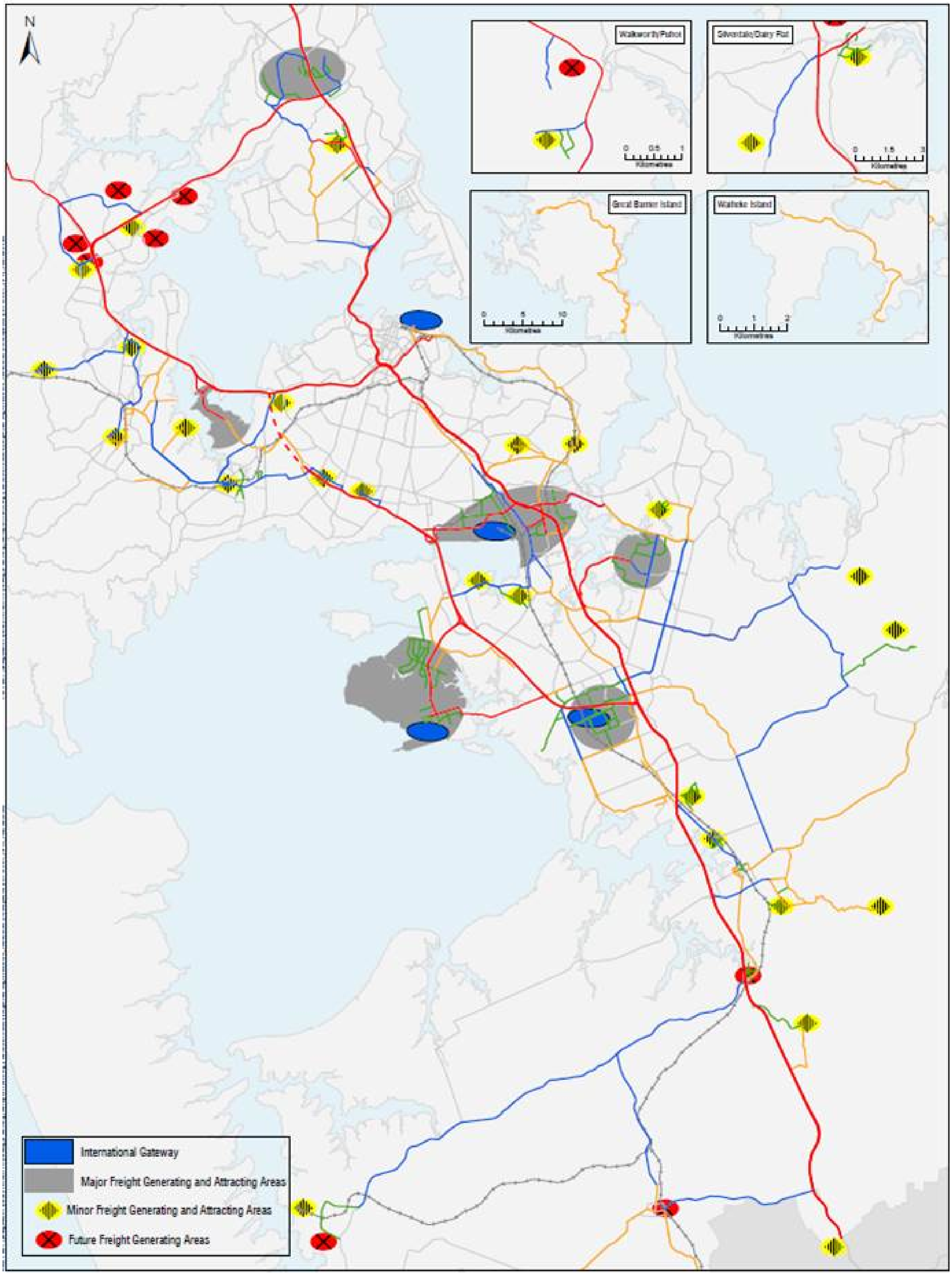
Auckland Transport has also developed a regional freight network to help in the planning of strategic freight initiatives shown in figure 2.1 (Auckland Transport 2015). The three levels of the freight network are:

- level 1 – important for the strategic movement of inter- and intra-regional freight
- level 2 – intended primarily to serve freight movements in areas such as industrial parks
- level 3 – freight has no specific priority but requires active management.

The key challenges in delivering this freight network include balancing the needs of the freight industry with those of other road users on prioritised roads, aligning improvements to the network with business developments, and managing growing congestion (Auckland Transport 2013). It is also important to ensure the identification and implementation of technology solutions to improve the movement of freight around the region support the freight network hierarchy.

Auckland Transport’s Integrated Transport Programme emphasises the requirement to actively manage and optimise the Auckland network using a One System approach to achieve the optimal movement of both people and goods safely and efficiently (Auckland Transport 2013). Two key priorities for transport in the Auckland plan include encouraging a shift to public transport to manage congestion problems, accommodating future business and population growth, and integrating transport planning and investment with land use to give emphasis to freight movements on Auckland’s transport corridors. Network operating plans (NOPs) are a mechanism within the One System approach to understand network users’ priorities in more detail. NOPs allow the movement and functions of the network to be balanced and prioritised by time of day, mode and location. This may require careful choices and trade-offs to achieve balanced outcomes (Auckland Transport 2013).

Figure 2.1 Auckland regional freight network (sourced from Auckland Transport 2015)



3 Literature review

The literature review centres on identifying similar research and learnings, and current best practice use of technology to measure and support urban freight movements. This includes the application of international ITS to identify problems and relieve bottlenecks on transport networks. A comprehensive review of New Zealand and international literature was undertaken and a wealth of information and resources gathered.

Changes in urban freight movements as a result of technology, societal change and the growth of e-business impact on how urban transport and network efficiency are managed. There is significant effort being placed on solving urban freight problems; however; a major obstacle is the lack of specific data on urban freight and the poor integration of data collection systems (Dablanc et al 2013). Strategies are largely being driven by regulatory measures recognising the importance of freight movements both strategically and environmentally. Clear direction on transport policy approaches such as the European Commission's aim to achieve CO_2-free city logistics in major urban centres by 2030 is a relevant example (MDS Transmodal Limited 2012).

Section 3.1 of this chapter presents an overview of existing New Zealand research aligning with this project. Section 3.2 presents urban freight management and section 3.3 network performance concepts, while sections 3.4 to 3.7 review ITS applications and supporting initiatives in Australasia, Asia, UK/Europe and the USA.

Appendix A contains a summary of literature resources grouped broadly by geographical region (Australia/New Zealand, Asia, Europe and the USA). The table was developed to enable readers to quickly determine the relevant information including key information parameters, from each literature source.

3.1 Synergies with existing New Zealand research

A review of existing NZ Transport Agency published research reports has been undertaken to determine alignment and synergies with previous research. Table 3.1 outlines the research reports examined and how the previous research learnings and recommendations may be able to contribute to understanding how existing and real-time data may be used to manage network performance and improve urban freight movement.

Previous research has focused on either understanding and improving how the freight sector can operate more efficiently as a whole or using data from emerging technologies to improve the functionality of transport networks. Specifically isolating bottlenecks and congestion that impede efficient urban freight movements has not been considered.

A common conclusion from previous research undertaken is the importance of system integration.

In 2013 the Ministry of Transport and AraFlow Ltd initiated an ITS trial focusing on freight movements along SH2 between Tauranga and Auckland. The trial investigated whether using Bluetooth technology to provide accurate real-time information to commercial transport operators would improve their productivity. The first two phases of the ITS trial, installing Bluetooth monitoring sensors along the routes and the development of a web-based tool providing travel times and congestion levels on the routes were completed successfully. AraFlow was also able to demonstrate the operation of their C-ITS communication devices in controlled tests. The trial did not continue due to an inability to recruit willing test vehicles for the operational stage of the trial. Operators expressed satisfaction with the existing supply of information and felt any additional data would be of limited practical use. Safety concerns were also raised along with concerns that the technology would be used for enforcement purposes (MoT 2015).

Table 3.1 Summary of previous NZ Transport Agency research

Research	Date	Title	Research summary and outcomes	Relevance
RR592	2016	Measuring the value of the movement of people and goods to inform the One Network Road Classification functional categories criteria.	This research develops measurable criteria for the economic value of the movement of people and goods for use in the One Network Road Classification and contributes to the development of a performance measurement framework. The research explored productivity indicators for roads, based on the output roads support and the input costs of roads. Four indicators, namely public transport productivity, total passenger productivity, commute productivity and freight productivity were developed. Estimates of the productivity of roads, enables a stronger correlation with performance measures.	Low
RR584	2016	Considering a cost-benefit analysis framework for intelligent transport systems.	The objective of this research was to explore the full range of common ITS project benefits and assess if they could be evaluated using the existing NZ Transport Agency (2016) *Economic evaluation manual* (EEM) procedures. The research confirmed there are major gaps in existing ITS evaluation methodologies and further work into these areas is recommended.	High
RR559	2014	Identifying the uses of emerging sources of digital data to assess the efficiency of the state highway network (Smith et al 2014).	The research assessed the potential use of emerging digital technologies and data sources within the context of ITS for monitoring the performance of the New Zealand state highway. A GIS-based proof of concept model was developed to demonstrate how GPS and Bluetooth data could be processed to generate of a number of network performance indicators covering private and public transport modes, safety, environment, activity and cost. The framework and web viewer provide a starting point for a national-level state highway performance monitoring portal. Recommendations for further research focus on the investigation of data quality, sensitivity, retention and storage to enable long-term trending suitable for supporting business decision making.	High
RR549	2014	Operating characteristics and economic evaluation of 2 + 1 lanes with or without ITS-assisted merging (Kirby et al 2014).	The focus of the research was on the development, implementation and measurement of safe and robust design principles and techniques for the operation of 2+1 passing facilities on New Zealand's highways. Extensive modelling was used to assess a range of ITS-assisted merge concepts to test flow rates, optimal length and spacing combinations for a given terrain and heavy commercial vehicle (HCV) composition.	Medium
RR548	2014	Literature review of the costs and benefits of traveller information projects (Raine et al 2014).	The objective of this research was to fill the knowledge gap in the field of traveller information systems (TIS) by providing detailed information on the costs and direct and indirect benefits associated with the use of TIS. Key outcomes included the importance of journey time reliability to travellers and the ability of TIS to influence this. A method to quantify journey time reliability is yet to be established. Vehicle to vehicle communication is recognised as an emerging technology with the ability to significantly impact on the delivery of TIS. Trials are currently being undertaken in New Zealand by the Transport Agency.	Medium
RR542	2014	Ongoing domestic freight volume information study. (Paling et al 2014).	This study considered how MoT's National Freight Demand Study 2008 (Paling et al 2014) could be updated by assessing how freight data is currently collected internationally and identifies possible data collection methods for the future. A framework has been identified for the desired data collection covering commodities, modes and origins and destinations. It emphases the need for a hybrid approach and any form of data collection should be voluntary. The research concludes there is unlikely to be any simple process that allows the national patterns of freight movement to be generated automatically.	Low – Med

3.2 Urban freight management

Freight movement is essential to the function of metropolitan areas, yet commercial traffic generates significant externalities, including congestion, air pollution, noise and traffic incidents as well as additional demands for increased road capacity. Urban freight management strategies provide a foundation to manage urban freight and offer practical tools to solve the basic problem of managing freight traffic in urban areas. Strategies generally fit into three categories, 'last-mile/first-mile' deliveries and pick-ups, environmental mitigations and trade hub strategies (Dablanc et al 2013).

The last-mile/first-mile effect is a term that has migrated from the business-to-customer logistics and telecommunications industries into transport planning and refers to the last-mile leading to a destination (Gronau and Kagermeier 2007). Originally referring to the distance to bridge from an exchange, which was approximately one mile, the term is used more generically to mean the delivery and collection leg of a goods journey which in Auckland may be several kilometres.

The use of technology to improve urban freight movements is one last mile/first mile urban freight management strategy. Additional last mile/first mile urban freight management strategies include:

- regulatory measures – access and parking restrictions, time windows and loading zones
- urban consolidation centres
- off hour deliveries
- certification schemes
- technical or best practice strategies
- loading zone occupancy detection
- future variable pricing for road user charging.

The importance and challenges of the first mile–last mile part of the journey is acknowledged in the *Auckland regional land transport plan 2015–2025* (Auckland Transport 2015).

3.3 Network performance concepts

3.3.1 Congestion and accessibility

Congestion results in unstable traffic flow and can significantly impair the efficiency and performance of transport systems. Congestion is a condition of travel delay and is generally characterised by (Wright et al 2006):

- slower speeds
- longer journey times
- increased queuing at intersections or bottlenecks
- increased stopping and starting
- less predictable journey times.

Congestion is either recurring, or unplanned. Recurring congestion is caused by:

- unexpected vehicle movements such as braking, last-minute lane changing or lane weaving

- traffic usage exceeding the design capacity of the corridor
- high volumes of traffic entering the main flow
- exit ramp queues extending back into traffic flow
- geometric features such as merges, tight curves or width restrictions.

Non-recurring congestion is brought about by unplanned incidents such as crashes, breakdowns, extreme weather conditions, road works and special events (Wright et al 2006).

Accessibility is fundamental to the efficient transporting of goods into and out of urban environments as well as within cities (Kaszubowski 2012). Traffic congestion, bottlenecks, scarcity of loading and unloading zones in city centres and sub-optimal delivery routes negatively impact on the accessibility and efficiency of urban freight. Congestion also reduces the ‘agglomeration economies’ of businesses operating in urban areas, thus raising their production costs (Weisbrod et al 2014). These additional costs for trucks are passed on to consumers in the form of higher prices in goods, which is a fundamental difference to the costs associated with congestion for private motor vehicles (Schrank et al 2012).

To develop an assessment of possible congestion relief solutions there are several economic impacts that need to be considered:

- travel cost – value of time, travel time reliability factors, additional distance travelled, vehicle operating costs and congestion-related crash costs
- additional business operating costs – inventory costs from spoilt goods, logistics costs, reliability costs and just-in-time processing costs.

ITS solutions are seen as strategic measures for increasing the efficiency of network performance and drastically reducing congestion and energy consumption (Weisbrod et al 2014).

3.3.2 Network intelligence

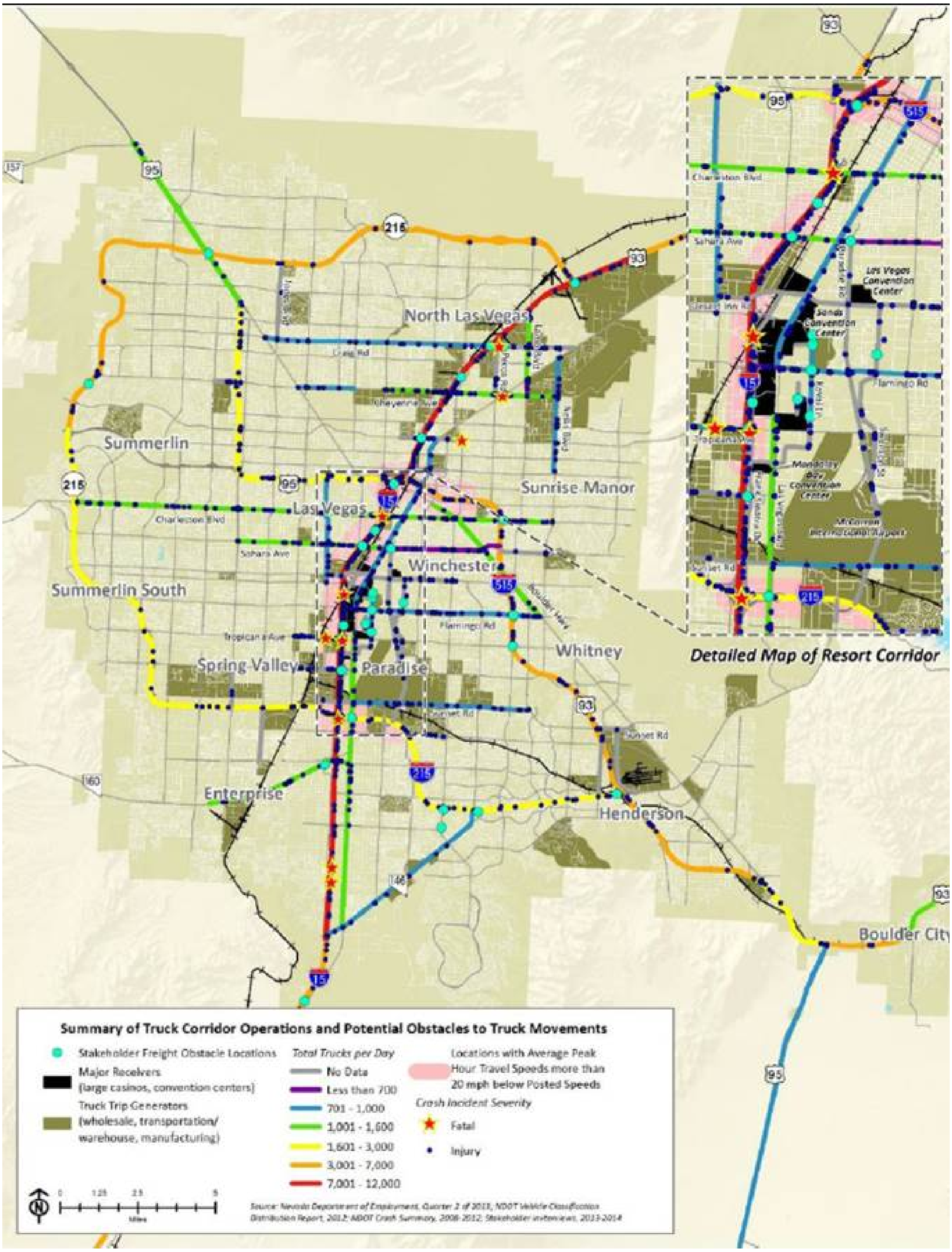
Arterial roads, freeways and local roads are complementary components of a transport system that are often poorly utilised as a whole, as they tend to be managed as separate entities resulting in under-utilisation and inefficiencies (Wright et al 2006). A network intelligence system collates comprehensive real-time data and aggregates and transforms this data into meaningful real-time and predictive content to manage travel times, delays, alternative routes, and warnings of problems and suggest responses to unusual traffic circumstances. This facilitates an integrated approach to network management that provides better information to road users and funding decision makers.

3.3.3 Identifying bottlenecks

A bottleneck is any point on the network where upstream a queue has formed, and downstream the traffic flows freely (Bertini et al 2012). Understanding travel behaviour where and when bottlenecks occur provides a foundation from which corridor and network functionality can be measured and managed.

Through analysis of data and interviews with private sector freight industry representatives, a series of freight obstacles were specifically identified in the Las Vegas metropolitan area (Xie and Anderson 2015). The information gathered through stakeholder participation combined with data from obstacle-related datasets (eg crashes, low travel speeds, truck volumes) was used by The Regional Transportation Commission of Southern Nevada to qualitatively assess freight obstacle locations as shown in figure 3.1.

Figure 3.1 Freight obstacle summary data



3.4 Freight ITS applications in Australasia

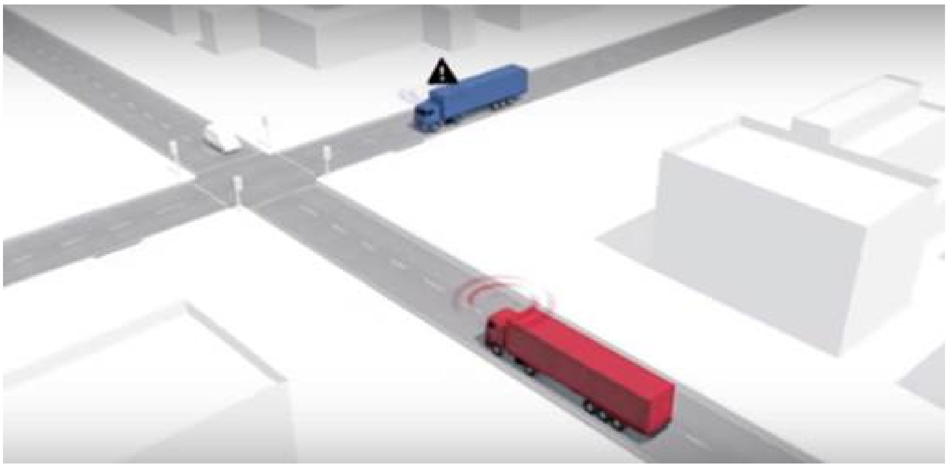
ITS offers a range of applications that can improve the overall efficiency of urban freight movements including access control and privileges, dynamic routing, lane sharing, delivery space availability and information about traffic and infrastructure condition. Some of the current international initiatives are described in the following sections, which are organised by geographic area.

3.4.1 Cooperative intelligent transport systems (CITS)

The Illawarra region in New South Wales, Australia, is currently the test bed for the only large-scale cooperative intelligent transport initiative (CITI) dedicated to heavy vehicles in the world. The pilot deployment area covers more than 2,300km of road network spanning both urban and rural areas. CITI uses vehicle-to-vehicle and vehicle-to-infrastructure communication in the 5.9GHz band of radio spectrum to allow drivers to receive safety and hazard messages (shown conceptually in figure 3.2) such as:

- intersection collision warning
- forward collision warning
- heavy braking ahead warning
- traffic signal phase information
- speed limit information.

Figure 3.2 Example of CITS intersection warning to vehicle



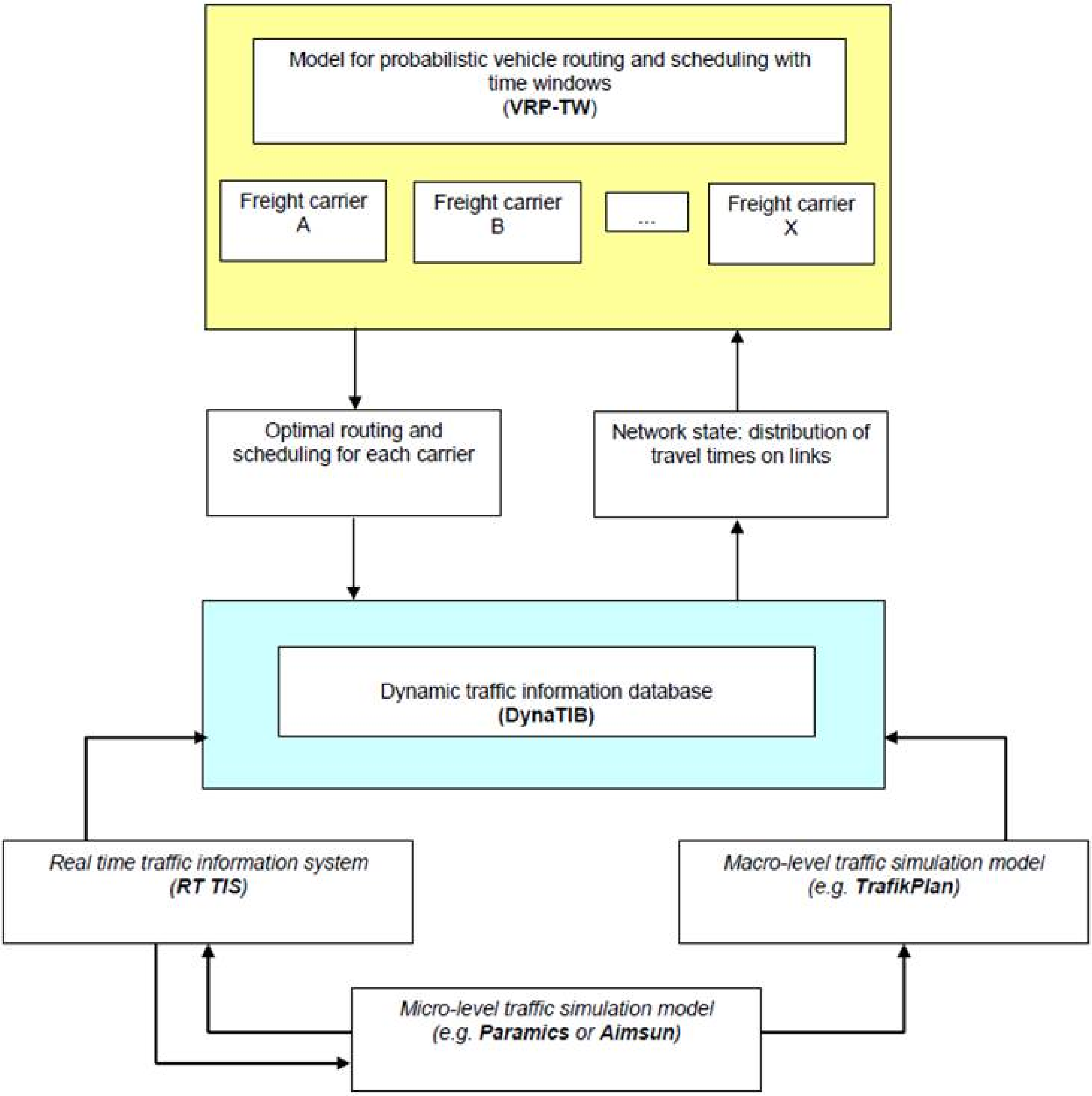
All data from CITI is being collected and analysed to improve road safety and enable driverless vehicles of the future to talk to each other (Transport for New South Wales 2016).

At the time of writing another trial focusing on urban traffic congestion is underway in Sydney, New South Wales. Cooperative intelligent transport system (CITS) technology will be fitted to 110 trucks and facilitate open communication between truck and infrastructure on key freight corridors. The trial aims to smooth the flow of traffic by allowing trucks to receive more green lights, reducing the number of times a truck needs to stop at traffic lights throughout the day (Australian Transport News 2016).

3.4.1.1 City logistics system

Urban freight transport and goods distribution has a significant impact on the economic, commercial, social and environmental operation of our cities. Through simulation modelling the city logistics system study uses dynamic management and operations of urban freight transport and distribution systems to optimise the performance of urban freight systems to meet both the objectives of freight operators, their customers and the community (Taylor nd). An example of such a framework is shown in figure 3.3.

Figure 3.3 Example of integration framework



3.5 Freight ITS applications in UK/Europe

The primary objectives of sustainable city logistics in Europe are to decarbonise freight transport while maintaining its competitiveness and economic strength, reduce negative externalities such as pollution, congestion and crashes, and foster innovation (Ruesch et al 2015). Sustainable urban mobility plans guide these objectives and the European Commission (2013) acknowledges ITS is a core element to solving the complexities of urban mobility. The effectiveness of ITS tools and applications is well recognised; however, fragmentation remains an issue that needs to be managed through collaboration and increasing the interoperability of solutions.

Multiple European initiatives have commenced to achieve these objectives using a bundle of strategies including ITS technology.

3.5.1 Cooperative intelligent transport systems

Information and communication technologies offer new solutions for transport problems. In CITS, vehicles communicate with each other and with roadside infrastructure, and data is shared between different applications both inside the same ITS station and across several ITS stations.

FREILOT is a large European project developing and testing new automotive and traffic technologies to reduce fuel usage and CO_2 emissions by freight vehicles in urban areas (Driven 2016). The technology provides communication between traffic lights and vehicles with 'in cab' driver advices to achieve benefits in four areas:

- improved traffic flow –traffic lights technology recognises trucks and gives them priority resulting in better traffic flow
- eco driving support for drivers – the in-truck technology gives advice on speed and indicates when to shift up or down in order to save energy
- enhancing safety through acceleration and adaptive speed limits
- real-time remote loading/delivery space booking – saves time and eliminates double parking and bottlenecks.

Helmond (Netherlands) is in the front line for the delivery of CITS and smart mobility. As one of the pilot cities for the European FREILOT project and Compass4D, 14 intersections in Helmond have been equipped with CITS roadside units to enable communication with the on-board units of local logistic trucks. Advice to drivers of speed and time-to-green enables trucks to get a level of priority at intersections that has facilitated a 13% reduction in fuel savings and CO_2 emissions (Lozzi 2016).

CO-GISTICS is a consortium of 33 state and private organisations dedicated to the deployment of CITS in at least 315 trucks and vans across seven European logistics hubs: Arad (Romania), Bordeaux (France), Bilbao (Spain), Frankfurt (Germany), Thessaloniki (Greece), Trieste (Italy) and Vigo (Spain) (CO-GISTICS nd).

Recognising the value of integrating existing freight and transport systems with new solutions, such as cooperative services and intelligent cargo, the seven pilot cities aim to make the operation of freight, trucks, roads, harbours, airports and rail terminals more efficient and sustainable. CO-GISTICS have deployed five services to achieve this:

1 Intelligent truck parking and delivery areas management: optimising vehicle stops en route, the delivery of goods in urban areas and the interface with other modes of transport

2 Cargo transport optimisation: supporting planning and synchronisation between different transport modes during logistic operations

3 CO_2 footprint monitoring and estimation: measuring CO_2 output of the vehicles and providing emission estimation of a specific cargo operation

4 Priority and speed advice: saving fuel consumption, reducing emissions and heavy vehicle presence in urban areas

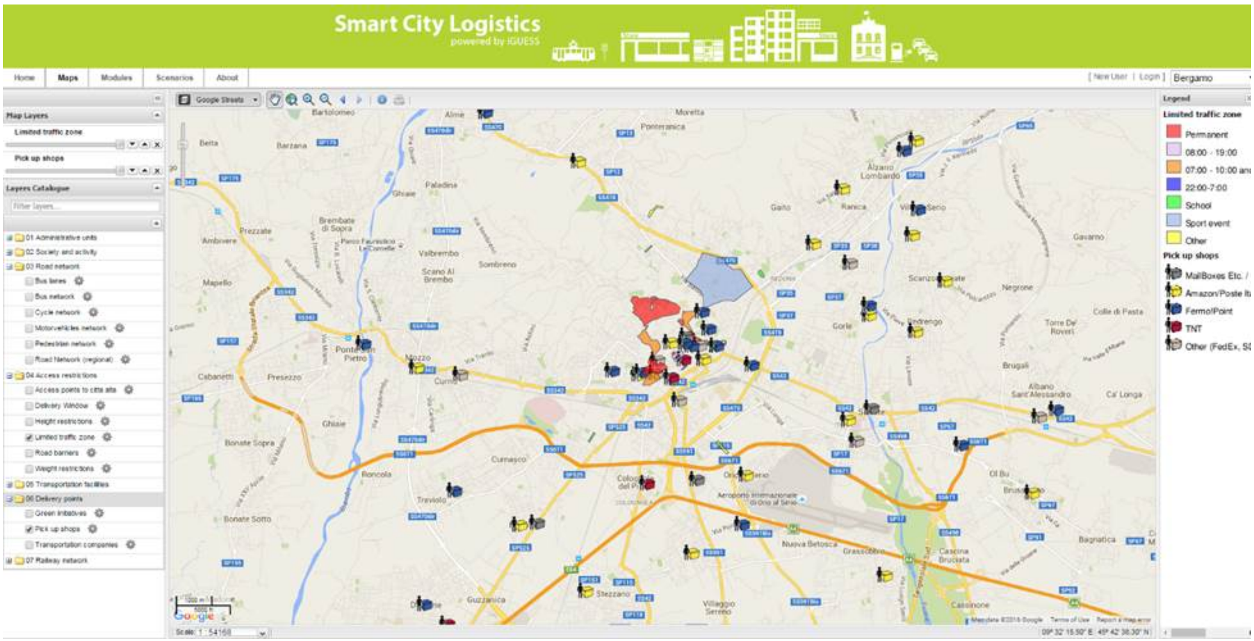
5 Eco drive support: supporting truck drivers to adopt a more energy efficient driving style to reduce fuel consumption and CO_2 emissions.

3.5.2 Last mile logistics

Last mile logistics (LaMiLo) aims to create a step change in freight deliveries by fully considering the 'last mile' of a supply chain when planning a freight logistics journey, ensuring a more efficient and integrated logistics approach throughout north-west Europe. Smart city logistics is a decision support mapping software tool that has been developed by the Luxembourg Institute of Science and Technology as part of the LaMiLo project (LAMILO 2014).

Smart city logistics (powered by iGUESS and shown in figure 3. 4) is an open source platform using GIS technology to map a range of useful datasets that provide information to minimise congestion, CO_2 and air and noise pollution for urban freight journeys. Data is currently available for London, Brussels and Luxembourg. The tool enables an integrated approach to be taken to find solutions for managing last mile logistics, including route planning that identifies the shortest path for a delivery vehicle taking into consideration parameters such as weight and access restrictions. It also allows different scenarios to be modelled to compare savings in terms of distance travelled, congestion and air pollution and explore options for suitable locations for logistics facilities such as urban consolidation centres.

Figure 3.4 Smart city logistics planning tool



3.5.3 Compass4D

Over a three-year period Compass4D installed equipment to operate CITS services in seven European cities: Bordeaux, Copenhagen, Helmond, Newcastle, Thessaloniki, Verona and Vigo. Compass4D focused on three services:

1 Red light violation warning – based on information exchanged via radio communication, the state of the intersection ahead is analysed and visual (and/or audio) warning messages are generated.

2 Road hazard warning – radio communication is used to alert vehicles in close proximity of an incident (static and dynamic) to avoid involvement in it and allow rerouting.

3 Energy efficient intersection – provides advice to drivers to optimise the way vehicles pass through the intersection.

These services have been implemented using dedicated short-range technology and cellular networks (3G/LTE) cooperating with standardisation organisations and global partners to achieve interoperability and future large-scale deployment. The success of this project over the initial three-year European Union co-funded period has seen it continued as a public–private partnership activity (www.compass4d.eu).

3.5.4 BESTFACT project

The objective of BESTFACT (Best Practice Factory in Freight Transport) is to develop, disseminate and enhance the utilisation of best practices and innovations contributing to meeting European urban freight transport policy objectives. BESTFACT focuses on the coordination and integration of information and solution in three areas: urban freight transport, green logistics and co-modality[1], and efreight (www.bestfact.net/).

The central aspect of BESTFACT is to identify and promote best practice. Best practice in this context is defined as an approach or solution that solves a relevant problem or challenge in freight transport and is characterised by four core attributes:

- innovation and feasibility
- addresses both business and policy strategic objectives
- delivers considerable and measurable positive impacts
- is transferable to other companies, initiatives or context.

This provides an assessment framework from which to measure the effectiveness of a solution.

The urban freight cluster provides a resource platform containing best practice handbooks, data collection and modelling approaches, policy and research recommendations and the quantification of urban freight transport effects.

3.5.5 Mobile supported traffic management system

ITS was implemented in Szczecin, Poland to increase the fluidity of traffic flow on the roads leading to the city. This was in the form of a traffic management system supported by a mobile application. The system consisted of application and execution elements, continuously monitoring traffic flows on the city bridges, and providing traffic and guidance information to roadside VMS displays and a mobile application. As all the city's freight trips must travel over one of the city's two bridges, the application allows freight vehicles to be directed to the less congested route. The use of a mobile application has supported the traffic management system in Szczecin and has had a significant positive impact. Emissions and fuel consumption have reduced by 23% and 2% respectively (this big difference is the result of the relatively small distance of the journeys over the bridges – about 3km), freight operating costs have fallen by 6%, and a 36% improvement in the freight vehicle flow has been achieved (Malecki et al 2014).

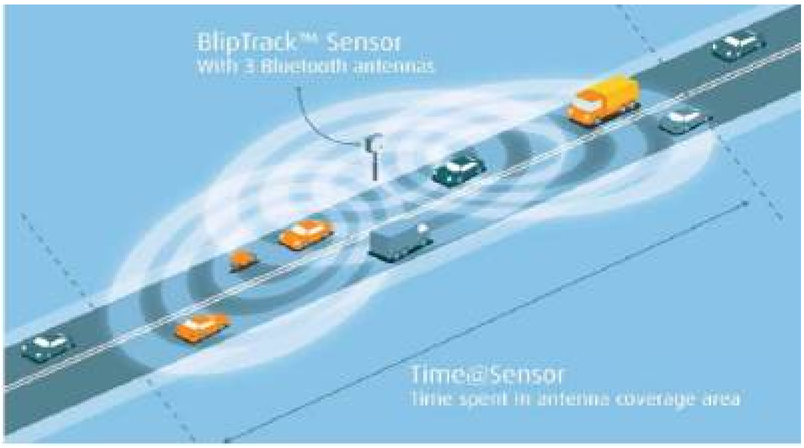
3.5.6 Bluetooth technology for congestion and queue technology

Araghi et al (2015) examined the feasibility of Bluetooth technology for detecting non-recurring congestion using a 'Time@Sensor' parameter depicted in figures 3.5 and 3.6 at each monitoring station for identifying congested points and queue estimation. Time@Sensor uses the entry and exit times of a

[1] Co-modality is a notion introduced by the European commission in 2006 in the field of the transport policy to define an approach of the globality of the transport modes and of their combinations. Co-modality refers to a use of different modes on their own and in combination to obtain an optimal and sustainable utilisation of resources.

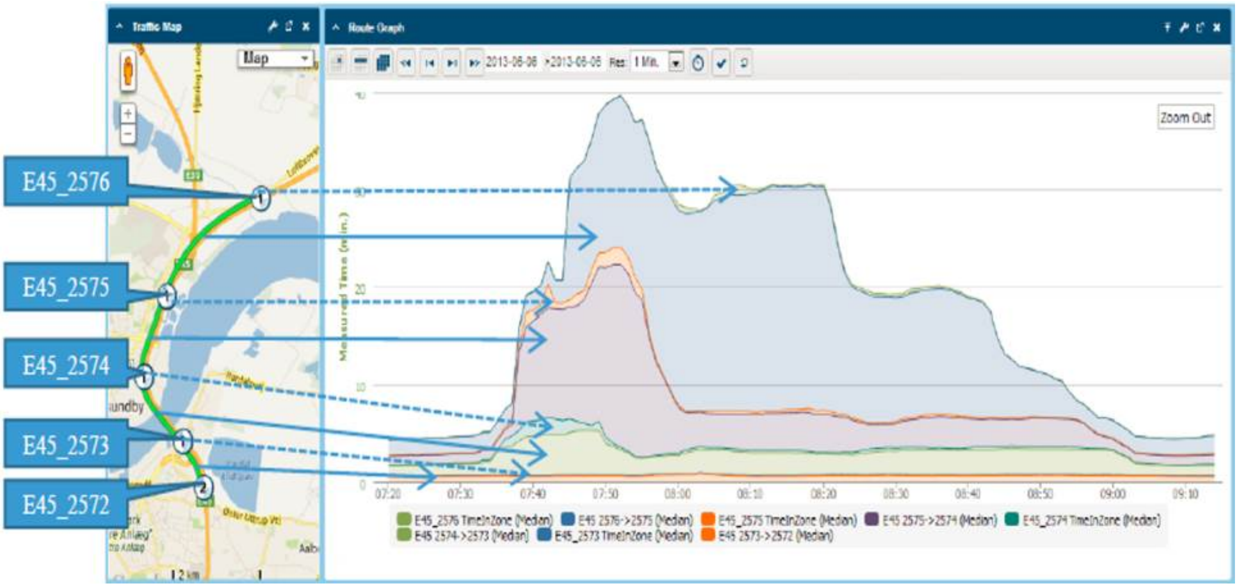
sensor detection zone to measure the duration the device was seen in the zone. This allows abnormal flow conditions to be detected.

Figure 3.5 Time@Sensor parameter



The increasing number of Bluetooth enabled devices provides the opportunity to utilise the media access control address-based tracking to estimate travel time and detect traffic incidents in real time without any additional cost to ITS infrastructure. Araghi et al (2015) tested the methodology on a corridor in Denmark and the incident report, paired with the Time@Sensor and travel time profiles proved the feasibility and accuracy of Bluetooth application for incident detection and clearance time estimation.

Figure 3.6 Stacked travel time and Time@Sensor profiles example



Auckland Transport is currently undertaking trials in expanding insight Bluetooth technology onto 15 key strategic routes to measure and analyse congestion before and after the Waterview tunnel.

3.6 Freight ITS applications in Asia

3.6.1 Sensing-based urban freight data collection framework

At the time of writing an integrated framework for urban freight data collection is under development at a test site in Singapore (Teo et al 2015). Teo et al (2015) propose freight data collection effort leverage GPS loggers, advanced sensing and communication technologies and machine learning architecture to deliver data that reflects observed rather than stated information on the decisions of the freight sector. The general structure of the framework embeds:

- sensing devices for tracking shipments, vehicles and driver behaviour
- a backend server database which collects and processes collected data
- web-based and tablet-based reporting and surveying tools.

The project is in its implementation stage, and promising results have already been achieved. In particular, by cost effectively collecting a wealth of valuable information, it is possible to achieve better quality and quantity data that can enable public and private sector decision makers to address issues related to road space allocation, congestion, energy consumption, environment and safety (Teo et al 2015).

3.7 Freight ITS applications in USA

3.7.1 Dynamic mobility applications

The advance of technology suggests future vehicles and the transport system will be able to communicate wirelessly to share safety, mobility and environmental information. The United States Department of Transportation (USDoT) dynamic mobility applications programme was begun in 2009 to utilise the increasing volume of data being generated within the transport system to improve mobility and efficiency. A number of innovative and transformative applications are being built to leverage connected vehicle data. One such application is freight advanced traveller information systems (FRATIS).

FRATIS is a package of applications aimed to improve the efficiency of freight operations using real-time traveller information, freight-specific dynamic travel planning and performance and drayage optimisation. Drayage is a common term in the US transport sector meaning the transporting of goods over a short distance via ground freight. The objective is to coordinate freight facilities to maximise loaded trips, minimise empty trips to guide adaptive and effective decision making.

The FRATIS package integrates five technologies as follows:

1 Intermodal exchange – data sharing capability

2 Wireless drayage updating – sending information directly to the user through smartphones and tablets

3 Real-time traffic monitoring – bringing together and sharing information from traffic management centres and third parties

4 Dynamic route guidance – provides operators moving through the network with the most efficient route considering current traffic and weather conditions, route restrictions, bridge heights and truck parking availability

5 Freight terminal wait time – measures queues at intermodal facilities and communicates to carriers to facilitate optimal time and resource management.

FRATIS application prototypes have been built and at the time of writing are being demonstrated in three US locations. Los Angeles-Gateway Region is using FRATIS applications to address the dynamic travel planning algorithm around the marine terminals and queues to move cargo out of the port more efficiently. In Dallas–Fort Worth, FRATIS applications to incorporate integrated corridor management capability and drayage opportunities are being tested, and South Florida has an added emergency response capability to FRATIS to test the use of freight transportation to bring supplies during an emergency (USDoT 2015).

3.7.2 Wireless roadside inspection

The wireless roadside inspection project is evaluating the viability of using wireless capabilities to provide real-time identification and status information about vehicles, drivers and carriers. A trial commencing in December 2015 involved fitting 1,000 trucks with commercial mobile radio service technologies. The trucks were inspected wirelessly as they came within range of current fixed and temporary inspection sites across the south-eastern United States. End-to-end telematics detected the vehicles approaching a geo-fenced inspection site and transmitted the inspection data to the government system in real time (Heavy Duty Trucking 2014).

3.7.3 Freight plans

The US 'Moving Ahead for Progress in the 21st Century Act' (MAP-21) was enacted in 2012 to provide funds and a framework to guide the growth and development of transportation infrastructure. Special emphasis was given to state and local freight plans to guide investment. Freight plans address freight transport issues and provide the foundation for freight priority projects including the use of technology to optimise the efficiency and capacity of the freight transportation system.

Freight plans require analysis of three key areas – economic development, freight flows and infrastructure from which objectives can be set. Stakeholders play a key part in identifying the challenges unique to each of these areas for the environment to be assessed. Key considerations to address include:

- How is the economy changing?
- What are the 'challenges' and who owns them?
- Why is congestion occurring? Is it due to freight trucks moving through the city, parking issues or signal timing?

USDoT FHA (2013) identified inefficiencies of curb-side parking to be contributing to congestion. The Downtown Curb-Space management plan developed a range of technological and other initiatives to address this inefficiency:

- reallocation of existing curb-side through regulatory signage
- loading zones extended and commercial loading zones moved to the approach end of a block to make access easier and reduce double parking
- prepaid commercial vehicle permits to use curb-side loading zones
- interactive truck parking map to pre-plan parking trip – advises where spaces are located and their size
- loading zone sensors to show availability of space in real time
- multi-space meters

- variable use of parking areas in which individual spots can serve as both loading zones and metered spaces at different times of the day
- enhanced enforcement.

3.7.4 Freight performance measurement

Understanding how supply chains perform from the perspective of the freight sector is critical to assessing freight system performance, and determining if and where public investment might improve freight system performance and support economic competitiveness and growth (Grenzeback et al 2016). The I–95 corridor coalition study of five supply chains (Grenzeback et al 2016) demonstrated it is feasible and practical to measure high-level performance of supply chains. Travel time, travel time reliability and cost measures were established as the most accessible and common across supply chains for measuring performance.

Truck travel time and travel time reliability data in the US is available from an array of public and private sources:

- The National Performance Management Research Dataset is a repository of historical vehicle probe data. It provides information about travel speeds and travel times and is calculated at five-minute intervals, 24 hours daily for every day of the year.
- The Highway Performance Monitoring System provides information on truck volumes and pavement conditions.
- American Transportation Research Institute uses micro data to follow the paths of individual trucks, making routes selected and time of day visible.
- Vehicle probe data is available to purchase from INRIX, HERE and TomTom and can distinguish freight traffic from other types.
- The Texas Transportation Institute incorporates INRIX data to estimate travel time reliability through a Planning Time Index which provides a buffer factor.

Participants in the I–95 corridor coalition study (Grenzeback et al 2016) anticipated significant benefits from a systematic approach to measuring supply chain performance. These included identifying freight bottlenecks and the business affected by them, targeting investments strategically to directly link transportation improvements to supply chain improvements, and providing robust evidence to justify freight transport investment to the public.

The Federal Highway Administration (FHWA) has developed a guide (FHWA 2015) to provide best practice approaches to measuring freight performance and analysing truck freight bottlenecks in the US. The purpose of the guide is to assist analysts with identifying and analysing truck performance and bottlenecks and outlines any limitations of underlying data and methods identified. The bottleneck performance measures relate to congestion and reliability and propose a range of measures of:

- total delay
- travel times
- hours of congestion
- queue lengths
- costs.

At the time of writing, research by E-Squared Consulting Corporation is underway into the production of a primer on freight performance measures for the FHWA. It is understood two key outcomes are that freight specific data is hard to source and organisations have a variety of expectations and uses of performance measures. Measuring delay and congestion on the road for cars and trucks is relevant for some, while other organisations wish to understand delay at freight terminals or truck turn times. Others may place higher value on understanding travel time reliability and consistency (Easley pers comm, 19 April 2016).

3.7.5 Measuring bottlenecks

Road congestion imposes significant costs on the movement of people and goods. Chen (2003) developed an algorithm that uses loop detector data to locate active bottlenecks and estimate the delay impact. While the location of bottlenecks may be known, the algorithm can systematically locate all bottlenecks that satisfy a set of criteria based on speed differentials between upstream and downstream detector locations. Bertini et al (2012) tested this methodology using Oregon PORTAL[2] data and developed it further to implement automatic mechanisms capable of converting historical data into live displays and traveller information systems to inform where and when recurrent bottlenecks were likely to occur.

3.8 International case studies

The literature review is extended in appendix B with the addition of an overview of several international examples of the use of technology to improve freight movements. There are a number of projects worldwide exploring the capabilities of new and evolving technologies to improve the management of urban freight. Three examples of current initiatives have been provided, one from each of the USA, Europe and Australia.

The case studies are in some ways peripheral to the main research; however, they are included for learning purposes and to generate ideas for potential application in Auckland. While they will not be directly replicable, they provide a resource to develop a greater understanding of trials in the application of ITS technology.

3.9 Conclusion

The role of ITS and technology enables innovative ways of measuring congestion and managing existing infrastructure more effectively, and are an important part of a wider integrated urban freight management plan. The use of technology to improve urban freight movements is one of several last mile/first mile urban freight management strategies alongside regulatory measures, urban consolidation centres and off-hour deliveries.

A lack of reliable data collection, availability and system integration has been highlighted in a number of trials internationally. Working towards developing ITS that are inter-operative with evolving technology, compatible with commercial models and interoperable between cities will allow this technology to be used to its greatest advantage.

[2] Oregon's regional archive of freeway data from inductive loop detectors

4 ITS data in New Zealand

The Transport Agency builds, manages and operates New Zealand's state highway (SH) network, which is of national and strategic importance for keeping people and goods moving. The Transport Agency operates five traffic operation centres (TOCs), which are located at Smales Farm on Auckland's North Shore, Auckland's city waterfront, Johnsonville in Wellington and in central Christchurch. These centres play a vital role in enhancing day-to-day travel experiences by managing traffic and incidents on the road network, as well as port operations.

The Auckland TOC is a partnership with Auckland Transport and focuses on reducing Auckland's congestion issues on motorways and arterials by integrating region-wide traffic management. The Wellington TOC's principal aim is to provide timely and accurate traveller information using the Transport Agency's network of advanced traffic management systems and VMS across the lower North Island, and Christchurch TOC has similar responsibilities across the South Island.

The TOCs are working closely with the Transport Agency to develop advanced real-time traffic information systems to deliver journey time information along key arterial routes (Auckland Transport 2011). To provide timely and accurate information the TOCs gather data from different sources such as road sensors (including Sydney Coordinated Adaptive Traffic System (SCATS) and Bluetooth), GPS data, closed circuit television (CCTV) cameras supplemented by video analytics, fibre-optic technology, police incident reports and feedback received directly from contractors and the public. Other tools used by the TOCs include the coordination of traffic signals, VMS, the Traffic Road Environment Information System (TREIS), InfoConnect and the role of crowdsourcing information is also emerging.

4.1 Digital data collected in New Zealand

The research team reviewed the status of the New Zealand digital data marketplace to determine which technologies are currently being applied with a particular focus on Auckland, and documented the various applications of each at a high level, as presented in table 4.1. This builds upon a recent review undertaken by Smith et al (2014), which focused on emerging sources of digital data to measure network efficiency in the New Zealand market.

More details with an emphasis on available technologies and the extent to which they may provide a measure of congestion impeding the movement of freight within the Auckland road network are addressed in the following sections.

Table 4.1 Technology applications in Auckland city for traffic monitoring

Technology	Application and coverage
Bluetooth	Bluetooth sensors supply travel time data for the Transport Agency, MoT and local authorities. Bluetooth sensor networks are installed in most of New Zealand's largest cities including substantial coverage in Auckland.
Global navigation satellite systems (GNSS/GPS) data	GPS data is collected to provide near real-time information for transport managers and road users, and to monitor the performance of public transport services. This is available from a number of sources and is available nationwide. There may be a cost associated with obtaining this data.
Mobile	Mobile activity (calls, text messaging and data usage) data is collected nationwide, but is not currently used for traffic management or monitoring purposes. This is an emerging area that the Transport Agency and local authorities are investigating and developing. The Transport Agency has a national licence for Google travel time data.

Technology	Application and coverage
Weigh-in-motion	Vehicle count and weight data by axle is collected at eight locations on the SH network (Auckland, Waikato, Bay of Plenty, Gisborne, Hawkes Bay and Canterbury). In Auckland, there are two sites: Auckland Harbour Bridge which is coupled with automatic number plate recognition (ANPR) technology, and Drury.
ANPR	ANPR uses cameras to recognise number plates from which vehicles can be identified. ANPR cameras aid in the assessment of volumes and route utilisation as well as revenue collection.
Fibre Optic	Fibre for traffic monitoring purposes is installed along SH 1 in Auckland terminating at the Auckland Harbour Bridge with a total length of 40–50km available. Applications and technology to collect and analyse fibre optic data for traffic monitoring are emerging.
CCTV	CCTV cameras are routinely installed in urban environments at intersections and other locations throughout New Zealand for traffic monitoring, security and other purposes. There are over 1600 cameras installed and linked to a video management system that uses video analytics technology for monitoring purposes.
Traffic counts	The Transport Agency and local authorities maintain regular traffic count programmes through using loop and tube counters which can produce classified vehicle counts and speed profiles.
SCATS	Traffic signals in most urban areas in New Zealand are managed through SCATS, which is a source of traffic counts by in-ground (stop-line and advance) detectors. SCATS is applied to manage the operation of traffic signals in Auckland.

4.2 Measuring freight congestion in Auckland

Interviews have been conducted with representatives of the Transport Agency, Auckland Transport and Auckland Motorway Alliance supplemented by a desktop review to collect information on the technologies currently available to measure freight movement in Auckland.

There are no specific technological applications for measuring the movement of commodities around the wider network; however, some technologies can provide guidance on the underlying fleet composition. While the fleet composition cannot be used to estimate the quantity and type of freight commodity movements, it can provide a proxy based upon the number of medium and heavy commercial vehicles detected on the network.

Of further note, measures of congestion and delays on the network for general traffic can also provide a proxy for freight movements as currently all vehicles traverse the same network except for a number of freight priority ramps (some of which are shared T2, T3 lanes).

The technology review is presented below by technology type with commentary provided as to how useful each may be towards isolating the measurement of urban freight congestion on the Auckland road network.

4.2.1 Bluetooth

A Bluetooth network of approximately 20–30 sensors is currently installed in Auckland with two technology providers servicing the local network. These sensors detect Bluetooth device IDs and the time these devices are recorded. At the time of writing a trial is imminent to install Bluetooth detectors at 50–100 intersections in a cross-agency initiative between the Transport Agency, Auckland Transport and Auckland Transport Operations Centre. There is the potential to expand beyond the trial to provide more network-wide coverage using Bluetooth technology. An example of a similar application is discussed in section 3.5.6.

The technology identifies individual Bluetooth IDs and matches the IDs between sensors to calculate the travel times for vehicles travelling from detector to detector using algorithms to remove outliers and to remove duplicate devices from an individual vehicle. It does not, however, differentiate between vehicle types and therefore is not able to isolate freight vehicles from general traffic. The travel times calculated across the network are point-to-point times between detectors which provide a relatively coarse representation of the network. However, one of the strengths of Bluetooth data is that by identifying individual vehicles it is possible to produce measures of travel time variability across the fleet which other technologies are less capable of or not able to deliver.

As the number and density of detectors on the network increases in the future, Bluetooth technology is likely to provide a more fine-grained representation of travel times and resultant congestion on the Auckland network. A trial is expanding to cover 15 strategic freight routes and analysis of Waterview. Freight movements, however, would only be inferred from general traffic outputs.

4.2.2 Global navigation satellite systems

GNSS including GPS technology is readily applied to understand the location and speed of vehicles travelling through the network. There are a number of vendors in the New Zealand marketplace and mapping of congestion from GNSS sources is freely available online using applications and websites such as Google maps, AA Roadwatch, the Transport Agency's TREIS application programme interface (API), Auckland Transport's Live Traffic Congestion API and a range of other monitoring sites.

In the Auckland context, there are three key data sources which are readily available through the Transport Agency and/or Auckland Transport to monitor the speed and measure travel times or general traffic. Auckland Transport and the Transport Agency receive GNSS data feeds from two separate suppliers. Both sets provide a relatively fine-grained representation of travel speeds for general traffic across the arterial (and other hierarchy levels) network. The data is generally sourced from contracts between the data providers and a mix of commercial and private vehicle fleets with a likely stronger weighting towards commercial vehicle data. The specific sources of data and the underlying fleet composition are not available and it is understood there are commercial sensitivity issues surrounding this information.

Subsequently, the GNSS data sources do not isolate freight vehicle movements but may be considered as a proxy for the speed of freight vehicles throughout the Auckland network; however, the sample size of the underlying fleet from which the speeds are calculated is unknown. Further to this the sample sizes are influenced by the activities undertaken by the commercial fleets that contribute data, the proximity of the road corridors to the activities visited by those vehicles, and where sample sizes are low may be less reliable.

There are a small number of vendors who provide systems to deliver electronic road user charge (ERUC) services for commercial clients using GNSS technology. The data extracted from one telematic vendor is interrogated by Auckland Transport to understand commercial vehicle movements across the transport network and can be used to measure the speed of vehicles across the network. The data is collected by road user charge (RUC) class which is not compatible with the PEM vehicle classification system adopted by the Transport Agency and derived from the Transfund NZ (2005) *Project evaluation manual* (PEM)

The telematics dataset has the same challenges as other GNSS data sources with respect to a lack of transparency of sample sizes on the network. Anecdotally, the dataset interrogated by Auckland Transport has higher sample sizes for interregional freight movements compared with intra-urban freight movements. Auckland Transport has been investigating the sample sizes of the data by comparing counts derived from the dataset against classified vehicle counts. This exercise is complicated by the lack of an equivalence between the RUC and PEM classes, which means the Transport Agency PEM class counts cannot be directly applied to calculate the sample rates of the dataset.

The commercial GNSS data sources are considered to be indicative of the speed of freight movement around the network and could be used as a proxy to identify where congestion has had an impact on freight movements but is unlikely to provide a reliable indication of the quantity of freight affected. The relatively low sample sizes in some urban areas, especially on lower hierarchy roads, may reduce the effectiveness of the data on these roads.

The recently established Centre for Space Science Technology in New Zealand (www.csst.co.nz) will provide future opportunities to develop data sets and products to understand and improve network operations. The centre will undertake research to explore the use of space-based measurements and satellite imagery unique to New Zealand to meet the specific needs of the New Zealand industries. Trials relative to the transport sector are understood to be underway.

4.2.3 Traffic counts

The Transport Agency and Auckland Transport both maintain regular traffic count programmes including permanent sites on both the state highway and local roading networks. A combination of inductive loop and road tube count technologies are applied throughout the city and are used to measure flows by vehicle class, speed and congestion. Auckland Transport maintains a three to four-yearly count programme in addition to permanent monitoring of loop sites and the Transport Agency maintains an annual programme across the state highway network including the two weigh-in-motion (WiM) sites. Specific details of the types of technology and coverage of the state highway network are available at www.nzta.govt.nz/roads-and-rail/research-and-data/counting-the-traffic-on-the-state-highways/.

The classified count information cannot isolate freight movements as such, but provides a helpful measure of medium and heavy vehicle numbers by RUC class. Anecdotally, it is understood the classification system becomes less reliable when congestion is experienced on the road network. Acknowledging this limitation, classified count information may have a useful role when coupled with other technologies such as Bluetooth or GPS data to supplement the travel time and speed information with medium and heavy vehicle counts as a proxy for the volume of freight which may be affected by congestion of parts of the network.

Loop information is used by Auckland Motorway Alliance (AMA) to measure network efficiency based on the relationship between the distance travelled across the network and the time taken to traverse the network for general traffic. The seasonal network efficiency trends are further used to provide a demonstration of the journey time reliability of the network. Network efficiency is one of many network performance measures reported monthly to the Transport Agency. Some of the loop counters classify vehicles by vehicle length but it is understood this is not always reliable.

At the time of writing, the AMA is scoping producing a similar network efficiency performance measure for heavy vehicles. If this is achievable and reliable it would provide an excellent measure to directly identify bottlenecks and impediments to freight movement across the network.

4.2.4 SCATS

The SCATS system maintained and operated by the Auckland TOC is used to monitor and adjust the traffic signal operations throughout the city and can also be used to extract detector counts and infer travel times in real time based on the signal timings. This is not considered to be a reliable means of estimating travel times particularly where traffic on the network is not free flowing through the adjacent signalised intersections. It is understood that to improve the reliability of the real-time SCATS data it has been necessary to validate the data using GPS sources, and subsequently SCATS data is not considered to be a reliable indicator of the location or extent of congestion on the road network.

4.2.5 Weigh in motion

WiM sites use plate-bending technology to measure the weight and distance between the axles of heavy vehicles. The primary purpose of the sites is to monitor the weight of large freight movers and at the time of writing there are eight sites in New Zealand including two in Auckland City. The Harbour Bridge site combines the WiM technology with ANPR technology and this is being expanded further across the network as part of the weigh right initiative. This combination of technology might provide useful data to understand heavy vehicle movements and related congestion. The low number of sites and cost of the technology, however, would mean significant investment to improve network coverage suitable for providing a practical role in measuring freight congestion on the Auckland network.

4.2.6 CCTV footage

CCTV technology is increasingly used for traffic monitoring purposes with over 1,600 cameras active in Auckland at the time of writing and accessible through a single video management system accessible at the Auckland TOC. The CCTV footage is currently predominantly used reactively to assess congestion occurring on the road network.

The application of video analytics to interrogate CCTV footage is emerging and facilitated through a graphic user interface which enables users to run queries on the video. The potential applications are understood to be quite varied but some may require validation to understand how reliable and robust the analytics are. In the context of this study potential applications include measuring queue lengths and congestion, vehicle sizes, average travel speeds and the enforcement of loading zone restrictions. Of further note is the potential for ANPR and vehicle model and make recognition analytics to be used to identify the movement and speed of vehicles throughout the network.

The CCTV and analytics technology has the potential to be a useful source to measure congestion affecting the movement of freight around the Auckland network. The effectiveness of this technology may be sensitive to, and potentially limited by the quality of the camera positions, and to a lesser extent the speed of processing, and level of connectivity and coverage of the network.

4.2.7 Privately held datasets

Another potentially useful source of measuring congestion affecting freight movement in Auckland may be data privately held by freight operators. This may include booking data and GNSS data which is collected by operators to understand fleet operations and performance and ultimately could be used by the operator for freight optimisation purposes. Due to commercial sensitivity concerns around the use of privately held datasets, there were no further efforts made to obtain them to inform this research.

4.2.8 Privacy

In New Zealand, information collected from individuals by public and private agencies is subject to the provisions of the Privacy Act 1993. If a government agency or local authority holds information about an individual, that individual has rights under the Privacy Act 1993 to access and correct this information (Harris et al 2016).

Technology that can record movements or journeys has the potential to invade privacy. A key theme arising in the research by Harris et al (2016) was that while the Privacy Act must be complied with, it should not be seen as a barrier in the development of innovative crowdsourced data applications. Instead, privacy principles must be factored into the system design and architecture.

4.2.9 Summary

There are a number of technologies currently being used to monitor network performance throughout New Zealand and particularly in Auckland City. None of these specifically address road freight movements, for example how much freight is being moved and where.

Existing datasets which measure travel times and speeds on the Auckland network can be applied as a proxy for congestion affecting freight movements. Some datasets are weighted towards measuring the speeds and travel times of commercial vehicle movements, specifically the GNSS technologies which are generally sourced from commercial fleet data. Care must be taken in interpretation in that there is little or no transparency as to the mix of private and commercial vehicles contributing to the datasets. Sample sizes are also variable, and largely unquantified. There are some initiatives underway within the Transport Agency, Auckland Transport and the AMA to understand existing datasets better.

Another potential source of helpful data is from CCTV footage collected throughout the city. The emergence and availability of visual analytics tools to interrogate this data coupled with significant coverage across the network show promise for the potential application of this technology.

5 Stakeholder engagement

A stakeholder workshop was held in Auckland in May 2016. The workshop attendees included the Transport Agency, Ministry of Transport, Auckland Transport, Auckland Council, ITS New Zealand, Auckland Transport Alignment Project, Port of Auckland, Auckland International Airport Limited, National Road Carriers and three transport fleet operators. Twelve further stakeholders (11 from the private sector) were invited to the workshop but were unavailable to attend and were subsequently invited to share their knowledge and experience with the research team following the workshop. The resultant feedback has been combined with the workshop findings reported in this chapter.

5.1 Methodology

The broad purpose of engaging with key transport industry stakeholders was to provide an opportunity for stakeholders to discuss their experiences, knowledge and needs with the research team. Gathering an understanding of the challenges encountered moving freight on the Auckland network provides an insight into the practicality and impact of possible solutions.

The workshop was structured in four sessions as follows:

- identifying the location and nature of problems affecting the efficient movement and reliable delivery of freight
- understanding the effects of these problems on the freight industry[3]
- addressing known and existing technology that offers solutions to these problems
- 'blue skies' session to discuss potential solutions including rules and policy.

Each session was conducted as an open forum to invite input from all attendees and provided an excellent perspective of the challenges faced by the freight community. While the primary focus of this research was how data could be used to improve journey predictability for urban freight, much of the workshop discussion did not focus on technology.

This chapter of the research report summarises the outcomes and learnings arising from each of the four sessions. The responses from stakeholders have largely been anonymised and aggregated, although specific examples have been used on occasion to illustrate a particular point. Effects on the freight sector were presented as congestion on the urban network and a lack of travel time reliability affecting the timely delivery of freight. These two aspects (that is congestion and reliability) are closely related and are used interchangeably in this section.

5.2 Problem locations

Workshop attendees were asked to identify the location of network congestion and impediments affecting the reliability of freight movement in Auckland. There was a strong feeling that Auckland roads are 'full'. Moving freight at any time of the day and night is challenging, with motorways experiencing congestion from 5am. Weekend traffic conditions are similarly congested, with school holidays providing the best general traffic conditions.

[3] Effects on the freight sector were presented as congestion on the urban network and a lack of travel time reliability affecting the timely delivery of freight.

Severe congestion is experienced between Wellsford to the north of Auckland, and the Drury Overbridge in the south. Specific locations expressed as causing the greatest problems for freight movement in Auckland were (in no particular order):

- Onewa Road
- Northwestern Motorway SH16
- Spaghetti Junction
- No parking in central city
- SH16 where three lanes reduce to one
- Neilson Street in particular the ends of Neilson St at Church St bridge and Onehunga
- Penrose Interchange
- Silvia Park turning onto SH1 and Mount Wellington Highway
- Drury Overbridge
- Pukekohe – Greenlane
- SH1/SH20 junction
- SH20B to SH20 junction
- Puhinui Rd SH20 Southbound southern access into the airport
- Right turn onto Parnell Rise accessing the port.

The Port of Auckland, MetroPort Auckland (Neilson Street), and Auckland International Airport are three key urban freight hubs. The Port of Tauranga plays a key role in relieving freight demand for the Port of Auckland. Shipping lines contracted to use MetroPort Auckland call at the Port of Tauranga and offload import cargo destined for Auckland. Cargo is then railed to MetroPort Auckland for distribution by road to its final destination (Port of Tauranga 2016). Any delays to the berthing and unloading of ships leads to 'chaos' on the ground for road freight carriers. The number of trucks accessing Auckland port and key arterials is sensitive to the current shipping contracts at Port of Auckland and Port of Tauranga.

Air freight is very time sensitive, and a number of logistics companies are located at Auckland International Airport. The number of privately owned roads and reliance on privately owned roads to enable the movement of freight in and around the airport often creates tension and inefficiencies for ground freight movements. Concern was expressed at the lack of investment in roading infrastructure in the vicinity of the airport and the deficiency of cohesion between public and private roading infrastructure investment.

5.3 Network impediments

The general volume of traffic on the Auckland network was expressed as the most significant impediment for urban freight movement. Merge locations, poor intersection geometry, poor signal timing and coordination, and lack of planning for freight vehicles are additional problems that intensify frustration and congestion. Obstacles highlighted by stakeholders included:

- too many signalised intersections
- signal controls unsynchronised or inadequate green time to facilitate flow

- parking of cars on roads in industrial areas limits road space and hinders delivery
- restrictive high productivity motor vehicle routes
- lack of space allocated for on-site deliveries at new industrial sites
- truck lanes turning to bus lanes
- delivery addresses that compete with on street parking and normal road volumes
- five-minute loading zones that are insufficient to make delivery to multi-story locations
- new housing subdivision roads that are too narrow for trucks, requiring traffic to stop when deliveries are being made.

Ramp signalling was perceived as penalising arterial road users and city freight movements to benefit motorway journeys.

Urban freight movements are critical to the basic functioning of a city. In an industry driven by competitive pricing, stringent deadlines and penalties, operators are being forced to use more vehicles to do the same amount of work due to the network impediments and lack of road capacity.

5.3.1 Weigh bridge locations

Concern was expressed at the bottlenecks caused by vehicles waiting to access weigh bridges and the implications recent regulatory changes have on this. Effective 1 July 2016, all containers for export are required to be weighed (or their contents and tare), and concern was expressed at the lack of publicly available information regarding the capacity and location of weigh stations. Stakeholders stated that the Penrose weigh bridge operates at capacity 24 hours a day, seven days a week with waiting vehicles causing traffic to back up.

5.3.2 New housing areas

The Auckland network generally lacks the capacity to manage the increased traffic demands generated by new housing subdivisions. Compounding this is the lack of provision for public transport from these areas increasing the need for residents in these areas to make long trips on the Auckland network. This means the extent of congestion is creeping further along the busy arterials over time.

Freight operators highlighted the important role of public transport to get cars off the road and free up road space, and praised the uptake of public transport in the last 10 years.

5.4 Effects of congestion

Discussion regarding the effects of congestion centred on the cost and other implications to freight operators as well as understanding how critical it is to receive timely, accurate information on the status of the network at any time. Urban freight companies face the increasing challenges of moving freight in an environment with more people, more cars, increased demand, low rates and insufficient drivers.

5.4.1 Network information

With much of the Auckland motorway network operating at capacity, if an incident occurs traffic stops immediately. Incident information gets to the truck drivers and control room through visual, radio, data or phone communication from a vehicle in the immediate vicinity of the incident. There appears to be no additional need to get information to the freight drivers. More importantly, network status information needs to get to the general road user to stop additional vehicles trying to get onto the motorway or affected corridors, exacerbating the impact of the incident.

The accuracy of information is highly important, however, freight operators generally thought they had access to all the information and technologies they needed to allow them to manage their operations. Fleet flexibility was cited as more of a constraint than technology. Movement planning is based on historical knowledge and highway camera feeds, and GPS tracking are used to monitor, direct, reroute and adjust vehicle operations in a dynamic fashion based on current network conditions.

5.4.2 Costs

Urban freight is working in a dynamic, competitive and time critical environment. Most freight movements in the Auckland urban area are 'just in time' deliveries with rigid delivery requirements. Time-critical deliveries were stated to correspond to 99% of freight movements with delays and disruption having significant consequences. Stringent customer demands for the movement of goods play a key role in how operations are managed. Examples of these demands include:

- delivery booking systems with an allocated 15-minute delivery window or the vehicle will be turned away
- malls requiring goods to be delivered prior to 9am as pallets are not able to be moved once the malls open
- more frequent deliveries required due to retailers having no stock room
- night deliveries constrained by the availability of the customer to receive goods at night, or not being allowed to open at night.

Disruption has extreme consequences including late delivery, which lead to later deliveries (knock on effect), increased costs and driver frustration. Contingency planning plays a big part in minimising the effects of congestion to the operation of freight movements, but it makes the industry very inefficient and has cost implications for businesses. Examples of direct and indirect additional costs incurred by freight operators as a result of poor network performance include:

- increased number of trucks on the road to ensure goods can meet customer requirements
- increased handling costs
- more time needing to be built into plans to allow for congestion and road works
- missed additional loadings
- loading additional trucks 'just in case'
- freight operators building multiple sites to alleviate issues
- vehicles waiting on side of road to ensure a booking slot window can be met
- a fleet of trucks often idle in the afternoon as all deliveries are required before 1pm
- lost loads and spoilt goods
- additional part-time drivers required to cover peaks.

Interrupted driving patterns as a consequence of congestion and poorly designed and controlled signalised intersections, have a significant impact on the fuel efficiency of freight vehicles. Trucks on the Auckland network are often required to stop at red lights and then take off uphill fully loaded, which not only inhibits traffic flow, but is extremely inefficient for fuel consumption. The short-term cost of these inefficiencies is borne by the freight operators, but there is a larger environmental impact that should also be considered.

The human aspect is also significant. Drivers are working in very challenging conditions where network congestion and inefficiencies escalate driver frustration and risk resulting in freight operators facing the cost of a high driver turnover. The lack of drivers places extreme pressure on managing driver hours meaning an incident or delay can lead to a driver having to get off the network so as to not exceed driver hours. This could mean additional costs to get a small vehicle out to remove the driver and get them home and/or motel costs to accommodate them.

The freight industry feels it bears the consequences and pay the cost of a lack of transport infrastructure and poor urban design. The cost of congestion can be approximately monetised based on a $90–$120 per hour standing cost per vehicle. In a very competitive industry, increased costs cannot be passed on to the customer or consumer, placing extreme pressure and risk on an important economic sector. A recent US study calculated the delay on the US National Highway System to be over 728 million hours. The productivity loss is equivalent to 264,781 commercial truck drivers sitting idle for an entire working year and equates to $49.6 billion in increased congestion related costs to the freight industry (American Transportation Research Institute 2016). New Zealand is a much smaller freight industry than that of the US; however this example provides a good illustration of the substantial additional cost borne by the freight sector as a result of congestion.

5.5 Technologies

The use of technology to solve network inefficiencies is rapidly developing. There are a number of technological initiatives currently being used or trialled overseas to aid the priority of freight movements and the research team sought to understand how technology could be used to improve the performance of the Auckland road network and movement of freight.

Modern truck cabs are saturated with technology. Cameras are used to monitor all areas and angles of the cab and vehicle and it is perceived by stakeholders that there is no room for further in-cab devices. Telematics are also used by most large freight companies. Issues relating to the privacy concerns of drivers and sensitivity of information being collected have largely been eliminated through clarity of driver contracts and the added security and integrity benefits that technology provides for drivers.

Stakeholders raised concern regarding privacy issues surrounding crowdsourcing technologies. Criticism centred on the collection of information by government agencies and what and how it may be used.

The drive to capture data for compliance is increasing. The industry perceives this as an expensive exercise with little commercial benefit, so uptake is likely to be low. Trust in the way the data will be used by an enforcement agency is also a potential barrier to any state implemented technology initiatives. The ownership of the data is of particular concern, therefore it may be more accepting for private organisations to collect and manage data, rather than public agencies.

The areas where technology could have a positive impact for freight movements were expressed as:

- providing more cameras on roads to aid operators to assess the impact of a situation to make appropriate adjustment to operations
- a port vehicle booking system to smooth out traffic peaks
- using variable speed signs to manage the smooth flow of traffic
- driver education on optimal use of lanes and merge manoeuvres.

The current use of VMS was considered to be ineffective, unsafe and adding to network issues.

Crash clean up and recovery was seen as an area that could significantly improve as the response and clean-up time has deteriorated recently. Procedural compliance has noticeably increased the time taken to clear incidents and the staff available to complete the recovery. The application of ITS to enable emergency vehicles to quickly reach incidents, has the potential to improve the predictability of time required to get traffic movement back to normal following an incident.

Heavy vehicle technology continues to evolve and there is an interest from the industry in the emergence of connected vehicle and automated vehicle technology. Much of the vehicle infrastructure already exists; however, there is a gap in the infrastructure to facilitate this technology. An example of this is the removal of lane departure technology from vehicles as the technology is not suitable in the current New Zealand road environment and is considered to be a safety hazard.

5.6 Potential solutions

The clear message from stakeholders is that infrastructure and urban design are the biggest constraints to relieving network impediments and these need to be addressed before technology can be helpful. It was seen that a coordinated response was required to invoke change, with a primary focus on having the right infrastructure provision, supported with appropriate regulatory and technology elements. An example of the misalignment of urban design and policy cited was the requirement to provide customer car parking, but not loading bays for trucks at malls. Infrastructure and strategies considered likely to improve the efficiency of freight movements were:

- variable lane use including dedicated truck lanes at certain times. This could be linked to the use of VMS, but would need to be carefully managed to avoid conflicts and lane weaving
- freight lane from Drury to Albany
- allow freight vehicles to use bus lanes, particularly the Northern Expressway
- remove some on-ramps
- remove unnecessary signals and facilitate green waves
- trial variable speed management to optimise flow, with optimal speed likely to be in the 60–70km/h range before and during congested periods
- provide an expressway from South Auckland
- overhaul loading zones to increase the availability of loading zones and ensure they are located in the right places. Pre-loading zone areas could also be considered
- increase the number of one-way rear service lanes for delivery vehicles (The Strand in Whakatane is a good example)
- more stringent monitoring and penalties for use of mobile phones in vehicles
- driver licensing review to improve the education and skill of drivers
- improved allocation of road space and elimination of cycle/truck conflict
- better town planning to provide facilities for trucks to pull over and drivers to take breaks.

With 90% of vehicles on the network being single occupancy vehicles, priority needs to be given to initiatives that encourage people to reduce car usage. Any technology that can assist in improving the uptake of public transport would benefit the movement of freight. Uber is a great idea to see where cars are going and reduce duplicate journeys, and a similar application could be useful for public transport. In addition, working from home could be incentivised as well as the reintroduction of carless days.

A 'blues skies' suggestion to consider for the future is to provide an underground hubbing network exclusively for freight.

5.7 Summary

The stakeholder workshop provided valuable insight into the current urban freight operating environment. Frustration at the lack of, or inefficiency of Auckland infrastructure was conveyed very strongly. The impact of this is very real and places significant financial and management pressure onto operators. The overarching themes that emerged and were expressed (explicitly or implicitly) by stakeholders to improve the movement of freight were to:

- build more infrastructure then there would be a place for technology to be used
- get people out of cars
- increase the uptake of public transport and use technology to help this
- utilise variable speed technology/highways to improve the flow of corridors and motorways, by reducing the speeds before a corridor is congested to improve capacity
- allocate road space better, and allow freight vehicles to use bus lanes
- improve incident management to clear incidents more quickly
- improve the placement and design of loading zones, including the use of booking systems and sensors to detect availability of loading zones
- educate road users to drive more efficiently and considerately
- utilise emerging connected vehicle and automated vehicle technology.

6 Data collection

The primary objective of the data collection stage of the research was to determine which datasets were accessible and considered valuable for further analysis, and to establish the extent of the Auckland urban study area to be included in the technical analysis. The literature review and stakeholder consultation concluded there are no datasets that specifically capture road freight movements. The most useful historical and real-time datasets that can be used as a proxy for measuring the magnitude and impact of congestion on freight movements in Auckland are:

- commercial GPS datasets
- ERUC telematics datasets
- online congestion mapping.

The following section documents the available datasets and presents mapping of congestion which will be used to locate bottlenecks and constraints to the efficient movement of freight.

6.1 Commercial GPS data

The research team analysed TomTom commercial GPS data as one of the main data sources for monitoring network performance on the Auckland network. The team analysed a dataset which is an aggregate of the last two years of data collected in five-minute intervals for each day of the week for every road segment. The resultant dataset interrogated to inform this research therefore approximates the average congestion experienced between mid-2014 and mid-2016 on the Auckland network.

The data was further aggregated to be reflective of the broad commuter periods as demonstrated by the underlying five-minute data. The typical morning and evening commuter periods in Auckland span roughly four hours and are as follows:

- The morning commute begins at 5.30am and concludes at 9.30am.
- The evening commute begins at 2pm and concludes at 6pm.

Two series of maps have been produced for each four-hour commuter period and each day of the week which compares the speed of the network against the free-flow speed, which is the average speed recorded between 9pm and 4am in the absence of traffic congestion. The first set represents the impedance which is calculated as the percentage of free-flow speed for each weekday and the second set represents the delay (or reduction in speed) which is the free-flow speed minus the average actual speed during the commuter peaks. An example of one of these resultant maps in the online viewer is shown in figure 6.1.

The impedance maps demonstrate a relatively uniform degree of congestion across both local and state highway and motorway networks, represented by the percentage of (and therefore irrespective of) free-flow speed. The delay (reduction in speed) maps demonstrate a higher degree of congestion on the motorway network due to the higher free-flow speed and resultant higher quantum of reduction from free flow speed relative to the local roads which exhibit lower free flow speeds.

The maps depict travel information in both directions; however, it is noted some road segments represent a single direction (for example where there is a divided carriageway) while others include two counts representing each direction of travel. The average impedance over the four-hour commuter peaks have been calculated by adding the total number of impedance values, divided by the total number of time intervals (that is 48 intervals).

These maps are supplemented by including layers which represent the heavy vehicle volumes. These have been included from two sources; available traffic counts and Corelogic RAMM data.

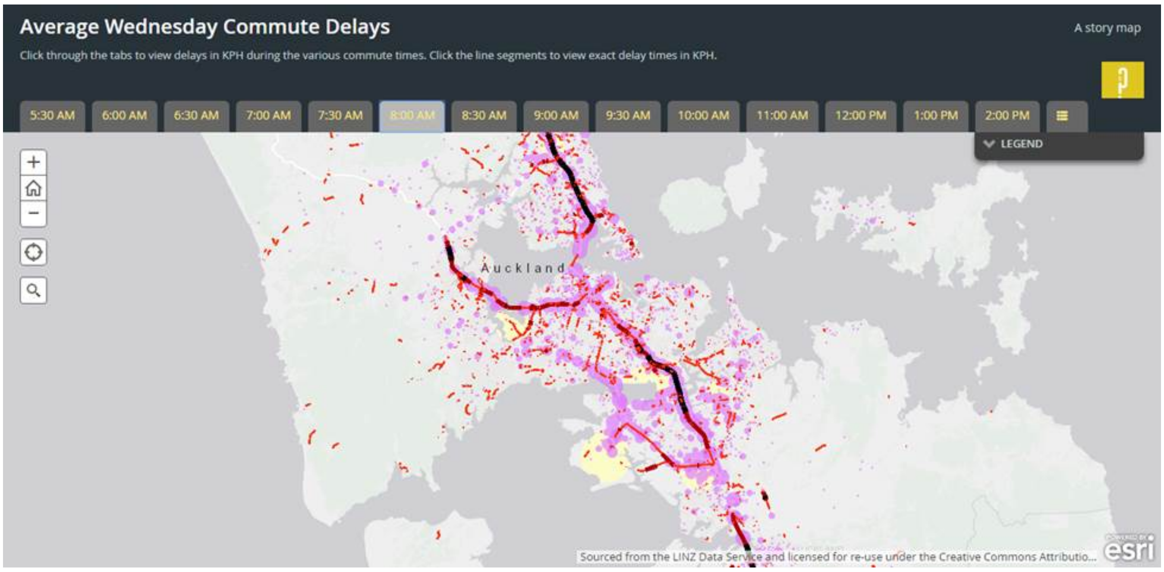
The available traffic counts are taken from Transport Agency and Auckland Transport classified count data with heavy vehicle (that is Transport Agency PEM medium commercial vehicle (MCV), HCV-I and HCV-II classes) annual average daily traffic (AADT) flows isolated and mapped as a series of circles where the size of the circle is proportionate to the heavy vehicle volumes. Given the data is based upon spot counts there are a large number of gaps in coverage although the state highway network is generally well represented.

The heavy vehicle volume field in the Corelogic RAMM count data provides a partial dataset which provides useful sensibility tests around the Transport Agency and Auckland Transport count data and presents this information as links instead of spot counts.

These datasets provide useful context so that the corridors with high heavy vehicle[4] (and by inference freight) flows can be easily identified alongside corresponding measures of the extent and location of congestion on the network. Variability in the extent and location of congestion on the network between the various weekdays is evident, and of particular note is that Monday and Friday are atypical, most likely due to bias introduced by pre-weekend and post-weekend travel coupled with a generally higher number of public holidays which may fall either side of the weekend (for example Good Friday and Easter Monday) which have not been filtered from the two-year dataset. The congestion outputs for Tuesday through Thursday are more uniform in nature for both the morning and evening commuter peak periods, and consequently the Wednesday data has been extracted for more detailed analysis.

The location, extent and temporal nature of congestion (based on the Wednesday dataset) has been considered further by producing a series of maps at half-hourly intervals during the commuter peaks and hourly intervals between 10am and 2pm, providing a comprehensive picture of when and how congestion occurs and subsequently propagates back through the road network. The heavy vehicle AADT spot counts sourced from the Transport Agency and Auckland Transport classified count data have also been included. An example map is shown in figure 6.1.

Figure 6.1 Average Wednesday congestion mapping online resource



[4] Heavy vehicle counts also include buses which may be significant on particular routes.

6.2 Electronic road user charge data

The research team consulted Beca, who maintains a comprehensive dataset of ERUC commercial GPS data on behalf of EROAD. The primary purpose of the data is to enable the calculation of RUC for subscribers, and the resultant dataset is available as a source of network performance monitoring. There are a number of ongoing initiatives that have been delivered and/or are being undertaken by Beca which provide additional context to inform this research.

Beca has prepared a series of outputs from ERUC data for Auckland Transport as part of the delivery of the Auckland Freight Network Demand Study (C Vallyon, email, August 2016). The results from the study are based upon commercial vehicle data collected in March 2015. The source data is classified by RUC acknowledging the 2014 RUC classifications are based on the number of axles, rather than the weight, enabling heavy vehicles to be filtered out by removing RUC classes 0, 1 and 2.

Subsequently, a GIS layer has been supplied which essentially eliminates light and medium vehicles from the dataset; however, as RUC class 2 crosses multiple weight classes, there will be some two-axle heavy vehicles in the source data that have been filtered out of the study as they fall into RUC class 2.

A map of the sample heavy vehicle volumes from the ERUC dataset focusing on the Auckland isthmus is included in figure 6.2. While this does not show absolute values, the pattern demonstrates the higher prevalence of freight on the state highway network through the Auckland metropolitan area. It also highlights the importance of the movements in the Church Street/Neilson Street area.

Auckland Transport is also investigating the use of variable RUC to control congestion and smooth the network.

Figure 6.2 Sample heavy vehicle daily flows from ERUC data

6.2.1.1 Google maps data

Google maps is a useful resource of real-time traffic information and provides a near real-time qualitative measure of congestion on the arterial road network. Using a 'screen capture' tool, two weeks of images of Google maps traffic congestion at 15-minute intervals have been collected. An image has been collected every 15 minutes as an overview of the Auckland urban area as well as a close-up image in the vicinity of the SH1/SH20 interchange.

These images will be useful for analysing specific problem locations or bottlenecks previously identified, and understanding the variance in congestion experienced over the course of the day, or from day-to-day over a two-week window. The outputs specified in sections 6.1 and 6.2 respectively are aggregated over years (in section 6.1) or a month (section 6.2) of data providing an average representation of traffic conditions over those periods. The Google maps data provides near real-time snapshots of traffic conditions which demonstrates the variability in network performance including the immediate and flow-on effects of incidents and events on the network.

The Google maps captures demonstrate the changes in congestion experienced at the same times during the morning peak, middle of day and evening peak on three consecutive days (Wednesday 27 to Friday 29 July 2016). The symbology shows relatively free-flowing parts of the network in green with progressively more congested corridors represented by orange, red and (if very heavily congested) brown. Google maps does not specifically quantify the speed, delay or other measure of congestion against this symbology, therefore the outputs should be treated largely as a relative qualitative measure. Two crashes were recorded during the peak periods and the location and timing of each are denoted on the corresponding outputs.

6.3 NZ Transport Agency network performance monitoring

The performance of the Auckland Motorway network is constantly monitored by the Transport Agency and AMA with a broad range of indicators published on a monthly basis in the *Auckland monthly network performance monitoring report*. The Transport Agency has supplied the research team with copies of these reports corresponding to March 2016 through June 2016 (inclusive); however, we do not have permission to re-publish any contents of these reports within the research report.

Regardless, the monthly monitoring reports include useful measures informed by various technologies including loop count and Bluetooth technologies. Specifically, the network performance is measured based on a number of indicators including a year-by-year comparison to monitor the change in the following:

- vehicle fleet size
- network efficiency
- route reliability and predictability
- journey times on key routes
- response to incidents.

Most helpfully, each report includes an 'ongoing operation improvement action log' which describes network operation problems and recommends actions where appropriate. This problem identification and action log is a useful resource to inform the next stages of research and enables the consideration of proposed Transport Agency and AMA initiatives alongside any case study development emerging from this research.

6.4 Freight flow 'hot spots' in Auckland

A workshop with the steering group was held on 15 August 2016 in Auckland. The workshop attendees included the Transport Agency, Ministry of Transport, Auckland Transport and national road carriers. The objective of the workshop was to identify where on the Auckland road network significant congestion was occurring and determine the likely significance of this to the freight sector. The datasets gathered and analysed from previous stages of the research highlighted several potential problem locations.

Table 6.1 lists Auckland locations experiencing freight and general traffic flow impedance. These locations are the sites previously identified by stakeholders, and through analysis of TomTom and Google maps data. As indicated in section 6.3, the Transport Agency produces a monthly network performance monitoring report which contains an on-going operation network improvement action log. This records problem locations that have no resolutions planned through imminent or future projects. Several locations identified either by stakeholders or data analysis, were also cited in this report.

This table was presented to the workshop participants and was the focus of discussion to determine Auckland's freight vehicle congestion hotspots. While the data primarily measured congestion, it was recognised that accessibility constraints and journey reliability were also key considerations for the freight sector. These terms are all closely related and interlinked, so the term congestion has been used broadly throughout this research and encapsulates the accessibility and journey reliability effects on the freight sector.

6.4.1 Outcomes from workshop

An initial review of the locations was made and any sites incorporated into existing or future infrastructure work programmes were eliminated from the discussion. These locations were deemed low priority as potential case studies.

The locations on table 6.1 numbered one through nine were agreed by the workshop attendees as locations requiring priority to address congestion-related issues. These locations have the potential for ITS to impact positively on the flow and efficiency of urban freight vehicles. Locations numbered 10 through to 16 were agreed to be low priority as future infrastructure solutions have been proposed for these locations. Overall there was acknowledgement of high levels or prolonged congestion impacting on freight operations network wide. Table 6.1 provides an overview of stakeholder perspective of freight flow hotspots relative to other data sources. It was compiled to verify the stakeholder identification. TomTom data was extracted and analysed using determined congestion-related measures, whereas there is lack of transparency to the underlining symbology and data analytics of Google's traffic maps.

Table 6.1 Problem locations identified in Auckland

	Problem locations	Stake-holders	Workshop	NZ Transport Agency report	Google maps	TomTom data
1	Onewa Road	✓	✓		✓	
2	Esmonde Rd City bound congestion		✓	✓	✓	
3	Sylvia Park and turn onto SH1 and Mount Wellington Highway	✓	✓		✓	✓
4	Mt Wellington to Greenlane – Ellerslie/Panmure and Green Lane interchanges	✓	✓	✓	✓	✓
5	Drury Overbridge,	✓	✓		✓	
6	SH20A/SH20 northbound merge		✓	✓		
7	SH16 Parnell Rise intersection (right turn)	✓	✓		✓	
8	SH1 interchange at Oteha Valley (southbound on-ramp)		✓			✓
9	Rosebank Rd		✓		✓	✓
10	North Western Motorway SH16	✓	✓		✓	✓
11	Central Motorway Junction	✓	✓		✓	
12	SH1 Northcote Road		✓		✓	✓
13	Neilson Street at Church St intersection	✓	✓		✓	
14	Neilson Street at Onehunga	✓	✓		✓	
15	SH1/SH20 junction	✓	✓		✓	✓
16	Puhinui Rd(SH20B)/SH20 southbound southern access into the airport	✓	✓			✓
17	Acknowledgement of network wide congestion	✓	✓		✓	✓

6.5 Summary

Several useful data resources have been assembled to demonstrate the extent and location of congestion affecting the efficient and on-time delivery of freight around the Auckland network. These are predominantly based upon commercial GPS data which demonstrate the location of congestion and are supplemented by representations of heavy vehicle flows on the network to determine which corridors cater for higher volumes of freight movement. The commercial GPS datasets are heavily weighted towards commercial vehicle movements over private vehicle movements so are considered an appropriate source which is relevant to the freight sector when cross-referenced against heavy vehicle flows.

Interrogation of the datasets enabled resources to be prepared that identified the location and extent of congestion affecting urban freight movements on the Auckland road network. A key consideration was the access to, and integration between, freight modes at freight hubs such as the Port of Auckland, MetroPort and Auckland International Airport. These resources were presented to the research steering group at a workshop on 15 August 2016 for an overall assessment and discussion. The aim of the workshop was to determine where the cost of congestion was greatest across the road network, and therefore where the greatest opportunities for improving the efficiency of freight movements through ITS intervention were. Some possible ITS solutions were raised during the steering group workshop, and their relevance and application on the Auckland network were broadly discussed.

Both the industry input and data outputs recognise a high level of network wide congestion in Auckland. It is therefore acknowledged that technologies addressing congestion from a more holistic approach would assist freight movements throughout the network. There are also opportunities to consider technologies that would address congestion at intersections where flows of freight vehicles are high, in order to improve the efficient movement of freight on the Auckland network.

7 Potential ITS interventions

An assessment of each of the 'hot spots' identified in the previous stage was undertaken to determine their suitability for trialling the application of ITS to improve the movement of urban freight. The magnitude of delay experienced at each location was analysed using GIS outputs developed from the commercial GPS datasets gathered as well as site visits. Consultation with the steering group and stakeholders including the Transport Agency, AMA and Auckland Transport was also undertaken to understand the impedance to the efficiency of freight flow at the identified locations. Additional locations were also proposed during the consultation process.

Drawing on the findings of the previous stages of the research a list of six potential types of ITS interventions or solutions was identified to improve the efficiency of freight movements and encourage better route planning as is presented in table 7.1. Consideration was given to vehicle-based technologies (real-time reporting of network conditions, routing solutions, signage), network operating interventions (traffic signal control, freight only lanes and other priority measures) as well as other optimisation strategies (freight booking systems, real-time loading zone and parking sensors and mapping.

A high-level evaluation of the technology and application of each to congested Auckland locations to develop into a specific case study was also considered, and recommendations for a shortlist of case studies are documented in this chapter.

Table 7.1 Potential ITS interventions

Technology	Stakeholders	Literature review	Case studies	Feasible
Information provision service	✓	✓	✓	✓
Parking/loading zone strategies	✓	✓	✓	✓
Traffic signal optimisation/CITS	✓	✓	✓	✓
Ramp signal optimisation	✓			
Analytics or sensors	✓	✓		✓
Mode prioritisation	✓	✓		

7.1 Information provision service

The use of technology to improve the information available to the freight sector would be helpful to support the efficient movement of freight.

Information relating to the journey predictability and reliability of freight trips has the potential to increase freight efficiency across the Auckland network. These improvements might be sought through the implementation of demand management strategies and booking systems, and it was proposed during the stakeholder workshop that a journey time tool customised for the logistics sector could be developed. This would potentially combine real-time and historic travel time (two-year rolling average) data to provide travel time and travel time reliability estimates. Engagement with the logistics sector would be made to understand the most useful means of delivering journey time data, potentially including the installation of VMS for key freight movement routes. These could also include 50th and other percentile timings to understand journey time reliability.

A further information-based initiative of value to the freight sector would be a tool that provides information about the location of loading zones, weigh stations and constraints on the road network which would impede larger vehicles in terms of thoroughfare or access. These were common concerns raised by stakeholders which could be simply addressed through the application of technology to enable the sharing of network information.

It was decided there was value in further scoping of both a freight journey predictability tool and a freight information tool in the final stage of the research. These have been carried forward to two of the case studies in chapter 8.

7.2 Parking/loading zone strategies

Improving the accessibility of loading zones and understanding loading and parking zone availability to enable efficient loading and unloading of freight vehicles is a further potential area of ITS application. Large retail complexes and central city locations are difficult to access to deliver goods. Frustration around the bad planning and management of loading zones and holding areas was expressed by freight operators. Frogpark and SmartPark are two applications that monitor and push out the availability of loading bays and parking space. A similar application could be used to improve the loading and unloading of urban freight at key locations in Auckland's urban area.

While not strictly an example of an application for the freight sector, the Westminster City Council undertook the world's largest deployment of real-time parking technology installing 3,000 sensors in parking bays across London. Parking bay sensors are a simple concept, which together with the ParkRight application allow Westminster drivers to view a current picture of spaces near to them. This delivers major benefits through improving the ability for people to find a parking space, and reducing congestion (SmartParking 2014).

Because of the potential to provide benefits to the Auckland freight sector, the development of a loading zone management tool has been carried forward as one of the case studies explored in chapter 8.

7.3 Traffic signal optimisation/CITS

The optimisation of the existing SCATS traffic signal control system to support the coordination of through movements of freight vehicles was raised as a possible solution for congestion-related issues experienced in corridors with multiple signals and high freight volumes.

Urban arterials with multiple sets of traffic signals could potentially benefit from ITS signal optimisation applications to improve flow. Engagement with industry stakeholders suggested the Rosebank Road, Highbrook Drive, Neilson Street or Saleyards Road corridors could be considered as potential case study locations.

The CITS trial in Illawara detailed in section 3.4.1 provides an example of the application of CITS using infrastructure to deliver messaging to vehicles including traffic signal phase information (Transport for New South Wales 2016). A similar application could be trialled in an urban arterial environment to enhance the flow of freight vehicles through multiple sets of traffic lights.

It was agreed to develop a case study around the application of CITS on a suitable Auckland freight corridor and this has been carried forward into chapter 8.

7.4 Ramp signal optimisation

The utilisation of ramp metering on the Auckland network is not considered by stakeholders to be optimised to support freight movement, and a suggestion was made to re-strategise or re-configure to accommodate this when there is a high volume of freight vehicles. Penrose, Sylvia Park and Ellerslie-Penrose on-ramps were raised as locations that could benefit from improved ramp metering.

Traffic count data for Auckland motorway on-ramps has been provided by the Transport Agency. Table 7.2 lists Auckland's highest heavy vehicle on-ramp volumes, including the AADT, percentage of heavy vehicles and the presence of any on-ramp priority lanes. Lane priority varies across the locations from no designated priority to bus or truck only lanes, mixed use, T2 and truck priority lanes, or lane gain.

The surrounding environment of these on-ramp locations has been considered in terms of what other infrastructure affects the flow of traffic. Some locations have several traffic lights in close proximity to the ramp and may benefit from signal optimisation to improve the flow of traffic leading to the ramps. These locations are noted in table 7.2. 'Yes' means there are several signals in close proximity and 'limited' means the signals are more widely spaced and so the benefits may be less. The three on-ramp locations identified during the stakeholder workshop (Penrose northbound, Sylvia Park southbound and Ellerslie-Penrose northbound) are all included in list of the top 12 heavy vehicle on-ramp volumes included in table 7.2 so would benefit from improved ramp signal operation where possible.

Table 7.2 NZ Transport Agency state highway on- ramp counts in Auckland

Site ref	Description	Priority lane	Potential for signal optimisation	AADT	Total HV	HV%
ID:02050014	SH20 Neilson St on-ramp SB	Truck/T2	Yes	16,200	1,216	7.51
ID:01N50437	SH1 Sth Eastern Hwy on-ramp NB (Penrose)	Truck/T2	Limited	17,254	1,158	6.71
ID:01N36429	SH16/SH1 Port on-ramp SB	Truck only	Limited	9,279	1,143	12.32
ID:02030009	SH20 20A on-ramp NB – virtual	No	No	18,446	1,124	6.09
ID:01N30428	SH1 Northwestern on-ramp SB	No	No	22,060	1,077	4.88
ID:01650006	SH16 St Lukes Rd on-ramp EB (NW1)	No – lane gain	No	17,532	1,055	6.02
ID:01650013	SH16 Lincoln Rd on-ramp EB (NW4)	Truck/T2	Yes	14,996	1,040	6.94
ID:01N30449	SH1 Southwestern on-ramp SB	No	No	18,306	1,009	5.51
ID:01N30439	SH1 Mt Wellington Hwy on-ramp SB (Sylvia Park)	No – lane gain	Yes	17,890	964	5.39
ID:01N50443	SH1 Highbrook Dr on-ramp NB	No – lane gain	No	11,500	889	7.73
ID:01N50433	SH1 Green Lane East on-ramp NB (Ellerslie-Panmure)	No – lane gain	Maybe	17,342	871	5.02
ID:01N50426	SH1 Fanshawe St on-ramp NB	Bus lane	Limited	18,028	828	4.59

The key concern with carrying forward ramp optimisation into one of the research case studies was that providing priority to freight at some ramps could adversely affect other traffic which in turn could hamper access to the motorway network for all vehicles. A further concern centred around general traffic identifying which ramps provided high levels of throughput and changing behaviour to benefit from this, which would further erode benefits to the freight community.

7.5 Analytics or sensors to identify freight vehicles

Technology that can identify the presence of freight vehicles from the general traffic stream may provide an opportunity to apply a separate treatment for this vehicle class. A laser sensor would be a simple technology to identify heavy vehicles based on height, while video footage provides an alternative for identification of more specific vehicle types such as courier or light urban freight vehicle.

Video analytics software is an emerging technology innovation which shows the potential to assist the freight sector. The research team attended a demonstration by Hewlett Packard Enterprises which provided insight into the potential application of video analytics to understand network impedance, through the scanning of video footage and isolating the movement of a selected mode, through a movement or an intersection. The software is heavily reliant on the quality of video footage.

Hot spots for freight vehicles that may be appropriate to test the application of video analytics are:

- right turn out of Parnell Rise
- Great South Road and Church Street intersection
- SH20/SH20A northbound merge.

It was agreed to carry forward the application of analytics to identify and prioritise freight vehicles at one key intersection as a case study to be explored further in chapter 8.

7.6 Mode prioritisation

Some stakeholders noted an integrated planning approach to prioritise public transport during peak periods, and freight during off-peak periods might offer greater network and mode efficiencies than a blanket priority of one mode during periods of high traffic volumes. It would be helpful if a technology application were available to aid in balancing conflicting modes during peak or mutually high demand periods and corridors. This might provide a mechanism to optimise public transport and freight priority based on time of day or demand while eliminating any conflict between these modes.

Workshop attendees agreed Onewa Road and Esmonde Road might be suitable locations to use as a case study to test an ITS application that could balance priority between several modes both within and between different periods of the day.

The feasibility of each of these ITS interventions along with the congestion mapping resources were analysed to identify which bottlenecks impacted most on the freight sector, and could benefit most from the application of technology to improve traffic flow and journey time reliability. It was strongly acknowledged that greater network wide congestion impacted greatly on the reliability of traffic flow throughout the Auckland network across the day. Locations where the impact of congestion was highly significance for the freight sector were isolated to carry forward as case studies.

The key concern with exploring mode prioritisation further within this research was there were no obvious technologies that would support the prioritisation of freight in alignment with the Auckland Transport Auckland Network Operating Plan (this document was not publicly available at the time of writing – readers are directed to contact Auckland Transport network optimisation team for further details). Rather, it was considered regulation and infrastructure were more effective measures of enabling the prioritisation of freight by time of day for corresponding corridors. This has not been carried forward as a case study.

7.7 Summary

Five case studies were shortlisted for more detailed consideration in chapter 8 of this report. These are as follows:

1. Freight journey predictability tool
2. Freight sector network information tool
3. Intersection freight priority using CCTV video analytics
4. Cooperative intelligent transport system freight corridor
5. Loading zone management tool.

8 Case studies

The five proposed case studies presented in this chapter demonstrate the application of technological solutions to improve the movement of freight in the Auckland urban area. Each case study describes the application of the technology, a possible location within Auckland where benefits will be realised, extent of current congestion in the vicinity and provides an overview of the likely benefits and broader considerations.

8.1 Freight journey predictability tool

8.1.1 Overview of case study

A journey travel time reliability tool customised for the logistics sector can be developed to provide information related to traffic congestion and travel conditions to reduce uncertainties through delivering journey time data on key freight routes. This tool will differ from Google maps by presenting a range of likely travel times (in addition to an average expected travel time) based on real-time network conditions, enabling freight operators to understand the likelihood of successfully meeting delivery deadlines and more efficiently schedule their resources and undertake contingency planning.

Travel time reliability information can be disseminated through a combination of roadside VMS as well as a web-based application that will be accessed on desktop and mobile devices.

8.1.2 Location: MetroPort to SH1N and SH1S

MetroPort is a key strategic freight location for shippers and road carriers. MetroPort currently has 1,000 ground slots and 60 reefer points. Shipping lines with import cargo destined for Auckland call at Port of Tauranga, where the cargo is offloaded and railed to MetroPort Auckland for distribution. The same process occurs in reverse for export cargo originating in Auckland. MetroPort is accessed from Neilson Street as shown in figure 8.1 in an area where many of Auckland's industrial, warehousing and distribution businesses are located. The entrance road to MetroPort also houses Toll's major distribution site, KiwiRail's container transfer site and the empty container transfer site, Metrobox. Neilson Street is also a key freight corridor forming part of the strategic freight network in Auckland.

The travel time reliablity information can be calculated as, for example, 15th percentile, average and 85th percentile travel times between the MetroPort access and key locations on the state highway network such as the SH1/SH16, SH1/SH20 and SH1/SH2 interchanges. This information is presented to road users as a travel time range, for example '15 minutes (12–18 minutes)'. Suggested VMS locations are MetroPort access, Central Motorway Junction, East Tamaki, Manukau and Hobsonville due to their general importance to freight.

8.1.3 Extent of congestion

The TomTom outputs show the congested corridors near Neilson Street and MetroPort as illustrated in figures 8.2 and 8.3 for morning peak and evening peak respectively. The shaded yellow area denotes the major freight generating and attracting areas of which Neilson Street is central. Congestion in the morning peak on Neilson Street reduces the free-flow speed of 50km/h by approximately 19km/h. In the evening peak westbound traffic backs up at the Onehunga end of Neilson Street from Onehunga Mall intersection reducing the free-flow speed by 33km/h.

The travel time reliablity tool will provide a range of journey travel time predictions taking into consideration the extent of congestion between MetroPort and the connection to SH1 as well as the extent of congestion along SH1 to the north and south which is also presented in figures 8.2 and 8.3 for the morning and evening peak periods respectively.

Figure 8.1 MetroPort access onto Neilson Street

Figure 8.2 Level of congestion during morning peak on Neilson Street

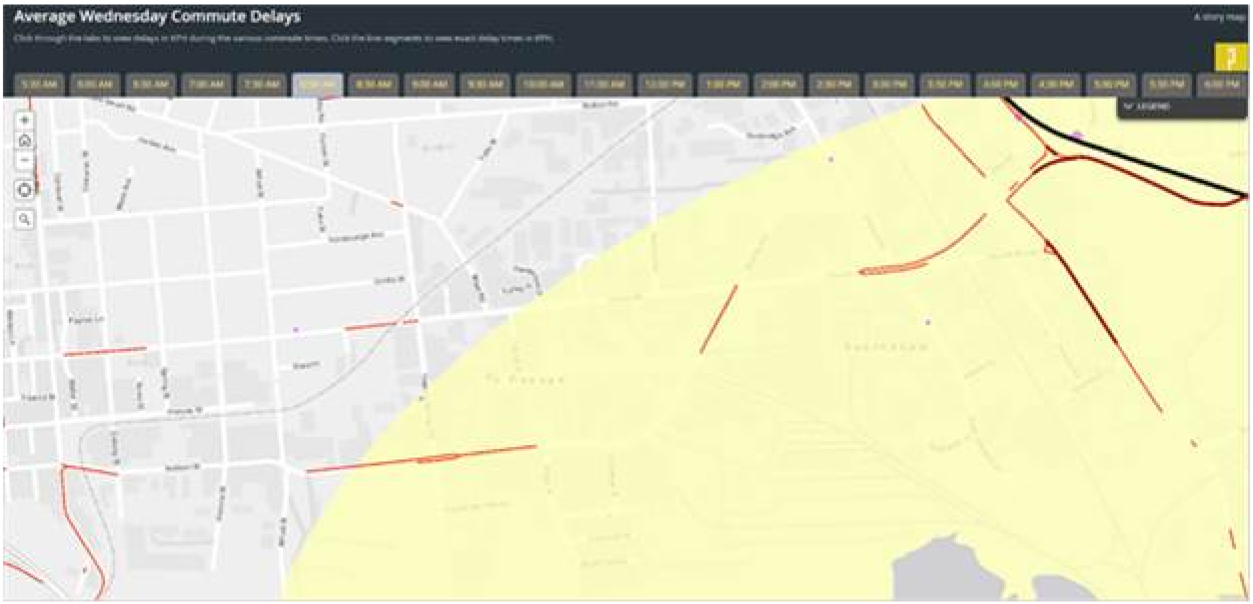
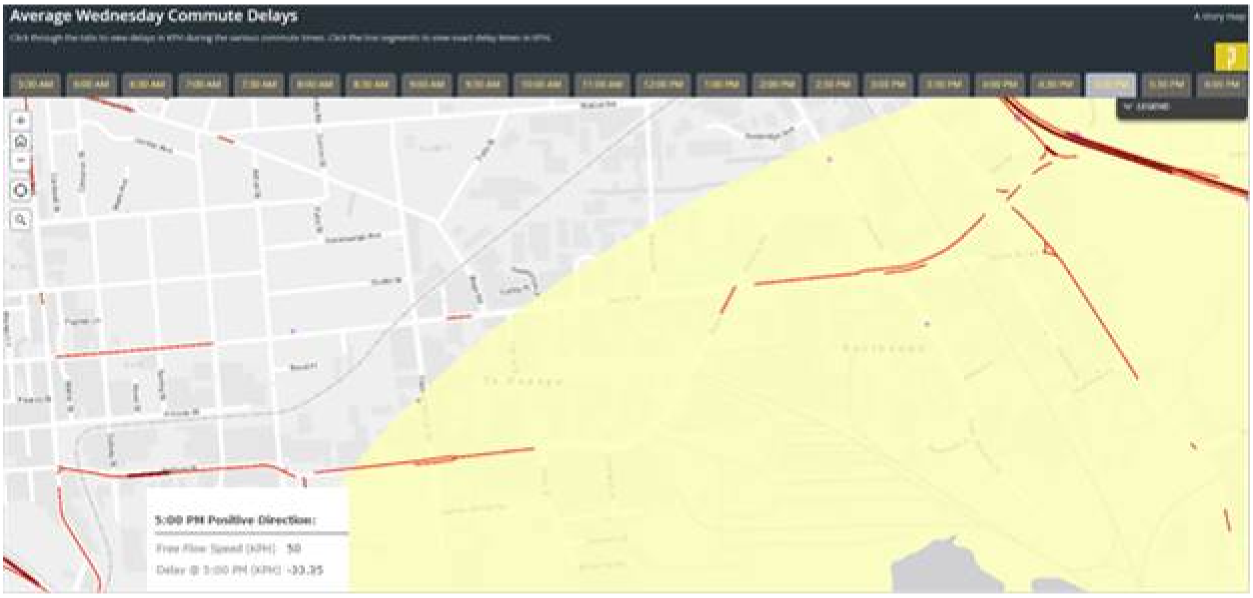


Figure 8.3 Level of congestion during evening peak on Neilson Street



8.1.4 Description of application

The application will use a combination of real-time and historic travel time data to provide travel time and travel time reliability estimates for freight operators. This information will be delivered across two platforms: a web application covering the entire Auckland road network, and through VMS at strategic locations on the network.

Real-time and historic travel time (two-year rolling average) data will be sourced from a GPS data vendor potentially using the Bluetooth sensor network as discussed in section 4.2.1. Algorithms will be developed to accurately predict expected travel times and travel time variability based on the real-time and historic travel time profiles. A route with high reliability will show a smaller travel time variability range than a less reliable route.

The travel time dataset will be hosted online as a road network API that allows integration into VMS and the web-based applications. This will be updated in real time or near real time to provide an accurate representation of travel conditions.

The development of a travel time reliability algorithm and API involves the following steps:

1. Building a road network dataset from the chosen GPS product
2. Integrating real-time and historic traffic data into the network dataset
3. Developing the mechanism for updating live traffic information
4. Developing an algorithm for accurately estimating travel time variability based on real-time and historic data inputs
5. Development of an API processing tool for returning travel times and reliability measures based on input origin/destination locations.

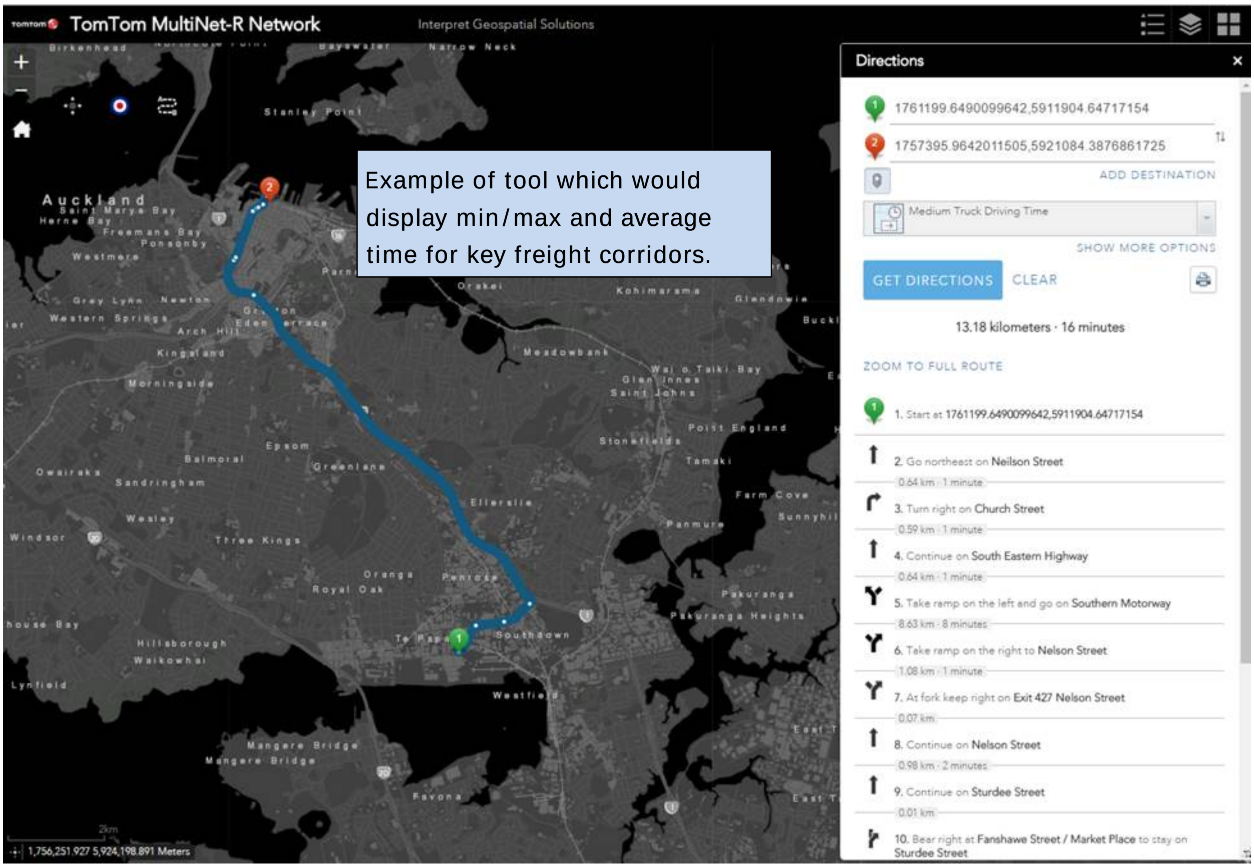
Maintenance of this API will primarily include updating the network dataset service with new base data when available, which is currently quarterly.

A web application will be developed based on the API that will enable freight operators and drivers to plan freight trips. This will be available via desktop application for pre-trip planning, and also available for real-time use on mobile devices. The application will require an internet connection for accessing the web-based application.

An example of a basic web-based routing application using historic speed profiles on which the journey predictability tool can be developed is shown in figure 8.4. The features of this web application will include:

- compatibility across operating systems
- the ability to optimise a route between multiple destinations
- calculation of routes based on vehicle type and classification
- the ability to display and print turn-by-turn driving directions
- estimated time intervals and distances
- location search.

Figure 8.4 Web- based routing application example



For the VMS application, the API can be adapted to provide travel time reliability estimates between fixed locations. Feedback from the industry suggests the use of colour to alert drivers to trip travel times that are worse than average for the time of day. For example, orange for congested and red for heavily congested. In addition to this the use of historical data to inform predictability can utilise arrows to display if the travel time is predicted to increase or decrease.

8.1.5 Overview of costs

For the web-based tool, the costs are related to software development and data licensing, analysis of GPS data and the cost of VMS hardware and implementation. The specific costs will be sensitive to the choice of vendor and full specification of the tool. Austroads (2003) estimates the capital cost of VMS as A$280,000 per sign, with annual recurrent costs of A$10,000 per unit. This type of large VMS is only used in New Zealand for a motorway. Signs for an arterial road are more likely to be a type D travel information sign at a cost of between $25,000 and $40,000 plus GST depending on the use of colour.

8.1.6 Overview of benefits

The primary benefit of this application over existing routing applications is the inclusion of the travel reliability measure giving freight drivers a better understanding of travel time variability, not just the average time.

For freight operators, this application will:

- improve visibility of expected travel times
- reduce uncertainty of effects of traffic congestion on operations, including fuel savings and reduced driver frustration
- improve preplanning, schedule and delivery window adherence
- improve management of driver hours and break requirements
- reduce congestion at depots and destinations through better preplanning and journey time prediction.

Some of these less tangible benefits will be difficult to quantify.

Driver frustration from network congestion and inefficiencies was conveyed very strongly by stakeholders. Technology that can reduce or remove driver frustration is likely to have a positive impact on safety through improved decision making relating to gap acceptance, intersection movements and route choice.

Estimates of benefits from roadside driver information (VMS) reportedly led to a 16% reduction in travel time in Piraeus, Greece (Austroads 2003).

The cost to congestion or delay to the freight sector was expressed by industry stakeholders as approximately $90–$120 per hour standing cost per vehicle. This is consistent with US literature, which reports a 2014 national average operational cost per hour of US$68 (NZ$100) per commercial truck (American Transportation Research Institute 2016). The cost of spoilt goods is additional. Extrapolating this cost out over the number of freight vehicles on the Auckland network daily indicates travel time saving through information provision on network conditions can translate to a significant benefit in vehicle operating costs to the freight industry.

8.1.7 Other considerations

A limitation of this approach is the availability and reliability of real-time and historic speed data. Further scoping is required to understand the implications of this based on available datasets. Travel time reliability calculations will be based on both datasets and therefore rely on accurate and timely provision of data and potentially significant real-time data processing capabilities. Consideration will also need to be given to how human factors relating to reliability are represented and what are regarded as critical thresholds.

The algorithms required to estimate travel time variability need to include a mechanism for ensuring recent road network and operational changes, as well as road works and other temporary traffic management measures are incorporated into the calculations. If the travel time variability measures are not consistently accurate, then drivers may lose trust in the application and ignore it completely.

A further challenge is the adaptability of the application for advanced route planning as well as in-vehicle use. The needs of each approach vary slightly and the ability to develop a single platform that meets both needs will be challenging. For example, during trip pre-planning, the user may wish to enter multiple destinations and calculate optimal routes based on historic travel time data. The ability to integrate with existing software systems and workflows is also desirable. For in-vehicle real-time use, the key priorities for drivers is to receive up-to-date navigation directions and alerts regarding any incidents or changes to the planned route. Safety is also a primary concern and the application must not distract the driver or require user input while on the road.

Finally, the development of the application and VMS needs to consider how the reliability measures are presented to drivers, taking into account human factors. Adding travel reliability measures may introduce clutter and be distracting or misinterpreted by users and drivers. Special consideration should be given to ensuring the messages are simple, easy to understand and match the needs of the users.

There are potentially benefits in all vehicular traffic having visibility of the range of likely travel times on key journeys, therefore the scalability of this solution is also an important consideration.

Consideration should also be given to the collection, ownership, management and use of travel data for the application. Industry and the public may have the perception that data could be used for surveillance, monitoring, enforcement and/or revenue collection purposes which may outweigh the perceived benefits of improved travel time reliability

As a next step, there is an opportunity for the transport sector to determine the feasibility of a trial to incorporate the tool into an existing service provider's system.

8.2 Freight sector network information tool

8.2.1 Overview of case study

The freight sector currently relies on despatch and the driver's experience and knowledge regarding network facilities such as the location of loading zones, weigh stations and other constraints that may impede larger vehicles, for example narrow corridors, challenging road geometry, and weight limits especially for larger vehicles. A web-based tool that shares information relevant to urban freight activities in an easy-to-use platform will benefit the entire freight sector.

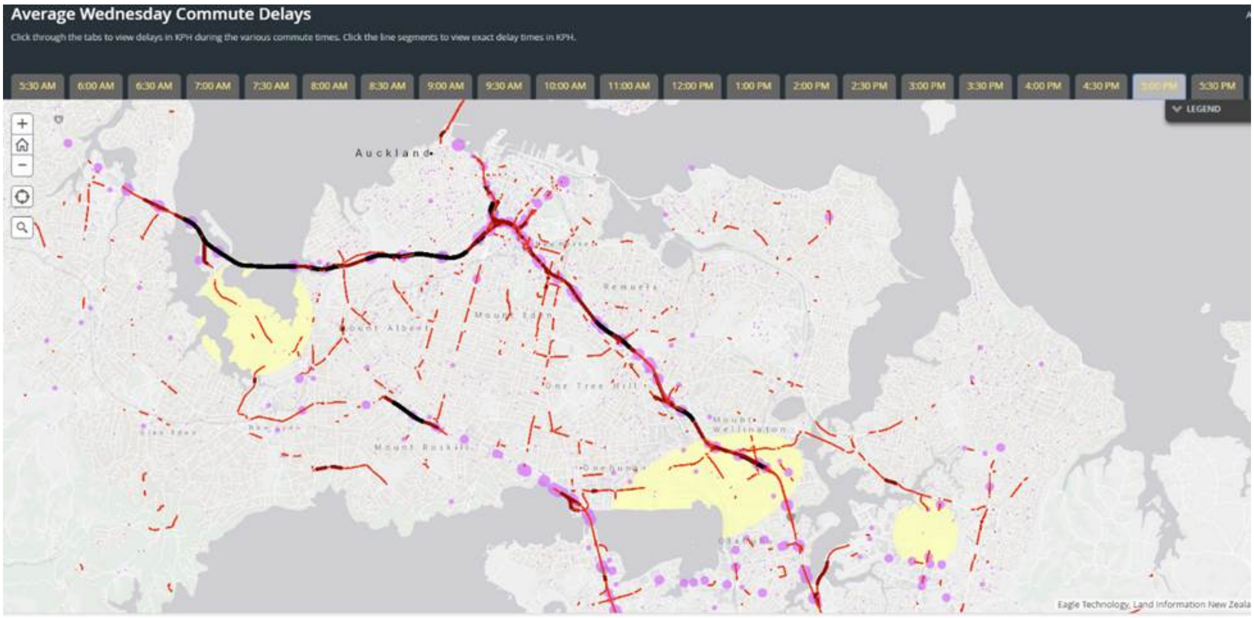
8.2.2 Location: Auckland urban area

The Auckland road network experiences widespread congestion, impeding the movement of urban freight vehicles. The impact of the network deficiencies has a significant impact on the timely and efficient movement of goods and the efficient operation of the freight sector, and a network-wide information tool has the potential to assist the freight sector across the board.

8.2.3 Extent of congestion

Figure 8.5 illustrates congestion across the Auckland network, focusing on the isthmus and surrounds during the evening peak period. While areas are affected to a greater or lesser extent, it is evident congestion is clearly widespread.

Figure 8.5 Congestion on the Auckland network in evening peak



8.2.4 Description of application

A freight sector network information tool can be developed as a map-based platform. This would empower the freight sector with location-specific information on key aspects relating to the accessibility and movement of freight vehicles around the Auckland urban network.

A significant amount of freight network information is already available from different data sources, including the commercially available road centreline data. Missing information can be obtained from survey data collection, and supplementary and updated data can be sought from the freight industry using a crowdsourcing interface. This allows the transfer and sharing of local knowledge and experiences across organisations.

Information already available in some format, which would be beneficial to the freight sector includes:

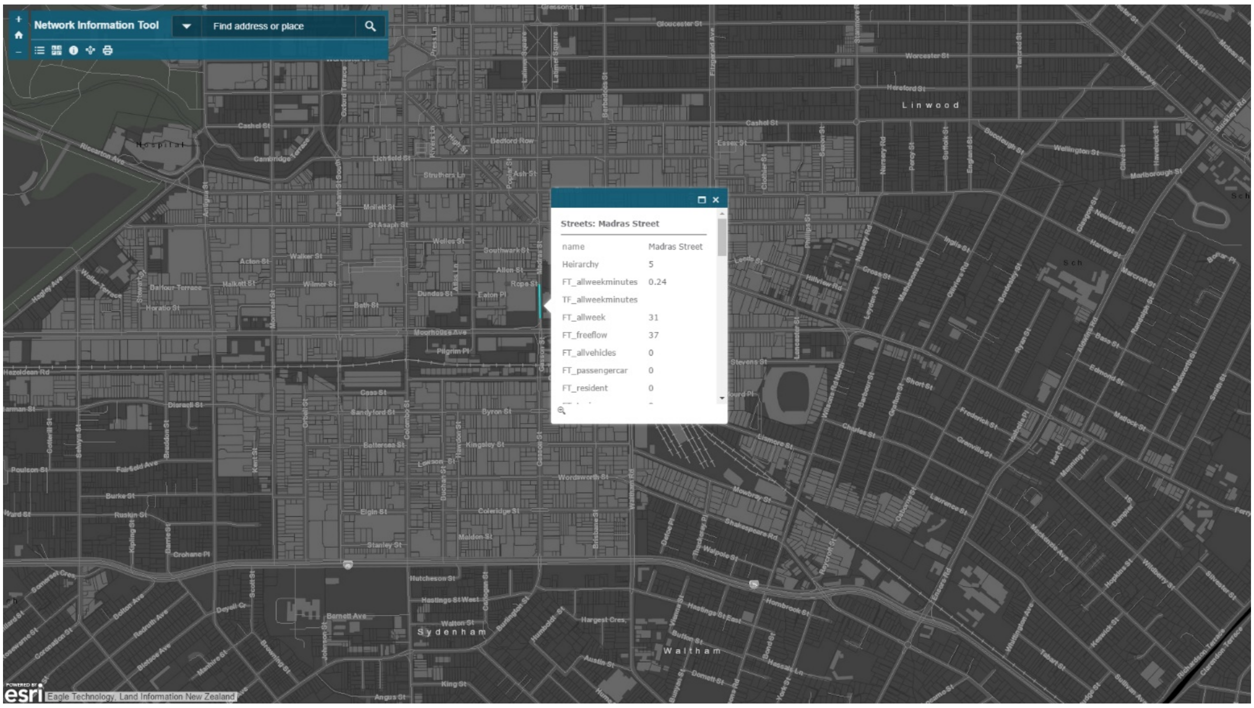
- traffic signals
- roundabouts
- bus lanes
- height restrictions
- weight restrictions
- speed restrictions
- freight priority ramps/T2/T3
- service roads and carpark entrances/exits
- blocked access roads
- axle restrictions
- excessive curvature (tight corners)
- gradient
- medians (raised/flush)
- lane/road width
- number of lanes
- high productivity motor vehicle routes
- unsealed/poor quality roads
- roads under construction
- private roads.

Additional information relating to loading zones and P5 spaces which would be beneficial to the freight sector, but not currently available includes:

- location, length and width of loading zones or P5 spaces
- side loading and/or rear loading status
- loading zone hours of operation
- road furniture or other obstacles that have an impact on the usability of loading zones
- weigh stations
- shared spaces.

Figure 8.6 shows a basic prototype of how a network information tool could be presented. The application could use a mix of link or point-based features representing roads and roadside infrastructure. This information needs to be in a format that can be easily searched and accessed. This can be achieved by building in location-specific queries such as 'Where is the nearest loading zone?'. Other restrictions such as difficult alignments, exceptionally narrow roads or weight restrictions can also be flagged on the map.

Figure 8.6 Example of a network information tool



There is an opportunity to crowdsource further information from freight operators to help keep the network datasets up to date and to provide further detail on the quality of road infrastructure. For example, this might include reporting new loading zones or restrictions, and identifying qualitative details that affect the ability to access certain sites or loading areas.

Subject to licensing restrictions for commercial datasets, this information should be shared using open data platforms or APIs, enabling developers and other interested parties to build custom applications or to incorporate this information into existing freight planning and routing systems.

8.2.5 Overview of costs

For the freight sector information tool the key costs relate to the development of an application and the ongoing cost of data collection, updating and validation. The accommodation of any crowdsourced inputs will require additional development work and administration to moderate and validate the inputs.

8.2.6 Overview of benefits

The benefits for the freight sector are:

- increased local awareness and knowledge sharing
- increased efficiency
- reduced congestion caused by parked or waiting vehicles
- a common framework for freight industry information storage
- ability to select the appropriate vehicle based on road restriction,
- improved safety
- reduction in circulating vehicles
- a timely and updatable system.

As outlined in section 8.2, the cost to congestion or delay to the freight sector is approximately $90–$120 per hour standing cost per vehicle excluding the cost of spoilt goods. Extrapolating this cost out over the number of freight vehicles on the Auckland network daily indicates travel time saving through information provision on network conditions could translate to a significant benefit in vehicle operating costs to the freight industry.

8.2.7 Other considerations

A key consideration for this tool is the accuracy of the data. While much of the detail can be collected through surveys and supplemented through crowdsourcing, there is always the chance features could be misinterpreted or misrepresented. Data validation and quality matters need to be addressed through quality assessments and field validations. Incorrect information can lead to decreased efficiency and increased travel times. There are also licensing matters that need to be considered regarding data sourced and shared from existing commercial road datasets.

The safe use of this data also needs to be considered, particularly how drivers will access the application while driving.

Industry feedback endorsed this concept as a planning and service tool to understand loading zones and their utilisation rates.

The next step is for the transport sector to engage with telematic providers to determine if there is commercial value or opportunity for the tool in the private sector.

8.3 Intersection freight priority using CCTV video analytics

8.3.1 Overview of case study

CCTV technology is increasingly used for traffic monitoring purposes with approximately 1,600 cameras active in Auckland and accessible through a single video management system at the Auckland TOC. The application of video analytics to interrogate CCTV footage is emerging and facilitated through a graphic user interface. A potential application of video analytics is to understand network impedance by vehicle type, through the scanning of video footage and isolating the movement of a selected mode through an intersection. Identifying the presence of freight vehicles from the general traffic stream provides an opportunity to apply a separate treatment for this vehicle class.

In particular, the application of video analytics technology to process CCTV footage in real time may enhance the management of freight vehicles at key intersections by facilitating extended signal green time to these vehicles, reducing queuing and increasing heavy vehicle throughput, particularly on inclined intersection approaches.

8.3.2 Location: intersection of Great South Road and Church Street

The intersection of Great South Road and Church Street is situated in a high freight generating area between Onehunga and Mount Wellington and forms part of a crucial link between this area and the southern motorway. The intersection is signalised with lane configuration detailed in table 8.1 and shown in figure 8.7 and signal phasing as shown in figure 8.8. The intersection has high traffic volumes on all approaches as detailed in table 8.1, with a particularly high number of right-turn flows from the east and west approaches and limited queuing space. Heavy vehicles are a large percentage (around 15%–16%) of the traffic using this intersection. Topography is also a factor in the function of the intersection, with the south approach on a slight incline.

Church Street has a two-way AADT of approximately 42,000 vehicles with 16% heavy vehicles. No mid-block counts were available for Great South Road in the immediate vicinity of this intersection.

Table 8.1 Great South Road and Church Street intersection lane configuration

Approach	Street	Number of approaches	Left	Left/ through	Through	Through/ right	Right
South	Great South Road	4	2 slip	-	1	1	-
		AM peak hour volume	751	-	301	333	-
		PM peak hour volume	702	-	396	328	-
East	Church Street	5	-	1	2	-	2
		AM peak hour volume	-	268	1,102	-	438
		PM peak hour volume	-	197	797	-	280
North	Great South Road	4	1 slip	-	2	-	1
		AM peak hour volume	163	-	406	-	242
		PM peak hour volume	389	-	490	-	246
West	Church Street	6	1 slip	-	3	-	2
		AM peak hour volume	305	-	966	-	582
		PM peak hour volume	303	-	1,331	-	598

Figure 8.7 Intersection of Church Street and Great South Road Auckland (source: Google maps)

Figure 8.8 Signal phasing for intersection of Church Street and Great South Road Auckland (Auckland Transport)

8.3.3 Extent of congestion

Both Great South Road and Church Street have posted speed limits of 50km/h and experience congestion because of queuing at the intersection as shown in figures 8.9 and 8.10 in both the morning and evening peak. The free-flow speeds and level of impedance for each of the approaches are summarised in table 8.2.

Figure 8.9 Congestion in vicinity of Great South Rd and Church Street intersection in morning peak

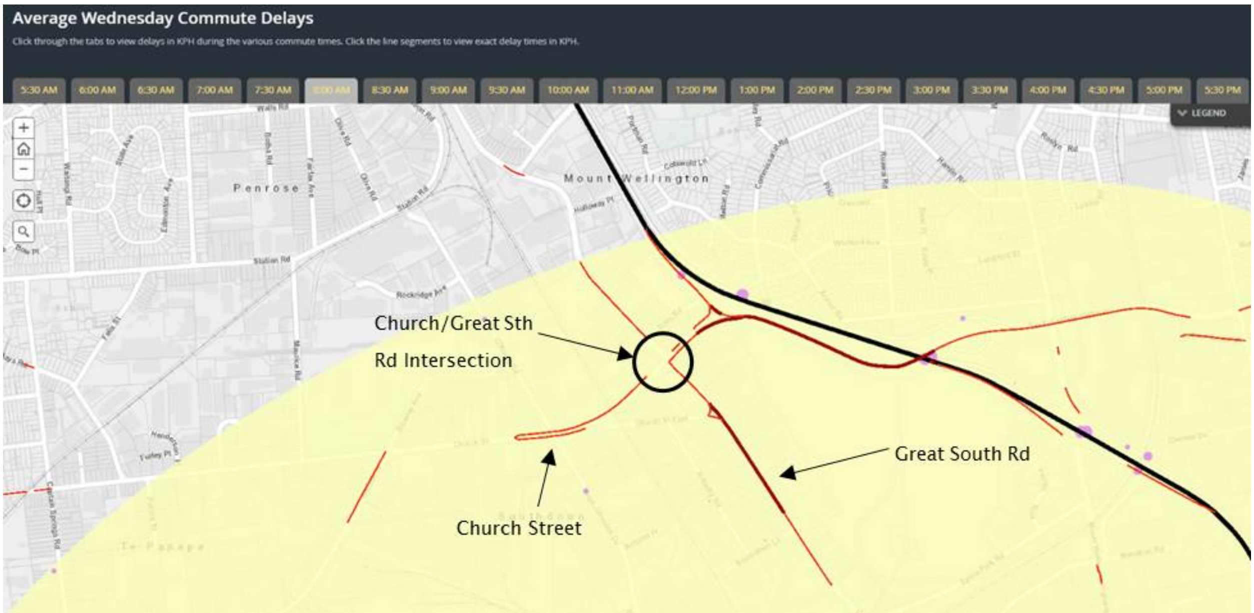


Figure 8.10 Congestion in vicinity of Great South Rd and Church Street intersection in evening peak

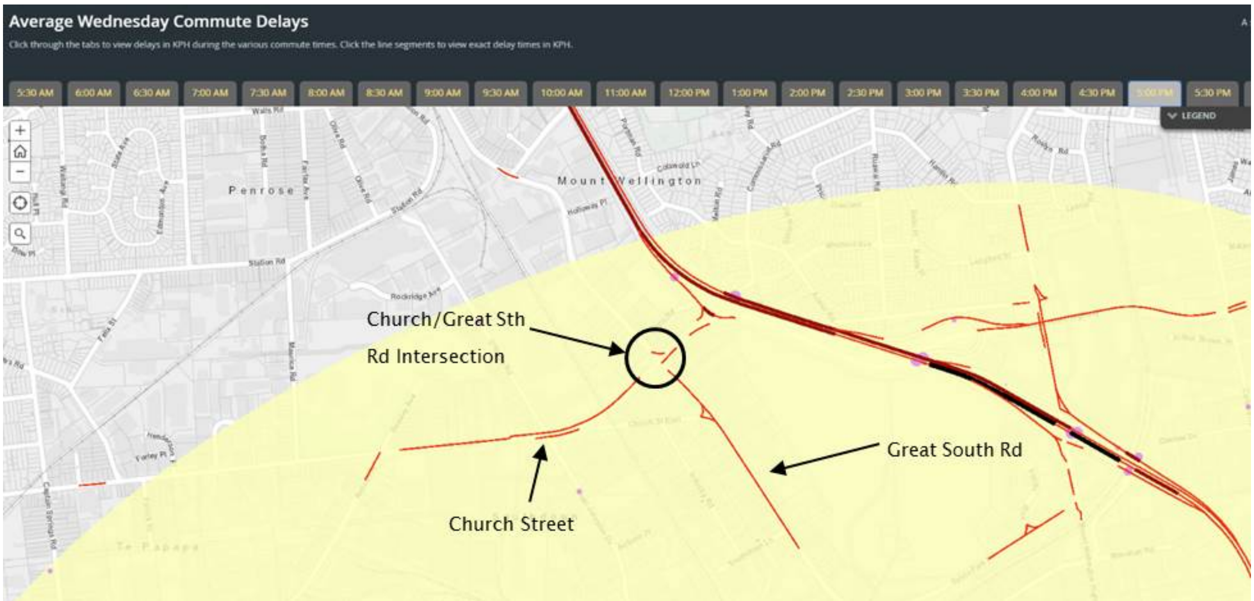


Table 8.2 Great South Road and Church Street intersection approach delays

Approach	Street	Number of approaches	Free- flow speed (km/h)	Deviation from free flow (km/h)	Free- flow speed (km/h)	Deviation from free flow (km/h)
			AM peak		PM peak	
South	Great South Road	4	27	-16.93	35	-17.78
East	Church Street	5	36	-22.57	36	-15.73
North	Great South Road	4	44	-19.45-	44	Less than 15km/h
West	Church Street	6	40	-16.36	40	-15.8

8.3.4 Description of application

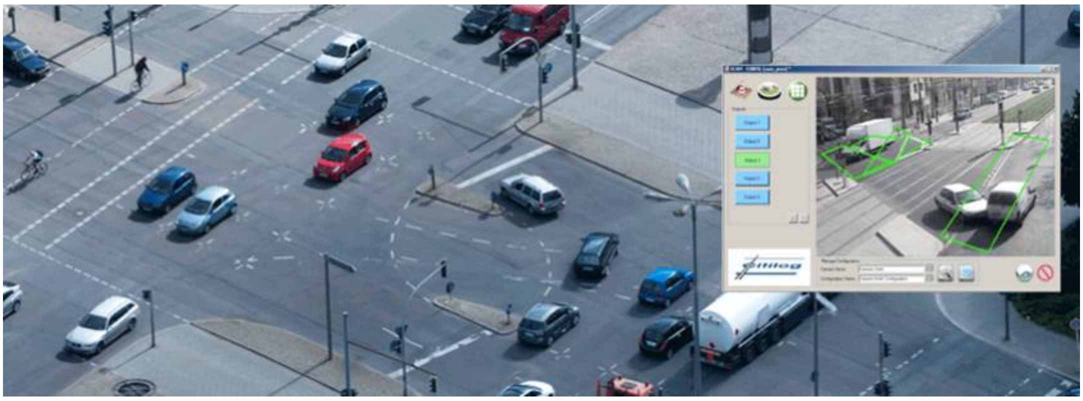
Hewlett Packard Enterprises have developed video analytics capability and work with the Auckland TOC to provide analytics support on suitably high-resolution CCTV camera video footage on the Auckland network. A query specifies frame size and vehicle parameters and then the software identifies images from real-time streaming video data that meets these specifications. A video analytics query can be developed to identify the presence of one or more heavy vehicles queued in the two short right-turn lanes from the Church Street west approach. Care will be required to ensure the camera is correctly located to minimise obscured vehicles and camera shaking on light poles or mast arms. A view from the driver's perspective of the right-turn lanes is included in figure 8.11.

When multiple heavy vehicles are detected and the signal's SCATS detectors identify the right-turn lanes are full, it is proposed an extended right-turn phase for Church Street traffic be allocated to assist southbound heavy vehicles and to avoid right-turning traffic from blocking back into the adjacent through lanes on the western approach to the intersection. The length to which the right-turn phase timing is extended needs to be carefully calibrated to avoid adverse effects on other vehicles travelling through the intersection. The communication link with SCATS from video analytics has not been tested in Auckland; however, Auckland Transport is currently testing the analytics. Timestamping is important to understand occupancy and gaps between vehicles. Current analytic capabilities do not appear to be able to provide gap times unless the camera is installed directly over the top of a vehicle.

Figure 8.11 Driver's view of western approach right- turn lanes (source: Google street view)

Citilog MediaCity is an intersection control software solution that can be used on existing video surveillance infrastructure as shown in figure 8.12. MediaCity provides real-time queue measurement per traffic lane and can optimise the operation of signals (Citilog 2015).

Figure 8.12 Example of Intersection video analytics software (Citilog)



8.3.5 SIDRA modelling trial

High-level modelling analysis was undertaken on the Great South Road/Church Street intersection using SIDRA Intersection version 7 modelling software for the morning peak (8am –9am) and inter-peak (10am–11am) to determine the likely benefits during peak and off-peak periods.

SIDRA Intersection offers a range of outputs for any given model. The outputs selected for this analysis include:

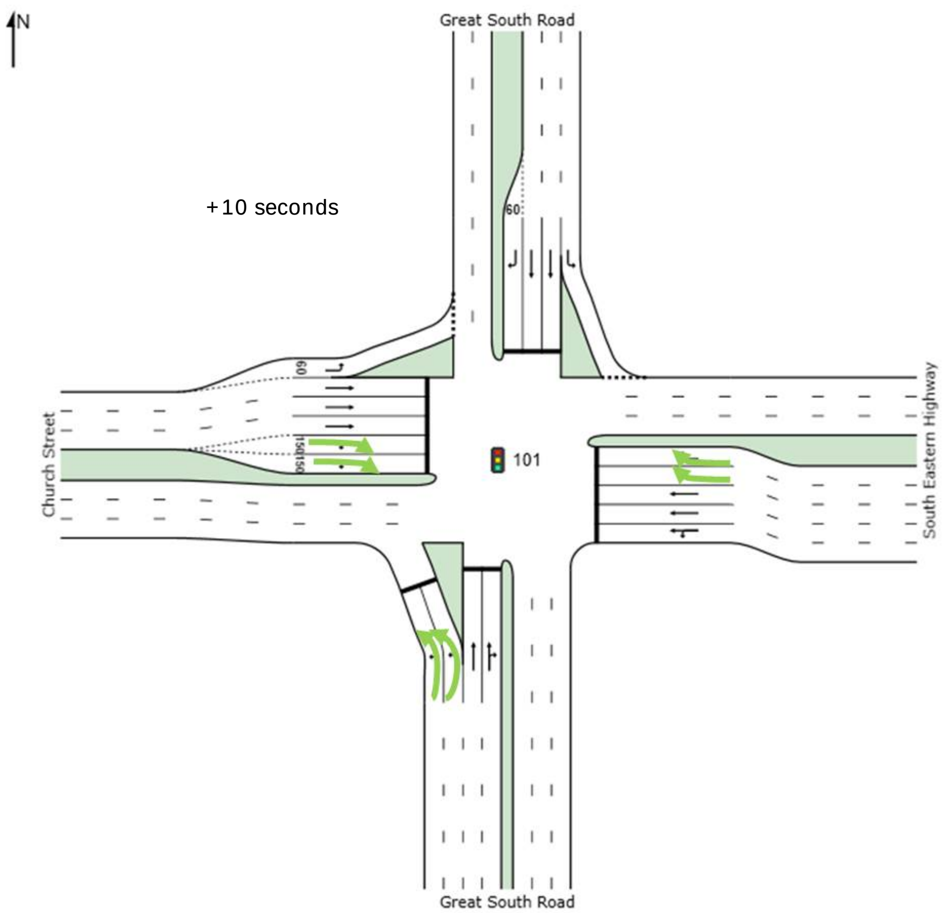
- degree of saturation (DoS)
- average delay (seconds)
- level of service (LOS)
- 95th percentile back of queue (vehicles).

The DoS is a ratio of the vehicle demand as a proportion of the theoretical capacity of the intersection. A DoS equal to 1.0 indicates the intersection is operating at its maximum theoretical capacity. Average delay is the delay experienced by vehicles travelling through an intersection and includes deceleration, stopping and acceleration time. LOS is a traffic engineering measure to describe the traffic conditions in terms of travel time, volume, capacity, freedom to manoeuvre and convenience. The LOS ranges from A to F where A represents the least impediment to vehicle movement and F represents heavily congested conditions. The 95th percentile back of queue is the value below which 95% of all observed queue lengths fall (ie 5% of all observed queue lengths exceed this value).

The layout of the intersection as it appears in SIDRA is illustrated in figure 8.13. The intersection was modelled with existing conditions and then with one of the signal phases extended. To set up the model, the geometry of the intersection and the movements for each approach were configured accordingly. Traffic volumes for each movement and the amount of heavy vehicles were then allocated. Further calibration involved setting the signal phasing and timing as it currently existed. This information was derived by averaging the timing of each phase during a full cycle from SCATS data provided by Auckland Transport. The default number of pedestrians per hour in SIDRA was set at 50, but this was altered to 10 pedestrians an hour, which is more representative of pedestrian movements in the vicinity.

The G signal phase was allocated an additional 10 seconds in the SIDRA model to represent giving additional green time to freight vehicles at the intersection. The movements of phase G which received additional time are denoted by green arrows in figure 8.13 below. This phase includes the movements with the highest heavy vehicle demands at the intersection, and corresponds to a key freight route in Auckland.

Figure 8.13 SIDRA layout of Great South Road/Church Street intersection



The modelling results of the morning peak (8am –9am) shown in table 8.3 illustrate the average delay for the right-turn movement from South Eastern Highway into Great South Road reduced from 64.6 to 60.5 seconds with the additional green time. The left turn from Great South Road and right turn from Church Street also exhibited a slight decrease in average delay. The overall intersection increased in saturation with the extended G phase, from 1.100 to 1.168.

The overall LOS for the intersection remained at LOS E. However, the back of queue distance received a 19% increase, from 251m to 298m. Additionally, the average delay for the intersection increased from 65.2 to 75.5 seconds. Thus, the results found a reduction in performance of the intersection as a result of the 10-second increase of phase G in the morning peak.

The interpeak (10am–11am) analysis found all movements in the G phase to have a decrease in average delay. However for the intersection as a whole there was 1.5% less delay to heavy vehicles and 0.7% increase in delay to light vehicles. Overall, extending the green phase in the interpeak resulted in 0.4% more delay for the intersection as a whole.

Table 8.3 Great South Road/Church Street Intersection SIDRA modelling base and extended signal phasing results.

	AM peak			**Interpeak**		
	Base	**Extension**	**Change**	**Base**	**Extension**	**Change**
Deg sat (v/c)	1.1	1.165	0.065	0.859	0.959	0.1
Average delay (sec)	65.2	75.5	10.3	54	54.2	0.2
Queue distance (m)	251.1	298.8	47.7	187.9	180.9	-7
Total veh delay (minutes)	6,536	7,568	1,032	4,161	4,177	16
Total cost ($) per hour	1,902.63	2,203.04	300.42	1,211.26	1,215.92	4.66

The total cost represents the cost to all vehicles travelling through the intersection at the given peak hour.

8.3.6 Overview of costs

Costs will vary depending on specific site and application circumstances; however, Tomecki et al (2016) indicate an average cost of $50,000 per site to install high resolution CCTV in Auckland. Additional costs to use video analytics may be required to complete a trial.

8.3.7 Overview of benefits

The benefits for the freight sector are:

- improved travel times and travel time reliability through reduced wait time for right-turning vehicles
- improved heavy vehicle throughput at intersection
- increased fuel efficiency through reduced stopping
- reduction in emissions and pollution
- other potential applications of video analytics including loading zone enforcement and safety.

Consideration needs to be given to the different generalised costs for light and heavy vehicles with the cost to heavy vehicles being approximately three times greater than light vehicles. Generalised cost equations are calculated as a function of time and distance using the guidance of the NZ Transport Agency (2016) *Economic evaluation manual* (EEM).

Light vehicle time is calculated from a weighted average of the base values of time published in table A4.1(a) of the EEM. According to table A2.4 of the EEM the typical weekday urban arterial split of work travel, commuting and other non-work travel by cars is 20%, 20% and 60%. Heavy vehicle time is also calculated using table A4.1(a) based on a medium/heavy commercial driver base values of time. According to table A2.4 of the EEM the typical weekday urban arterial split of work travel, commuting and other non-work travel by MCV/HCV is 90%, 5% and 5%. The greater proportion of work travel and higher operating costs results in a greater value of time and cost for heavy vehicles than light vehicles. The full set of assumptions are documented in Nelson arterial investigation project model update report (Abley Transportation Consultants and Beca 2015).

No specific literature on trials implementing video analytics to optimise an intersection could be sourced; however, Citilog (2015) states intersections using MediaCity experienced a 12%–15% reduction in average wait time. In addition, Tomecki et al (2016) cite a study of 26 traffic signal optimisation projects in Texas that found signal optimisation benefits outweighed costs by 38 to 1, although no details of the study were provided.

8.3.8 Other considerations

Additional considerations to be explored further include:

- technical feasibility of the video analytics scenario including compatibility with SCATS (the research team will engage with both Hewlett Packard Enterprises and the Auckland TOC regarding capability, infrastructure and systems)
- exploring functionality within SCATS. SCATS are likely to multilevel priority as part of their future rollout and the potential to provide this via an approved mobile device or cell phone
- understanding the extent of both light and heavy vehicle queuing
- monitoring impact on overall intersection performance to ensure changes in signal timings do not adversely affect side-road operation, delays for other traffic and modes of transport.

Due to a strong desire to see a benefit for freight movements in this area, proceeding to a trial of CCTV and video analytics application to dynamically adjust SCATS phasing to reduce the queueing of freight vehicles is recommended.

8.4 Cooperative intelligent transport system freight corridor

8.4.1 Overview of case study

The application of CITS technology fitted to trucks to facilitate open communication with the infrastructure could be trialled on a key freight corridor. The aim of CITS is to smooth the flow of traffic by allowing freight vehicles to receive additional green time to reduce the number of times a truck needs to stop along a high-volume freight corridor. We understand Auckland Transport is currently testing the feasibility of CITS communications, and Hewlett Packard Enterprises have successfully tested it overseas.

There is potential to combine Bluetooth with SCATS to provide traffic volume and travel times, and many precedents in terms of bus pre-emption with waypoints approximately 80m upstream from an intersection are already in place. Switching pre-emption functionality to freight vehicles along a key freight corridor could be trialled to understand possible efficiency gains. The potential locations include:

- Great South Road between Manukau and Mt Wellington

- Saleyards Road south of Great South Road
- Corridors from Allied Concrete (Mt Wellington), Holcim or Firth concrete suppliers where deliveries are time critical due to perishable goods.

Saleyards Road/Walmsley Road corridor was considered the most suitable corridor to carry out a study to understand the likely impact of a CITS tool that could prioritise freight through a series of signalised intersections. However, it may also be beneficial to consider corridors with intersections that are nearing capacity to deliver an intervention that provides benefits and delays the onset of intersection saturation.

8.4.2 Location: Saleyards Road/Walmsley Rd corridor

The Saleyards Road/Walmsley Road corridor in Otahuhu provides a connection between Great South Road and James Fletcher Drive via Kaka Street, and Great South Road and Mangere Road. The area is populated with commercial operations including transport, vehicle sales and servicing, shipping containers and warehousing. The route has a high density of urban freight movements as shown in figure 8.14.

Figure 8.14 Saleyards Road, Otahuhu Auckland (Google maps)

Traffic counts on Saleyards Road indicate there is an AADT two-way volume of approximately 20,000 vehicles with 11% heavy vehicles. South of Station Road intersection, Walmsley Road has a two-way AADT of approximately 29,000 vehicles with a similar share of heavies of 10%.

There are signals at each of the Station Road and Kaka Street intersections with Saleyards and Walmsley Roads. The lane configuration and signal phasing for each of these intersection is shown in figures 8.15 and 8.16.

Figure 8.15 Signal phasing for intersection of Saleyards Road and Station Road (Auckland Transport)

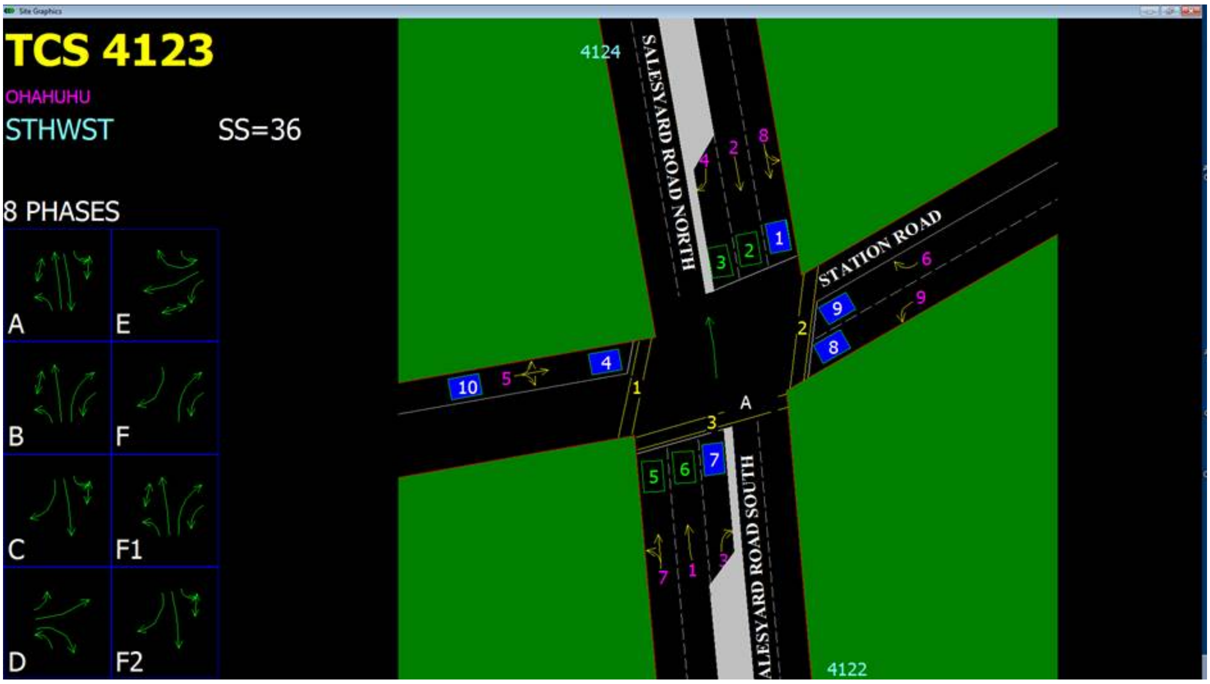
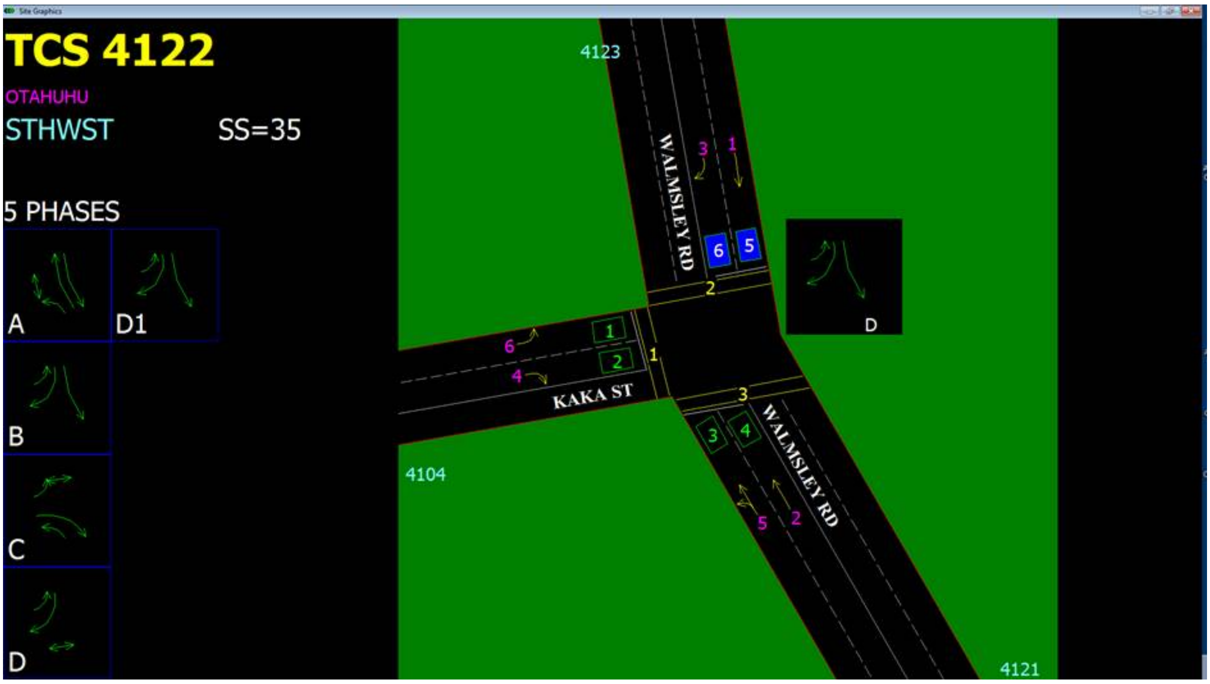


Figure 8.16 Signal phasing for Walmsley Road and Kaka Street intersection (Auckland Transport)



8.4.3 Extent of congestion

Saleyards and Walmsley Roads have a posted speed limit of 50km/h and experience congestion as shown in figures 8.17 and 8.18 in both the morning and evening peak. The level of impedance in the morning peak is approximately 18 km/h from a free-flow speed of 38km/h, and is centred around the intersection with Station Road. The evening peak delay at 5pm is approximately 22km/h below the free-flow speed of 40km/h.

Figure 8.17 Level of congestion on Saleyards/Walmsley Rd corridor during morning peak

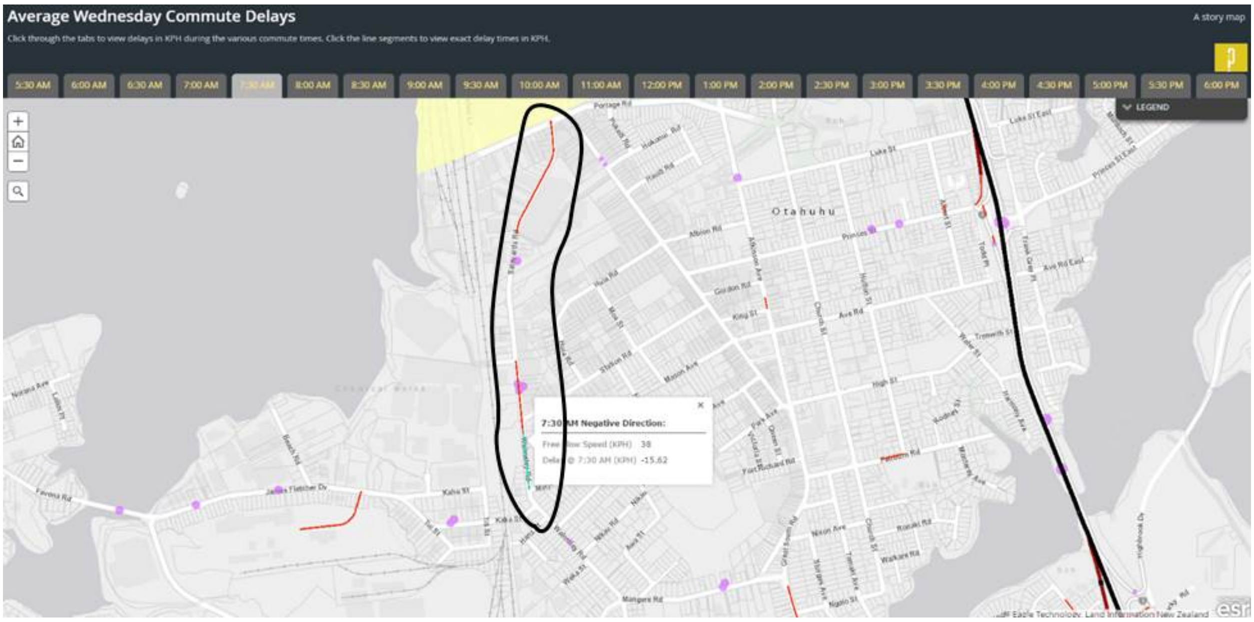
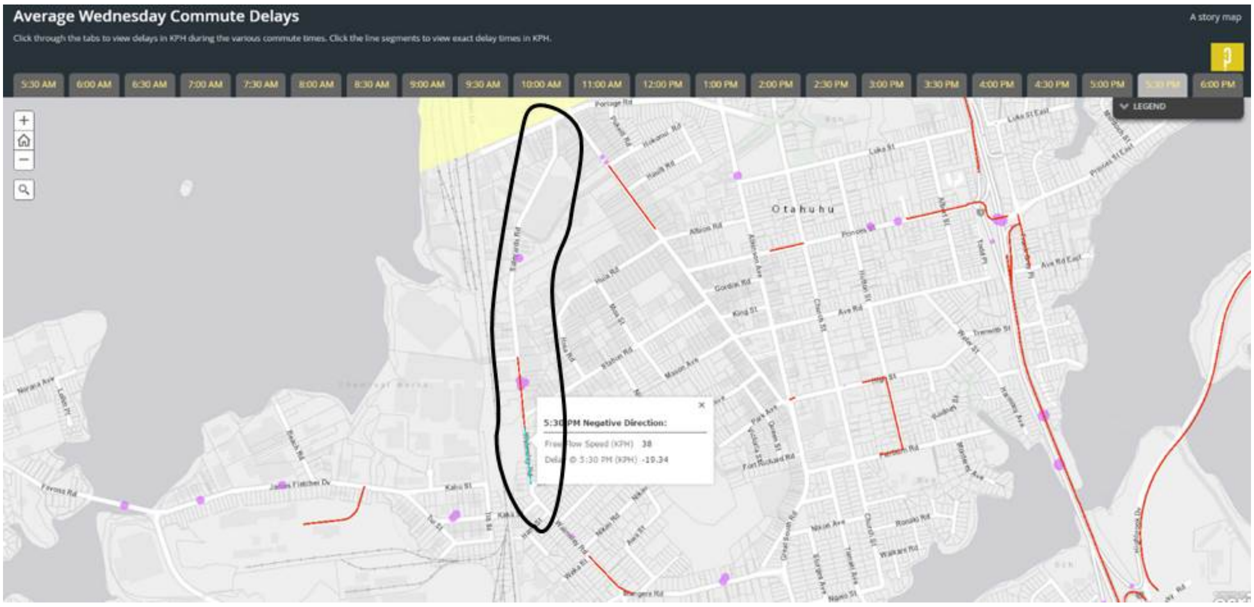


Figure 8.18 Level of congestion on Saleyards/Walmsley Rd corridor during evening peak



8.4.4 Description of application

A signal priority trial could be delivered in partnership with freight companies and a technology partner such as Cohda Wireless. Cohda Wireless is currently commissioned to work on a similar project in New South Wales, Australia. The trial would involve equipping trucks with a Cohda dedicated short-range communications on board unit as shown in figure 8.19 and connect smart infrastructure units to traffic signal control cabinets. A trial may be limited to certain times of day to ensure that the signal timings are only adapted at those times when there are clear benefits for freight movements along the corridor.

Figure 8.19 Cohda dedicated short- range communications device

An alternative option is the use of a cooperative ITS system to advise vehicles of the optimal speed to pass the next traffic light without stopping. This approach consists of anticipating the road profile and the upcoming dynamic events like traffic lights and has been trialled through the French public project Co-Drive using the green light optimal speed advisor developed by Valeo (Lebre et al 2015).

An example of a similar application that links traffic light information with drivers and vehicles is the 'Enlighten' application. This in-car smart phone application tells drivers when traffic lights are going to change, including how long until the light changes from red to green when stopped at an intersection, and whether an upcoming light is about to change to red. This application is currently available in Christchurch, where signals data from SCATS is processed and returned as a countdown or alert to drivers based on their location and direction of travel. A screenshot of the application interface is shown in figure 8.20.

Figure 8.20 Screenshot of the Enlighten interface showing the red- light countdown (Source: Connected

Signals)

8.4.5 SIDRA modelling trial

Two intersections were analysed in SIDRA along the Saleyards/Walmsley Road corridor:

- Walmsley Road/Kaka Street
- Saleyards Road/Station Road.

Both of these Intersections were modelled in SIDRA Intersection version 7 modelling software using the same process as at Great South Road/Church Street. Pedestrian movements were set at 10 pedestrians/ hour. The proportion of heavy vehicles for both intersections is set to 5%, as informed by Auckland Transport tube counts.

The Walmsley Road/Kaka Street intersection modelling involved extending the D phase by 10 seconds to simulate the signals giving freight vehicles green time as they approach the intersection. The layout of the intersection as it appears in SIDRA and the movements given extra green time is shown in figure 8.21.

Results from the morning peak analysis illustrate how the impact of extending D phase by 10 seconds has minimal impact on overall intersection LOS. The degree of saturation and average delay are both decreased for the through and right-turn movements and the overall 95% back of queue decreases from 32.1 to 27.4 vehicles for the intersection. The results show a negligible impact on intersection performance.

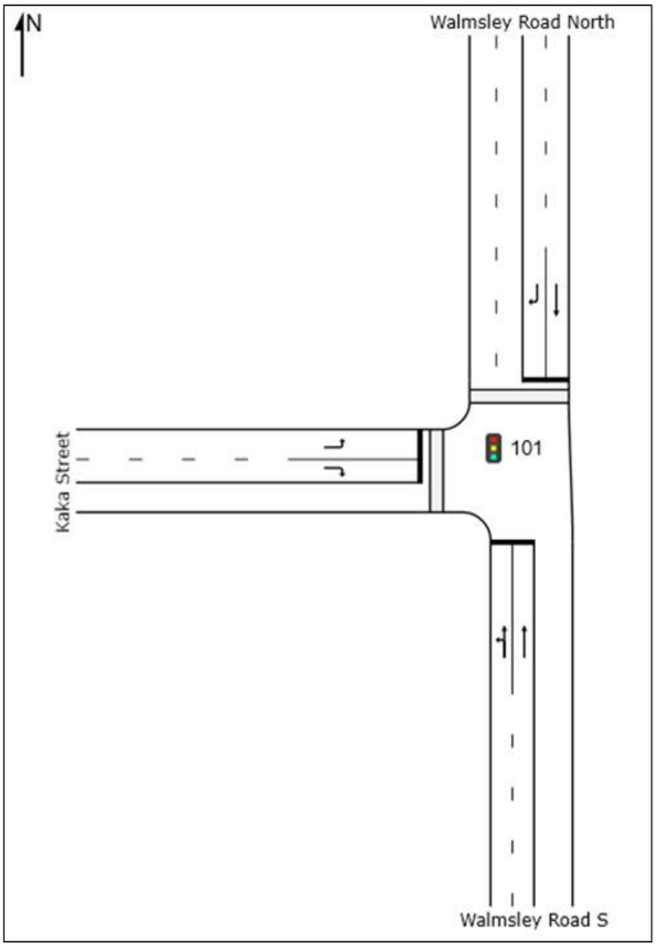
Results from the afternoon peak exhibited a similar trend to the morning peak, where overall average delay was reduced slightly from 31.1 to 28.5 seconds. The Walmsley Road North approach exhibited a significantly improved performance, in particular the right-turn movement, where average delay is reduced by 35%. The 95% back of queue is also reduced for the entire intersection from 39.8 to 32.1 vehicles.

As illustrated in table 8.4, there was a total cost saving of $34.35 (8%) in the afternoon peak with the D phase extended. There was a $9.02 (2%) increase in cost in the morning peak.

Table 8.4 Walmsley Road/Kaka Street intersection SIDRA modelling base and extended signal phasing results

	AM peak			PM peak		
	Base	Extension	Change	Base	Extension	Change
Degree saturation (v/c)	0.91	0.971	0.061	0.929	0.902	-0.027
Average delay (sec)	36.7	37.5	0.8	31.1	28.5	-2.6
Queue distance (m)	234	200.3	-33.7	290.4	234.1	-56.3
Total vehicle delay (minutes)	1,433	1,464	31	1,400	1,282	-118
Total cost per hour ($)	417.15	426.17	9.02	407.54	373.19	-34.35

Figure 8.21 SIDRA Intersection layout of Walmsley Road/Kaka Street intersection



The second intersection on the corridor analysed in SIDRA was Saleyards Road/Station Road. Phase B was extended by 10 seconds, the movements given extra green time are shown in the SIDRA diagram of the intersection as shown in figures 8.22 and 8.23.

The morning peak exhibited overall improvements to intersection performance when Phase B is extended by 10 seconds. Improvements include a decrease in queue distance and reduction in the degree of saturation for the intersection. Saleyards Road South approach saw a slight decrease in average delay and queue distance. The other movement that was modelled with extended green time was the Station Road left turn, which also saw a slight decrease in average delay and queue length.

The results from the two intersections modelled on the Saleyards Road corridor showed no deterioration in overall intersection performance when phases with movements key to freight were given additional green time. This was largely due to the intersection not being highly saturated. When an intersection reaches capacity, changes to existing signal phasing result in greater disbenefits for general traffic. The aim of the trial was to adjust green timing to facilitate greater free flow of vehicles through the two closely located intersections reducing the disbenefits associated with heavy vehicles stopping and starting in close succession.

The morning peak had a total cost savings of $5.82 (1.3%) when phase B was increased. When phase C was increased, there was no cost saving.

Table 8.5 Saleyard Road/Station Road SIDRA Intersection modelling base and extended signal phasing results

	AM peak			PM peak		
	Base	**Extension**	**Change**	**Base**	**Extension**	**Change**
Deg sat (v/c)	0.836	0.74	-0.096	0.792	0.697	-0.095
Average delay (sec)	38.6	38.1	-0.5	33.7	34.1	0.4
Queue distance (m)	160.3	153.1	-7.2	160.3	146.5	-13.8
Total veh delay (minutes)	1,502	1,482	-20	1,371	1,383	12
Total cost per hour($)	427.23	431.41	-5.82	399.10	402.59	3.49

Figure 8.22 SIDRA Intersection layout of Saleyards Road/Station Road intersection with AM peak additional green time

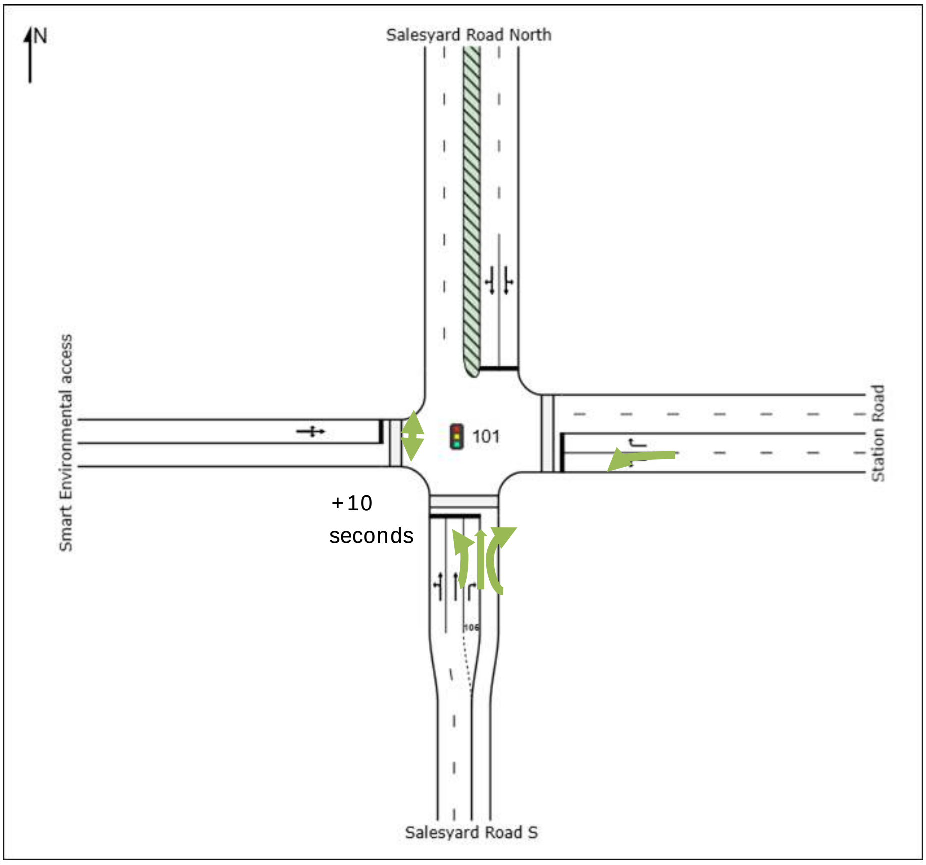
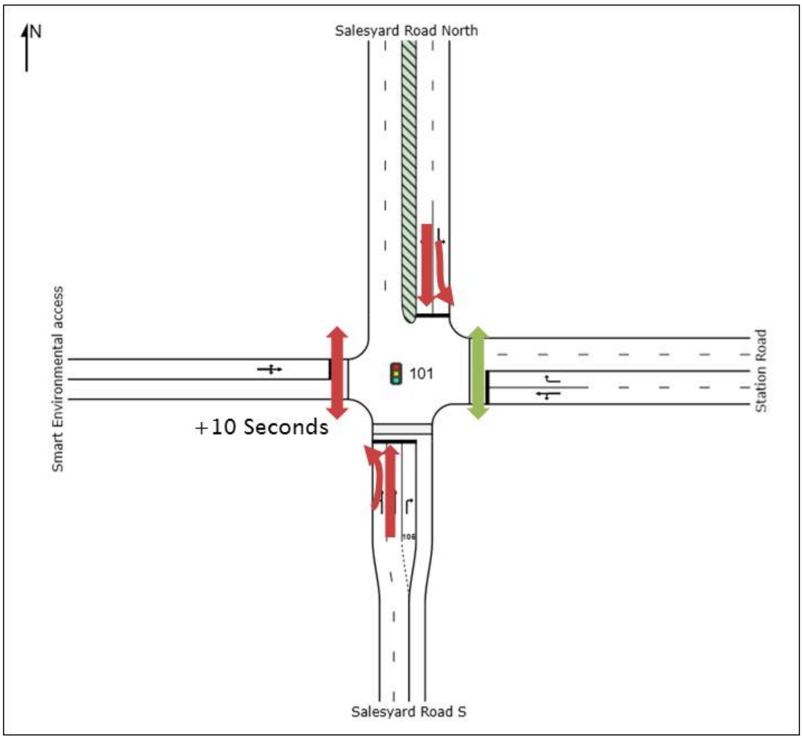


Figure 8.23 SIDRA Intersection layout of Saleyards Road/Station Road intersection with PM peak additional green time



8.4.6 Overview of costs

Cost information pertaining to existing trials in Australia was sought from Transport NSW, Data61 and Cohda Wireless but was unavailable.

8.4.7 Overview of benefits

The benefits for the freight sector are:

- improved travel times and journey time reliability
- reduced emissions, fuel consumption and noise from less stopping, acceleration and deceleration
- other potential applications of the CITS technology including safety.

In order not to understate the benefits, the higher value of time of heavy vehicles to light vehicles needs to be considered. As stated in section 8.3.1 the generalised cost to heavy vehicles is approximately three times greater than to light vehicles.

Tomecki (2016) states co-ordinated traffic signals have been reported as saving between 8% in travel time in Toronto and 20% in Michigan. The variance in reported travel time benefits could be attributed to differences in traffic volumes, local driver behaviour, road configuration, statistical sampling techniques or greater existing SCATS efficiency.

8.4.8 Other considerations

Additional considerations to be explored in future research include:

- GPS accuracy will be essential

- maturity of hardware
- mixed success of application of CITS technology internationally
- uncertainty of compatibility with SCATS (further research with the Auckland TOC would be required)
- understanding the mix of through versus local freight traffic
- changes in signal timings may adversely affect side-road operation increasing delays for other traffic and modes of transport.

Possible positive benefits for freight movements illustrated through Sidra modelling suggest there is merit to proceed to a trial on the Saleyards Road corridor. Further investigation into the feasibility and available technology options is recommended.

8.5 Loading zone management tool

8.5.1 Overview of case study

Improving the accessibility of loading zones and understanding loading and parking zone availability to enable efficient loading and unloading of freight vehicles is a further potential area of ITS application. Using the simple concept of parking sensors, loading zones could be more efficiently managed using a loading zone location application or a loading zone booking system.

It is acknowledged that the management of loading zones on private property is complex and impacts on the greater road network. ITS technology has the potential to increase the efficiency of freight loading/unloading operations in large retail complex. However, planning and design elements that can improve the holding areas for trucks (like those for taxis at airports) also play a crucial role in the efficient movement of freight vehicles. Consideration should be given to whether this problem sits in the private sector rather than the wider Auckland network.

A loading zone management tool would be equally as valuable for managing on-street loading zones and P5 spaces. Data on the exact location and size of loading zones in Auckland is currently unavailable. Mapping this data in the first instance would be key to employing technology to better manage it, then the installation of a sensor system could be rolled out. A trial could focus on highly sought and utilised loading zones in central Auckland.

8.5.2 Potential location: Sylvia Park Shopping Centre

Sylvia Park in Mt Wellington (Auckland) is one of New Zealand's largest shopping centres. It is an expansive complex with 69,000 square metres of lettable space and 3,900 car parks. There are a number of small loading docks suitable for small trucks or vans spaced around the perimeter of the complex. Access to these is often through customer car parking areas as shown in figure 8.26. In addition, there are a small number of larger loading docks for the larger retail stores and supermarkets as shown in figures 8.24 and 8.25. Some of these were observed to have possibly self-imposed time restrictions on receiving inward goods (7am –2pm) and others were fully occupied with parked vehicles during the team's site visit as shown in figure 8.27 and may have only limited availability as loading docks.

Figure 8.24 Loading docks on the east side of Sylvia Park (Google streetview)

Figure 8.25 Larger loading dock and inward goods area at the southern end of Sylvia Park

Figure 8.26 Shared access to small loading dock and larger supermarket loading bay

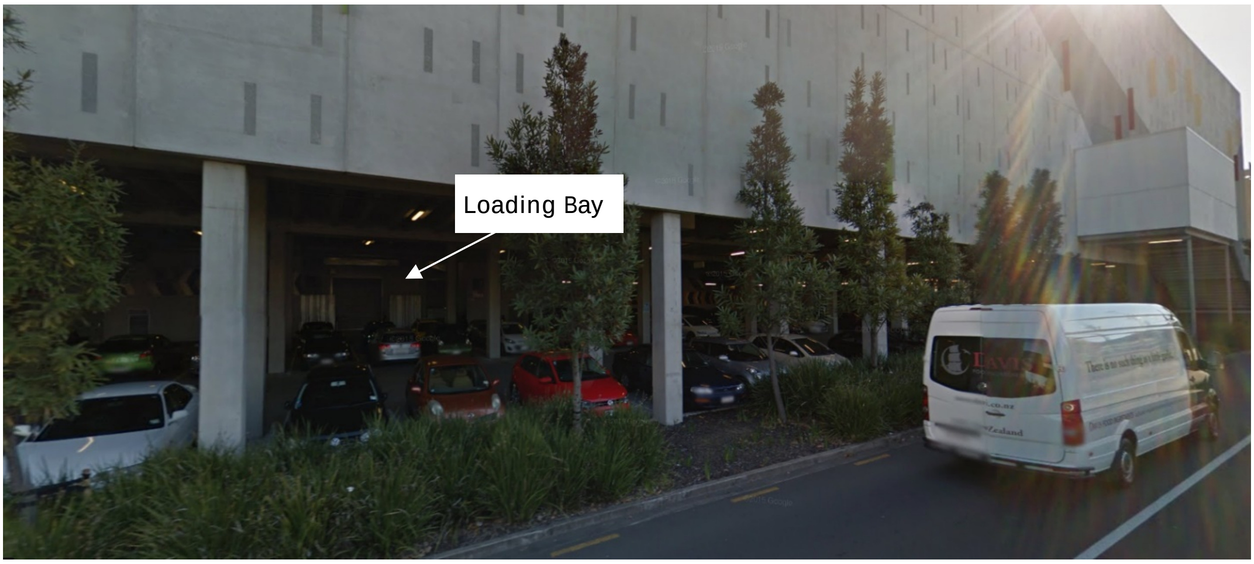


Figure 8.27 Loading dock filled with parked vehicles

The key issue for trucks delivering goods to large retail complexes and developments like Sylvia Park is both the lack of loading bays, and absence of or inadequate spaces for trucks to wait to unload. This issue is partially being dealt with through scheduled time slots to deliver goods, but the use of similar delivery times and windows at multiple locations means vehicles cannot be in several locations at once.

8.5.3 Extent of congestion

The commercial TomTom GPS data did not highlight any significant congestion issues in the morning peak around Sylvia Park as shown in figure 8.28. Congestion at the intersection of Aranui Road and Mount Wellington Highway is present in the evening peak as shown in figure 8.29. The left slip lane into entrance two of Sylvia Park has an impedance of approximately 20km/h at 5pm.

Figure 8.28 Level of congestion in vicinity of Sylvia Park during morning peak

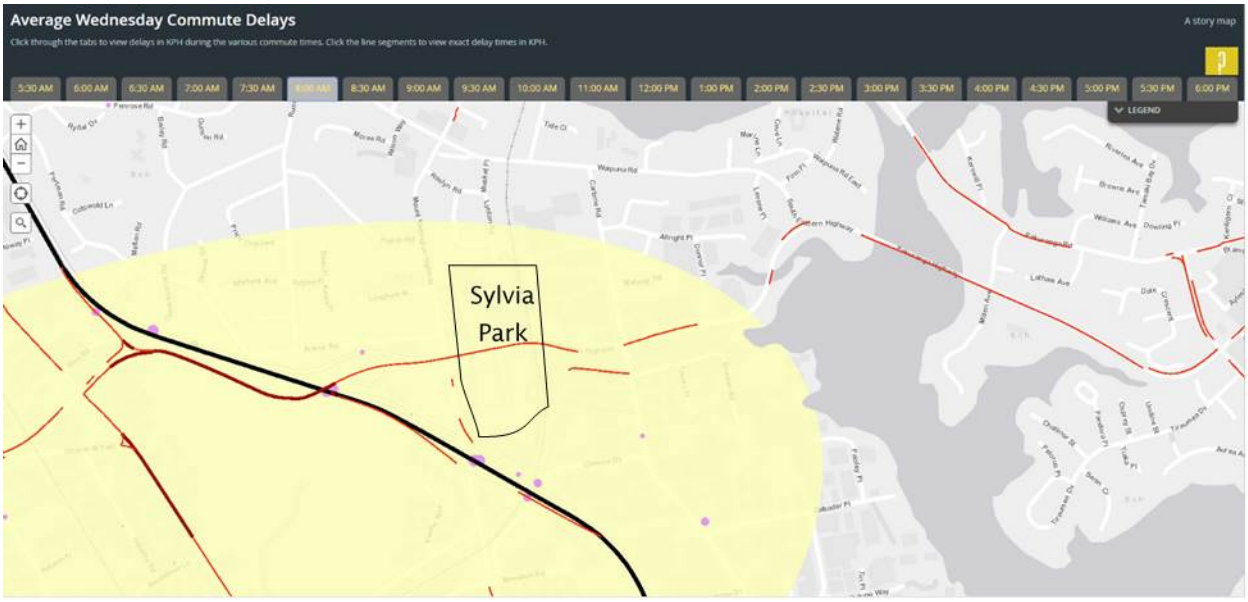
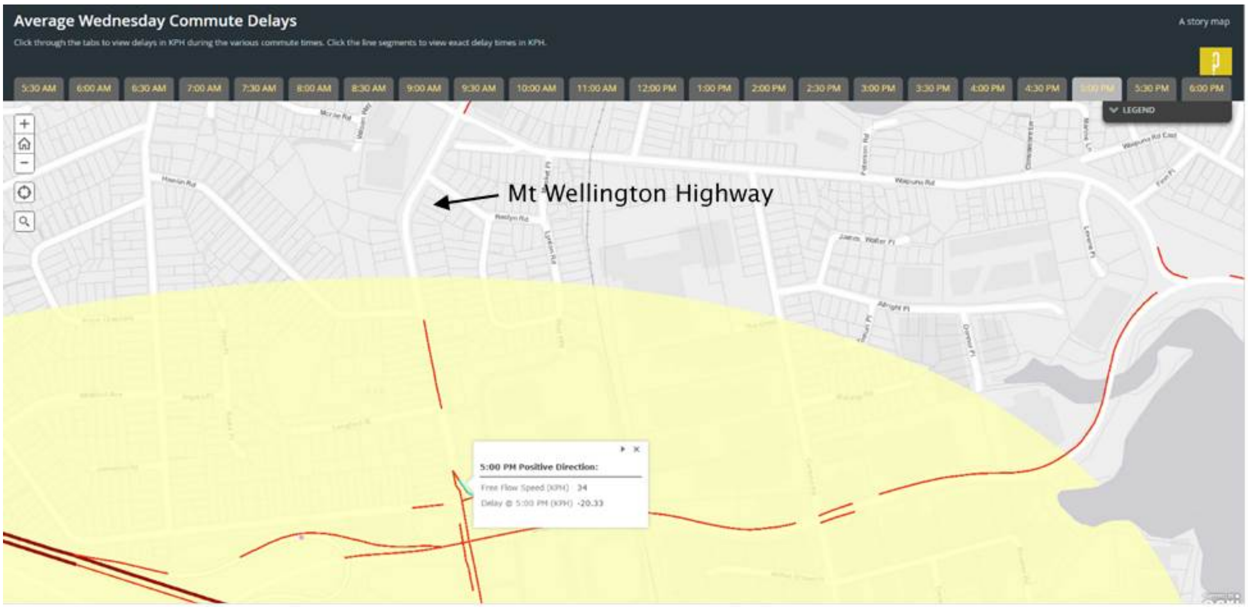


Figure 8.29 Level of congestion during evening peak in the vicinity of Sylvia Park



8.5.4 Description of application

Frogparking and Smart Parking are two known existing real-time applications that use parking sensors to monitor and push out the availability of parking spaces. Frogparking's wireless occupancy sensors are innovative, high-tech hardware incorporating a range of Bluetooth, near field communication (NFC), radio frequency identification (RFID) and wireless iBeacon innovation. Frogparking is currently in operation at Auckland, Wellington and Christchurch airports, and Palmerston North city. An example of the Frogparking off-street and AppyParking on-street application interface are shown in figure 8.30.

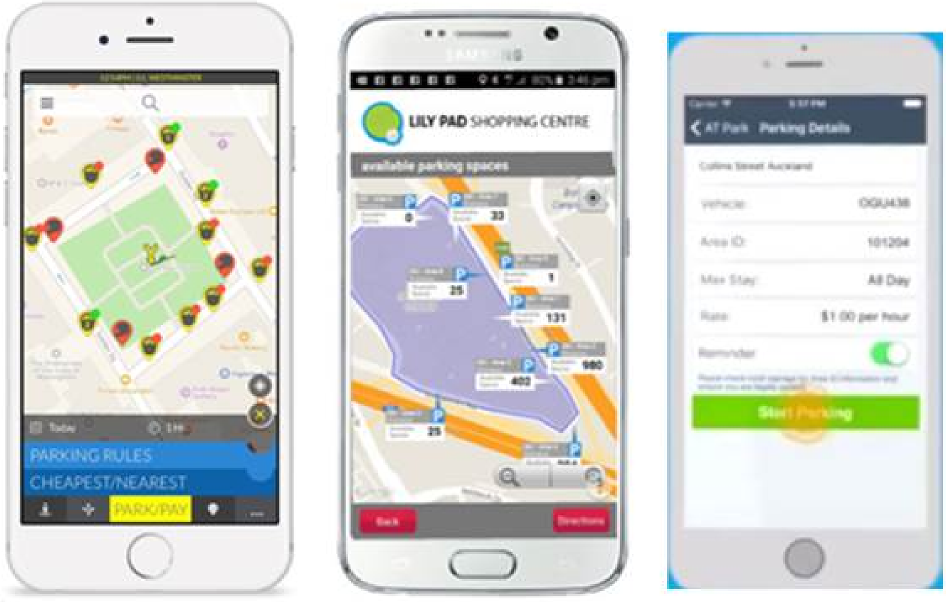
Current use of this type of application appears to be primarily aimed at improving parking turn over and user compliance of parking restrictions. Extending the use for greater emphasis for wayfinding could be trialled to better understand wider network benefits. Data on occupancy, efficiency and flow is valuable for future planning and management, and there is also opportunity for the technology to be used for dynamic pricing.

A sensor-based system and application could be developed to provide information and guidance on the availability of loading bays and loading zones and possibly extended to monitor waiting areas for trucks. This would provide real-time availability of loading zones to reduce circulating vehicles and double parking. These could potentially be used in combination with a loading zone booking system if appropriate.

Bestrane Dock Appointment Scheduling is an example of a system that streamlines the booking process by ensuring all supply chain partners are involved in the process of moving goods to and from the distribution location. Organisations that schedule dock bookings achieve higher throughput of deliveries and pickups, maximising dock asset utilisation (Dock Appointment Scheduling 2016).

Auckland Transport has developed AT Park, a parking application which enables central city parking to be paid for via a mobile application, website, text or phone call. AT Park is available anywhere in Auckland where there is paid parking with AT pay and display machines. Auckland Transport's future development of the application includes enabling vehicles to be directed to parking spaces and loading zones.

Figure 8.30 Example of on and off- street parking applications



8.5.5 Overview of costs

A desktop review of this type of technology was not able to ascertain an approximate cost; however, Frogparking indicates their sensors and systems are easy and cost-effective to install and maintain, and have been operating successfully around the world for several years. Smart Parking was awarded a $1.4 million five-year contract in 2016 for the provision of about 3,000 high-tech parking sensors in Wellington's CBD (NZ Herald 2016).

8.5.6 Overview of benefits

The benefits for the freight sector are:

- improved ability to locate an available loading space, or book a loading bay
- improved trip planning and delivery efficiency
- reduction in circulating or double parked vehicles
- reduced need to load back up trucks to ensure delivery windows can be met
- increased overall productivity of vehicles on the network
- increased safety in and around loading areas
- reduced driver frustration.

8.5.7 Other considerations

Additional considerations to be explored following this research include:

- to develop an application for shopping malls such as Sylvia Park requires close liaison with the Shopping Centre management

- in the wider context of Auckland, the exact location of loading zones appears to currently be unavailable, and obtaining and mapping this information is critical to being able to better manage loading zones
- regulatory and planning measures need to better consider freight movements and delivery requirements (including timings) for developments
- depending on the location of interest, this problem potentially sits more in the private sector, rather than the urban road network.

The loading zone management tool has the potential to be a useful tool for the freight community and the next step would be to determine with the freight community whether there would be demand if the product proceeded to development.

8.6 Benefits

Tomecki et al (2016) report the benefits of advanced traveller information systems to improve drivers' ability to make informed route choices. This corresponded to a reduction in travel delay caused by incidents by up to 70%, up to 20% travel time saving due to informative VMS and up to 50% reduction in secondary crashes at incident sites. While published material generally suggests ITS can provide significant benefits, Tomecki et al (2016) highlight that benefits can also be overstated. An example of this is when a significant number of drivers react to VMS by selecting the same alternate route creating congestion and delay on the alternate route greater than that experienced by vehicles remaining on the original route.

In addition, the recent research by Tomecki et al (2016) identify that the economic value of disseminating traveller information as a result of the implementation of ITS can be difficult to evaluate using the current New Zealand transport project evaluation procedures contained in the EEM. These difficulties include uncertainty as to whether drivers receive relevant traveller information (for example through an application or VMS), whether they act on the received information and whether the expected benefits are derived. None of these can be easily or satisfactorily assessed using the EEM procedures and Tomecki et al (2016) recommend further work into these areas of benefit assessment.

8.7 Safety considerations

ITS technology provided through a mobile application can be a distraction for drivers. Harris et al (2016) discuss the various types of driver distraction that affect the ability of a driver to control a vehicle and respond to environmental conditions. Driver distraction generally falls into one of three types (Rickard-Simms 2015):

- *Physical distraction* – distractions where a driver's attention is diverted away from the road to physically engage with or use an object or device
- *Cognitive distraction* – distractions which happen inside a driver's mind taking the driver's mind away from the task of driving
- *Emotive distraction* – any type of distraction that engages with the driver and can affect a driver's emotions.

Applications to improve the provision of network information and journey conditions should ideally not increase the workload of the driver or cause an unacceptable level of distraction. It is crucial that any development considers:

- the increased risk to the driver if the distraction involves more than two seconds of glance time, or if the driver is required to glance at the device repeatedly over a short-period
- audio output
- voice recognition inputs as these are considered less risky than physical input methods (but can be less accurate)
- platform display as screens of mobile devices can be small, and therefore require longer periods of glance time (Harris et al 2016).

Harris et al (2016) review a number of applications and conclude that those most likely to distract drivers are those designed for private vehicle use and require active and ongoing user inputs. Depending on how they are used, these applications display many potentially distracting items on a single screen, including road hazards, traffic conditions and navigational instruction. In some applications, this hazard is mitigated, to some degree, by restricting text input while the car is in motion, and allowing drivers to enter alerts using voice commands.

9 Conclusions

This research explored existing data sources and the use of technologies to analyse, identify and measure impediments to the efficient flow of freight vehicles on the Auckland road network, and investigated the potential of ITS solutions to better manage network performance and improve journey predictability for urban freight.

An extensive review of both national and international research of ITS applications in the freight sector provided examples of innovative ways technology is being applied to measure congestion and manage existing infrastructure more effectively. ITS forms part of a wider urban freight management plan, alongside regulatory measures, infrastructure, urban consolidation centres and off-hour deliveries. The challenges highlighted from international projects include a lack of reliable data collection and availability, high rates of positioning errors due to ITS hardware immaturity, and system integration.

The research team reviewed the status of the New Zealand digital data marketplace to determine which technologies are currently being applied, with a particular focus on Auckland. The technology applications being used in Auckland city for traffic monitoring are Bluetooth, GNSS (GPS) data, mobile, weigh-in motion, fibre optic, CCTV, traffic counts and SCATS. There are no data sources that isolate freight movements from general traffic. At the time of writing, video analytics software and mobile data in particular were rapidly emerging in the market place.

Stakeholder engagement provided insight into the current urban freight operating environment and informed the identification of significant network impediments. There was a high level of frustration and urgency to find solutions to improve network efficiency and improve operational and financial efficiencies for operators. There was an acknowledgement that technological solutions could have a useful part to play, however the industry sought more substantial solutions to relieve the magnitude of congestion. There was resistance to additional technology platforms in their vehicles as well as caution towards the ownership and use of data being collected for additional enforcement purposes.

The magnitude and location of congestion on urban freight movements in Auckland were demonstrated through the assembly of several resources using GPS data sets. These presented a comprehensive picture of when and where congestion occurs and resultant propagation of delays back through the road network. Several locations where the impact of congestion was significant for the freight sector were isolated to carry forward as potential case studies. Analysis also highlighted the greater network-wide impediment to reliable traffic flow.

The application of ITS solutions has been demonstrated using five case studies to prioritise the movement of urban freight, reducing congestion affecting and increasing the operational efficiency of urban freight operations. The technological solutions proposed and recommendations towards next steps are as follows:

- a freight journey predictability tool – the transport sector and big data providers to determine the feasibility of a trial in conjunction with existing services provided to the Transport Agency
- a freight sector network information tool - the transport sector and telematics providers to determine if there is commercial value or opportunity for a tool to be developed by the private sector
- intersection freight priority using CCTV video analytics – proceed with a trial of CCTV and video analytics to dynamically adjust SCATS phasing to reduce delays and queuing of freight vehicles.
- a CITS freight corridor – proceed to a trial to determine the feasibility and best technologies to support CITS on the Salesyard Road corridor

- a loading zone management tool – engage with the freight community to see if there is demand for a loading zone management tool to be developed.

Each case study describes a possible application of technology, the location within Auckland to be applied and the likely benefits and broader implications for consideration. Positive feedback from the steering group was received and the proposed solutions and engagement with third party suppliers to determine feasibility of proceeding to trial was recommended in two cases. There is a real willingness to see technology improve the level of service on the network for all vehicles; however, there was a consensus that the available technology is still in its infancy.

The objectives of the research were addressed successfully and it was agreed there was limited benefit in proceeding to a detailed cost–benefit analysis of the initiatives. Cost and benefits have been identified at a high level to provide an overview of likely returns of investment.

Technology and the application of technology in the freight sector are moving very quickly. At the time of finalising this report, there were a number of new initiatives, including virtual freight hubbing and mobility as a service marketplace planned by Auckland Transport, that have not been addressed in this report. It is important to follow and understand technology developments to capitalise on opportunities for applying technology to continually and progressively improve the network efficiency and the movement of goods.

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Appendix A: ITS and emerging technology literature review sources

	Network performance indicators											Summary Information				
Reference	Transport volume	Network reliability	Freight industry specific	Freight Management system	Cost/Benefits	On/Off road costs	Transport Policy	Infrastructure & investment	Environmental/sustability focus	Heavy Vehicle Monitoring systems	ITS Definition	Traffic Management systems	Congestion problems	Solutions	Freight	Data use/Challenges/Lessons learnt
Australia/New Zealand																
Traffic management systems for Australian urban freeways - Review of urban congestion trends, impacts and solutions (2006). John Wright, Charles Karl and James Luk, Consultancy Report prepared for Council of Australian Governments.												Compares unmanaged vs managed urban freeways. Managing the allocation of road space.	Summarises causes of congestion and associated costs.	Network intelligence		
CITI - NSW (RMS) Cooperative Intelligent Transport Initiative (FREIGHT) http://roadsafety.transport.nsw.gov.au/research/roadsafetytechnology/cits/citi/index.html			x		x			x		x		✓		✓	✓	
NSW heavy Vehicles (Trucks) linked with Traffic lights http://www.fullyloaded.com.au/industry-news/1604/more-green-lights-for-nsw-truck-drivers/?utm_source=atn_newsletter&utm_medium=email&utm_content=article4_readmore&utm_campaign=20-04-2016&user_id=6d2ef58ec6b0f7d32a72f2422c3499bbd1ce0f7c		x	x					x	x				✓	✓		
Austroads, 2015. Freight Axle Mass Limits Investigation Tool (FAMLIT) User Guide. Will Hore-Lacy and Dr Tim Martin, Austroads Report AP-R502-15. 2015.			x					x							✓	FAMLIT is a Microsoft (MS) Excel-based pavement life-cycle costing analysis tool that takes road and traffic inputs and produces equivalent annual uniform cost (EAUC) outputs.
In-truck cameras at Toll NQX Information based on a symposium presentation facilitated by Sarah Jones at the Australasian Road Safety Conference, 2015, Gold Coast, Queensland, Australia http://acrs.org.au/publications/journals/current-and-back-issues/			x	x	x	x	x			x				✓	✓	
Roads to riches: better transport investment ISBN:9781925015843					x		x	x								
The city logistics paradigm for urban freight transport. (2005) Michael Taylor		x	x	x				x	x			Considers Sydney case study that models a number of scenarios including RTI, infrastructure improvement, better traffic managagment and logistical changes.				
Austroads, 2003. *Economic Evaluation of Road Investment Proposals: Valuation of Benefits of Roadside ITS Initiatives. Niel Nielson*, Austroads Report AP-R216.				x		x	x			x	Yes	Sets out approach and parameter for valueing road user benefits of roadside ITS initiatives		Example case study of economic appraisal for ITS initative	Application of Freight Management Systems	Valuing road user benefits of ITS initiatives

Reference	Transport volume	Network reliability	Freight industry specific	Freight Management system	Cost/Benefits	On/Off road costs	Transport Policy	Infrastructure & investment	Environmental/sustability focus	Heavy Vehicle Monitoring systems	ITS Definition	Traffic Management systems	Congestion problems	Solutions	Freight	Data use/Challenges/Lessons learnt
	Network performance indicators											Summary Information				
Austroads, 2003. *Economic Evaluation of Road Investment Proposals: Valuing Travel Time Savings for Freight. Trevor Fuller, Nigel Rockliffe, Dr Marcus Wigan*, Dr Dimitris Tsolakis & Thorolf Thoresen. Austroads Report AP-R230.			x			x	x								Use of SP surveying	Examine four performance attributes - viz freight rate, travel time, on time delivery and loss or damage
Austroads, 2007a. *National Performance Indicators for Network Operations.* Rod Troutbeck, Michelle Su, James Luk, Austroads Report AP-R305-07. 2007.	x	x		x	x			x	x			The project aims to establish new operational performance indicators which are suitable for automated measurements and are suitable for adoption to the National Performance Indicators Program.				
Austroads, 2007b. *Tools that Impact Network Performance: Summary Report*. Dr Charles A Karl, Austroads Report AP-R313/07. 2007.	x	x			x							The project aims to provide a better understanding of how various traffic management tools and proposed operational changes to the road network affected the performance of the entire road network with a focus on roads operating under congested conditions.				
Austroads, 2006a. *Understanding Network Performance Information Provided to Road Users.* Charles Waingold, Dr Darryn Paterson, Austroads Report AP-R285-06. 2006.	x	x		x	x			x				A study aimed at determining performance indicators which all road users would understand and use to make informed road transport decisions, and would also be used by road managers to make decisions relating to the management and operation of the road network.				
NSW Route Assessment Guide for restricted access vehicles, 2012. RMS12.450, Roads and Maritime Services NSW												Route assessment principles and planning. Restricting access to heavy vehicles.				
Austroads, 2006b. *A Review of Road Use Data Integration and Management Models.* Dr Charles A Karl, Austroads Report AP-R292/06. 2006.	x	x	x	x	x			x				Discussion of issues and possibilities of a data framework that integrates road use data and network performance data. The data framework shall be applicable to all road authorities and offer guidance on a way forward while taking into consideration the current outlook of the private and public sector.			Yes - collection and opportunities	Not enough data
Auckland Network Performance Monitoring and Reporting: Evolution through collaboration, 2013. Hooper, Pant and Dakers.	X	X										Discusses the development of Network Performance Measurement and Reporting tool to provide a feedback loop to inform and guide the development and review of network strategies and operating plans.				
Other ITS _ How the NZ Government sees ITS (No title page to document From Kathryn Musgrave's email											x	Outlines the potential for ITS in the NZ context				
Auckland Transport Alignment Project - Transport Technology - options and impacts. - Project Team												An overview/outlook of the likely impacts of existing and emerging transport technology on Auckland's transport system over the next 3 decades. Touches on the role of ITS systems but alot of emphasis on Connected Autonomous Vehicles (CAV) and other vehicle technology.				
NZTA Journey Performance Measurement - Data Collection Briefing Memo - TomTom Data												NZTA Memo to the SH Management team Auckland that outlines the procurement of Journey Performance Data to TomTom including available analysis.				
Regulatory ITS Telematics framework for heavy vehicles (2015). Wandel, Sternberg and Hill				x			x	x		x	x	In Australia a national public/private telematics framework has been established, which is administered by Transport Certification Australia (TCA). The first application was the Intelligent Access Program (IAP), which has enabled several road transport reforms by managing infrastructure risks associated with the operation of extra heavy vehicle configurations. The paper uses the IAP to demonstrate the principles of successful ITS deployment, and outlines implications for policy makers and stakeholders.				

Reference	Transport volume	Network reliability	Freight industry specific	Freight Management system	Cost/Benefits	On/Off road costs	Transport Policy	Infrastructure & investment	Environmental/sustability focus	Heavy Vehicle Monitoring systems	ITS Definition	Traffic Management systems	Congestion problems	Solutions	Freight	Data use/Challenges/Lessons learnt
Semantic Freamework for ITS Procurement (2015). McBride and Pinchen.							x	x				Project by project procurement in NZ has led to a lack of uniformity of ITS infrastructure. This paper focuses on NZ's ITS standards and specification framework. The framework aims to deliver fit for purpose specifications to support procurement processes, transform current technical knowledge into a semantic and recurvsive set of ITS standards and specifications; support consistencym while delivering value for money, safety and productivity outcomes.				
NICTA comments on the Draft NSW Freight and Ports Strategy, 2013				x										List individual projects and benefits		
CRRP COAG Road Reform Plan			x									Looks at the feasibility of introducing more direct heavy vehicle road use charges and ssociated funding arrangments in order to promote a more efficient, productive and safe heavy vehicle industry. Low relevence to this research.				
UK/Europe																
Thinking Highways, 2013. *http://thinkinghighways.com* Accessed February 2013.	x	x	x		x			x	x			Bluetooth detection sensors – installed on the road-side including any existing roadside equipment such as VMS signs, gantries or tollbooths where there is an electrical supply.				Provides highly accurate information regarding travel times and incident-detection
LAMILO Smart City Logistics: Innovative mapping platform for urban freight planning http://www.lamiloproject.eu/smart-city-logistics/ Accessed: 30 Mar 16		x	x	x	x			x	x	x		Decision support mapping software tool to help local authorities develop sustainable freight plans		Last Mile Logistics project and Case Study of LBCC consolidation centre in London	Urban freight	Case study examples and testing in Luxembourg, Brussels, London
Intelligent Transport Systems for Smart Urban Freight: the cities' perspective, Giacomo Lozzi, 2016. http://thinkinghighways.com/coming-up-with-the-goods/ Accessed: 30 March 16				x								Examples of Urban freight ITS projects in Helmond Mobiel, Bilbao, Spain and City of Pisa, Italy.				
Challenges and Good Practices in urban freight in Europe (2015). M. Ruesch, S Bohne, J Leonardi.			x	x								This paper aims to review some of European initiatives. It is based on case studies being carried out in the ECfunded project entitled «Best Practice Factory for Freight Transport » (BESTFACT) which commenced in 2012 and runs for 4 years. The project is examining and disseminating European best practices on co-modality, green logistics and e-freight, and especially in urban freight transport. The paper describes the challenges in urban freight transport, the methodology for Best Practice identification and evaluation and selected Best Practices which contribute to a more sustainable urban freight transport				
Influence of Intelligent Transportation Systems on reduction of the environmental negative impact of urban freight transport based on Szczecin example *(2014). Malecki, Iwan and Kijewska*												The need for telematics solutions to support goods transport and distribution in cities is mainly due to the complexity of the processes taking place in urban transport systems and the importance of the optimisation of transport operations via ensuring adequate availability of linear and point infrastructure, while reducing the adverse impacts of the transport system on the environment. This paper is focused on an example solution implemented in Szczecin. The basis of this solution is the utilization of mobile devices to support traffic management system. An analysis of the influence of system on the reducing the negative impacts of urban freight transport on the city				

	Network performance indicators											Summary Information				
Reference	Transport volume	Network reliability	Freight industry specific	Freight Management system	Cost/Benefits	On/Off road costs	Transport Policy	Infrastructure & investment	Environmental/sustability focus	Heavy Vehicle Monitoring systems	ITS Definition	Traffic Management systems	Congestion problems	Solutions	Freight	Data use/Challenges/Lessons learnt
Best Practices in Urban Freight Management:Lessons from an International survey Dablanc et al 2013			x	xx												
Mobilising Intelligent Transport Systems for EU Cities, 2013. European Commission, Brussels												Effective multi-agency cooperation is critical to ITS traffic management.	Relief through management systems	A good list of potential ITS tools		Standards and policy
Ott, 2013. Timely Travel Information using GIS, by Ernest K Ott (undated). *http://www.esri.com/news/arcuser/0799/romanse.html* Accessed, 31 March 2016.	x	x			x							Description of the development and implementation of GIS-based traffic monitoring and analysis program called ROMANSE. http://www.romanse.org.uk/				
Road pricing and urban freight transport practices and developments from the BESTUFS project (2004). M Ruesch			x			x						Looks at congestion charging and urban road pricing schemes				The key problems for transport operators and logistics services providers are congestion, accessibility, increased costs for the last mile delivery and the reduced reliability and predictability of deliveries.
Needs, Measurements and Solutions for Highly Relieable positioning (2015)		x										The paper has presented an algorithm which, based on the measurements of a GNSS multi-constellation receiver and a low cost IMU, provides a PVT solution and Protection Levels that are considered state-of-the-art technology. Its performances have been evaluated in different realistic scenarios according to the metrics recommended by different standardization bodies in particular the prEN16.803 developed by CENELEC/TC5. Accuracy performances have been demonstrated to improve the ones provided by classical COTS receiver algorithms. But even more relevant, the solution provides position integrity that guarantees the TIR and provides Protection Levels whose size is considered close to the theoretical minimum. The difficulties and challenges of providing such integrity in urban environments have been also evaluated.				
CIVITAS New concepts for Distribution of Goods (2009). Breuil, Hatfield and Monteanu				x					x			Demonstrated the application of a package of mobility and traffic management measures including RTI systems		Focus on medium size cities		There is 'no absolute best practice'
Smart Urban Freight Designer Online http://www.polisnetwork.eu/publicnews/939/45/Smart-Urban-Freight-Designer---Online-33			x	x					x	x		An ITS based tool which simulated logistics scenarios in order to promote discussion and present potential solutions. Demonstration of Smart Urban Freight Designer http://80.146.239.140:50000/samplebrowser/samples/tour-planning-electro-mobility/				

	Network performance indicators											Summary Information				
Reference	Transport volume	Network reliability	Freight industry specific	Freight Management system	Cost/Benefits	On/Off road costs	Transport Policy	Infrastructure & investment	Environmental/sustability focus	Heavy Vehicle Monitoring systems	ITS Definition	Traffic Management systems	Congestion problems	Solutions	Freight	Data use/Challenges/Lessons learnt
Evaluation of Urban Freight Transport Management Measures (2012). Daniel Kaszubowski				x			x					ANP worked well for evaluting freight management solutions within urban transport policy		Use of analytic network process theory for decision making		
DG MOVE European Commission: Study on Urban Freight Transport (2012). MDS Transmodal Ltd			x	x				x	x			Reviews existing and planned practices and measures relating to the urban freight across the member states of the EU.		· Regulatory measures; · Market-based measures; · Land use planning measures; · Infrastructure measures; · New technologies; · Management and other measures.		*Provides examples of case studies that are practicing UFT techniques including ITS.*
CLASS:A DSS for the analysis and the simulation of urban freight systems (2013) Antonio Comi and Luca Rosati				x				x				The use of Decision Support Systems for the analysis and simulation of the effects of city logistics.				Demonstrates two application examples for the simulation of urban freight transport in a large urban area and the assessment of freight distribution activity location in a medium size urban area.
Urban Freight research roadmap (2014). ALICE/ERTRAC Urban Mobility WC			x	x					x			Provides overview of a number of relevent projects and initatives		Design and operation of urban freight delivery infrastructures		Addresses safety and security issues of freight in the urban environment.
Feasibility of Congestion Detection and queue monitoring using Bluetooth technology (2015). Araghi, Dastjerdi and Christensen		x		x										This paper investigates the feasibility of Bluetooth technology for congestion detection and queue estimation.		
TIME project: Using real-time traffic data to evaluate congestion *http://www.cl.cam.ac.uk/research/time/press_release.html , Accessed 31 Mar 16.*	x	x			x			x	x			TIME (Transport Information Monitoring Environment) project proposes an open platform for capturing processing and delivering transport related data. Aim is to build suitable sensor and network technolog and build reusable software components.	Aim to have continuous life-cycle of data harvesting, processing and display as sensors generate traffic flow and road occupancy readings every four seconds.	Project study area 3.5 km by 8km; 112 inductive loop sensors		Road congestion and traffic pollution have a large negative social and economic impact. The project aims to highlight how these problems can be reduced through investment in the monitoring, distribution and processing of traffic information.

Reference	Transport volume	Network reliability	Freight industry specific	Freight Management system	Cost/Benefits	On/Off road costs	Transport Policy	Infrastructure & Investment	Environmental/sustability focus	Heavy Vehicle Monitoring systems	ITS Definition	Traffic Management systems	Congestion problems	Solutions	Freight	Data use/Challenges/Lessons learnt
	Network performance indicators											Summary Information				
Asia																
An integrated sensing-based urban freight data collection framework:methodology and pilot projects in Singapore (2015)Teo, J., Lee, Y., Marzano, V., Santos, J., Azevedo, C., Zhao, F. and Ben-Akiva, M			x	x												Demonstrates a framework for urban freight data collection using next generation sensing and surveying capabilities .
USA/Canada																
FHWA, 2013b. Freight Management and Operations - Data Sources Related to Freight Transportation. Federal Highway Administration. *http://ops.fhwa.dot.gov/freight/freight_analysis/data_sources/* Accessed March 2016			x									A list of resources which provide national road freight data. Includes list of four urban freight case studies in the US.				
I-95 Corridor Coalition March 2016 FREIGHT PERFORMANCE MEASUREMENT Measuring the Performance of Supply Chains across Multistate Jurisdictions			x		x	x	x							✓	✓	✓
FMCSA (US Federal Motor Carrier Safety Administration) Reaches Final Phase of Wireless Inspection Project; October 2014 http://www.truckinginfo.com/news/story/2014/10/fmcsa-reaches-final-phase-of-wireless-inspection-project.aspx			x					x								
FMCSA Seeks Input on "Beyond Compliance" Program; April 2016 https://www.fmcsa.dot.gov/newsroom/fmcsa-seeks-input-%E2%80%9Cbeyond-compliance%E2%80%9D-program			x				x									
Initial Concept of Operations for the I-710 Zero Emissions Freight ITS Corridor; September 2013																
Simplified Scenario Planning Workshop to Evaluate, Rank, and Select Regional Freight Strategies; August 2015			x													
Mitigating Urban Freight through Effective Management of Truck Chassis; 2014 https://trid.trb.org/view/2016/M/1398389			x					x				Shared equipment management strategy involving the establishment of a chassis pool involving three third-party equipment managers that operate their own independent pools in and around the San Pedro Bay		Assesses the development of a pooled chassis strategy for the Southern California goods movement sector - focusing on the Ports of Los Angeles and Long Beach - and its implications for urban and regional freight mobility.		
GPS Data for Truck-Route Choice Analysis of Port Everglades Petroleum Commodity Flow; February 2016			x				x						The procedures and the data developed in the project offer significant opportunities to understand truck trip chaining and			
Evaluation of the Effects of Driver Assistive Truck Platooning on Freeway Traffic Flow; 2016 (TRB Annual Meeting) https://trid.trb.org/view.aspx?id=1392795		x	x									Interest in driver assistive truck platooning (DATP) through the application of coordinated adaptive cruise control in the freight trucking industry is on the rise due to its expected benefits on the roadway. The simulation results are analyzed using travel time benefit and average speed as the measures of effectiveness. A general trend of increasing travel time benefit was found as market penetration increases and as headway is reduced.				

Reference	Transport volume	Network reliability	Freight industry specific	Freight Management system	Cost/Benefits	On/Off road costs	Transport Policy	Infrastructure & investment	Environmental/sustability focus	Heavy Vehicle Monitoring systems	ITS Definition	Traffic Management systems	Congestion problems	Solutions	Freight	Data use/Challenges/Lessons learnt
Management and Dynamic Routing of Hazardous Materials Transportation in Urban Areas https://trid.trb.org/view.aspx?id=1336781			x	x								dynamic geofencing application, designed for the monitoring, the control and management of hazardous materials transportation in urban areas.				
The Trend of Urban Freight Regulatory Path under the Cloud			x													
Identifying traffic signatures of traffic events on urvan arterials (2015) Jason So and Aleksandar Stevanovic		x		x									Studies a well ITS equipped corridor in Fort Lauderdale to determine traffic signatures of various traffic events.			
Affordable traffic management centre (2015) Kuzmanovski and Boan				x								Adaptive traffic signal coordination (ATSC) Corridor travel time system				
FHWA, 2012. Operational Performance Measures: The Foundation for Performance-Based Management of Transportation Operations Programs. Federal Highway Administration. 2012. *http://ops.fhwa.dot.gov/publications/fhwahop12018/fhwahop12018.pdf* Accessed February 2013.	x	x	x	x	x	x	x	x	x	x		Overview of how transportation networks can be made more efficient by measuring network performance against appropriately selected criteria.				
FHWA, 2011. Urban Congestion Trends (by year 2011). Federal Highway Administration. *http://ops.fhwa.dot.gov/publications/fhwahop12019/fhwahop12019.pdf* Accessed March 2016	x	x	No	x	x	x	x	x	x			Discussion of improvements to transport operations and benefits yielded by them				
Inrix, 2013. *www.inrix.com.* Accessed March 2016.	x	x			x							Product brochure for INRIX presenting its capabilities in traffic and travel services				
Bottleneck Identification and forecasting in traveller information systems (2016). Robert Bertini, Huan Li, Jerzy Wieczorek and Rafael Fernandez-Moctezuma.		x		x									This paper looks at providing automatic mechanisms that incorporate learned features from historical data into live displays, traveller information systems may better serve users as they are told when and where to expect recurrence in bottlenecks in addition to detecting non-traditional			Mainly focused on freeway congestion
TTI's 21012 Urban mobility report powered by INRIX Traffic Data (2012). Schrank, Eisele and Lomax	x	x	x	x	x			x					Explores methods to measure congestion	An overview of congestion relief strategies		
Estimating Urban Freight Congestion costs: Methodologies, measures and applications (2013). Eisele, Schrank, Schuman & Lomax.		x			x	x							Provides formulas for calculating congestion costs		Isolates freight component from other vehicles	
Congestion and Bottlenecks Indentification (CBI) Software Tool User Guide (2015)Federal Highway administration													Development of a tool designed to compare and rank traffic bottlenecks including an annual reliability matrix (ARM) and bottleneck intensity index (BII) using INRIX data			
Measuring the economic costs of urban traffic congestion to business (2003). Glen Weisbrod, Don Vary and George Treyz					x	x	x						Demonstrates how it is possible to estimate the economic implications of congestion which may be able to be applied for BC analysis of urban congestion reduction strategies.			Recognises different types of congestion costs

Reference	Transport volume	Network reliability	Freight industry specific	Freight Management system	Cost/Benefits	On/Off road costs	Transport Policy	Infrastructure & investment	Environmental/sustability focus	Heavy Vehicle Monitoring systems	ITS Definition	Traffic Management systems	Congestion problems	Solutions	Freight	Data use/Challenges/Lessons learnt
	Network performance indicators											Summary Information				
Measuring marginal congestion costs of urban transportation: Do Networks matter? (2013). Elena Safirova and Kenneth Gillingham					x								Provides an approach from measuring congestion			Uses strategic transportation planning model (START) to compare marginal congestion costs computed link by link with measures taking into account
Washington DOT, 2004 *Measuring Congestion: Learning From Operational Data*. Daniela Bremmer, Keith C. Cotton, Dan Cotey, Charles E. Prestrud, Gary Westby. 2004.	x	x	x	x	x	x	x	x	x	x		Report summarizes how the Washington State DoTT (WSDOTT) uses operational data to assist in measuring congestion, evaluating capital and operational improvements. It describes wsdot's experience in learning more about congestion measurement using real time data.				
Case Studies																
Los Angeles 2009 http://ops.fhwa.dot.gov/publications/fhwahop10020/fhwahop10020.pdf Accessed: 31 Mar 16		x	x	x	x	x	x	x					Issues and deficiencies identified	Examples of potential solutions focused into 4 categories	Freight specific urban study	
New York 2009 http://ops.fhwa.dot.gov/publications/fhwahop10019/fhwahop10019.pdf Accessed: 31 Mar 16		x	x	x	x	x	x	x				Curb side monitoring Thru Streets Programme Sign improvements Education	Issues and deficiencies identified	Potential solutions, major findings and conclusions discussed	Freight specific urban study	
Orlando 2009 http://ops.fhwa.dot.gov/publications/fhwahop10021/fhwahop10021.pdf Accessed: 31 Mar 16		x	x	x	x	x	x	x						Potential solutions, major findings and conclusions discussed	Freight specific urban study	
Washington DC 2009 http://ops.fhwa.dot.gov/publications/fhwahop10018/fhwahop10018.pdf Acessed: 31 Mar 16		x	x	x	x	x	x	x				Truck Circulation Plan Truck routing Parking strategies	Pending actions discussed	Potential solutions, major findings and conclusions discussed	Freight specific urban study	

Appendix B: International case studies

B1 Introduction

This section supplements the literature review and stakeholder engagement in developing a greater understanding of current ITS initiatives involving trials in the application of technology. There are a number of projects worldwide exploring the capabilities of new and evolving technologies to improve the management of urban freight. Three examples of current initiatives have been provided in this appendix, one each from the USA, Europe and Australia.

The case studies are in some ways peripheral to the main research, but are included for learning purposes and to generate ideas for potential application in Auckland. While they will not be directly replicable, there may be aspects that would be useful in the New Zealand environment.

B1.1 Automated vehicles/connected vehicles/ITS Florida

Several automated vehicle initiatives utilising emerging technologies are under way in Florida. The primary objectives of these are to:

- leverage existing infrastructure to maximise benefits
- develop a rich dataset that demonstrates quantitative safety and efficiency gains
- inform policy, design and engineering standards
- measure performance
- undertake comparative analysis before and after automated and connected vehicle technologies are deployed (Florida Department of Transportation 2016).

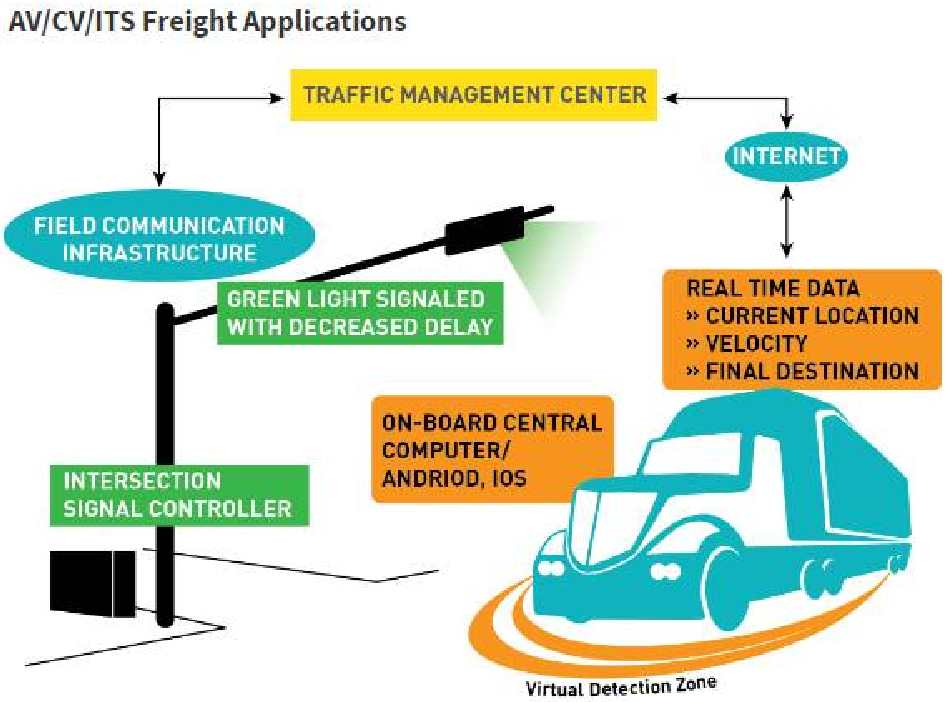
Specifically, the automated/connected vehicle and ITS freight applications project aims to demonstrate that automated vehicle technologies can improve the management, safety and efficiency of freight operations on highly repetitious freight routes. Figure B1.1 depicts the use of connected and automated vehicle and ITS technology to facilitate communication and management between vehicle and infrastructure.

This project follows a three-phase approach to measure, deploy and prioritise portions of the perishable goods supply chain.

The first phase involves the use of connected vehicle technologies to better understand vehicle progression through delivery corridors and where bottlenecks occur at traffic signals. The same installed connected vehicle devices from phase one will be used in phase two to connect the freight vehicles to traffic signals through the back-end systems at the Miami-Dade County Traffic Management Centre. Phase three will involve granting traffic signal priority to study vehicles during non-peak congestion hours (potentially midnight and 5am), to improve delivery performance (Florida Department of Transportation 2016).

Preliminary analysis showed a standard trip from Miami, travelling along Northwest 25th Street, to 1500 NW 70th Avenue, had a total travel time of just over 30 minutes for the 2.5 mile journey. When the additional green time was given to the vehicle along the corridor, the trip time reduced to 8.5 minutes. The significant reduction in travel time resulted in improved on-time delivery performance, and direct fuel and emissions savings (Florida Department of Transportation 2016).

Figure B.1 Automated/connected vehicle/ITS technology components



B1.2 'SMARTFREIGHT' transport in urban areas.

SMARTFREIGHT was a research project co-funded by the European Commission to specify, implement, develop, demonstrate and evaluate technical solutions that can make urban freight transport more efficient, efficient, environmentally friendly and safe through:

1 *New traffic management measures towards individual freight vehicles* using open information and communication technology (ICT) services, on-board equipment and an integrated heterogeneous wireless infrastructure within the framework of communication access for land mobiles (CALM).

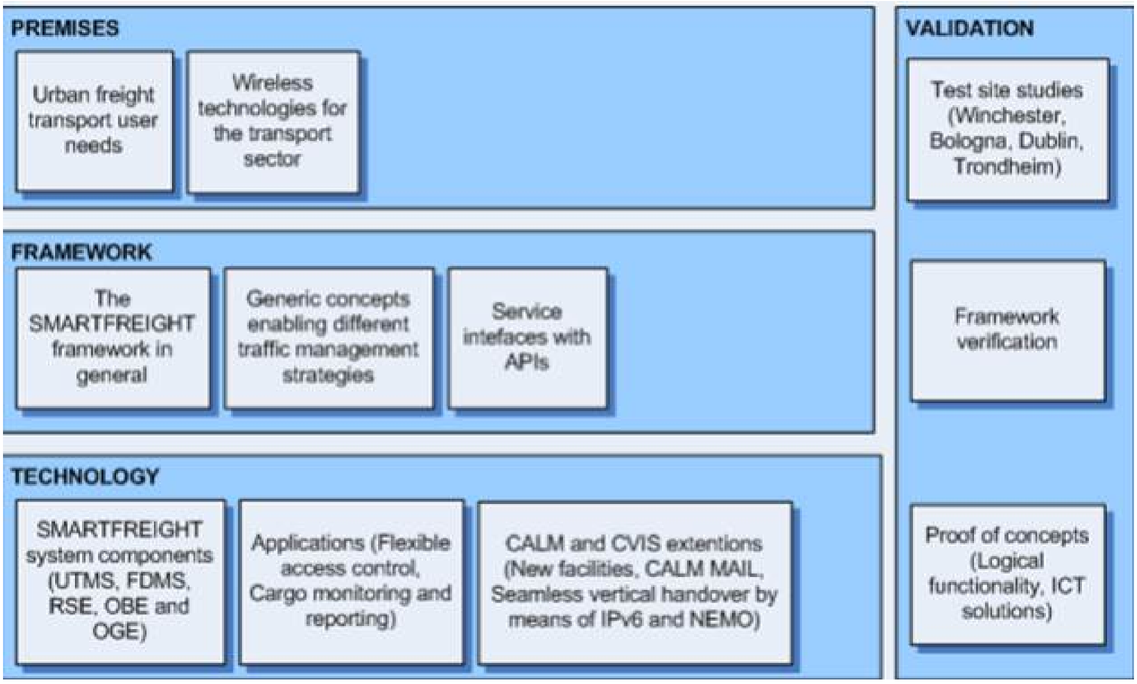
2 *Increased interoperability between traffic management and freight distribution management systems* by means of open ICT services.

3 *Better coordination of all freight distribution in a city* using open ICT services, on-board equipment, the heterogeneous wireless communication infrastructure and CALM media adapted interface layer (MAIL) implementations in on-board and on-cargo units.

4 *Documentation of new knowledge and specification of open and generic solutions* that are adaptable to future needs and are applicable to a variety of European cities.

Figure B.2 provides an overview of the project results. The project premise identifies the user needs and wireless technology component, while the resultant SMARTFREIGHT framework provides generic solutions that can be tailored to a city's different needs and ICT infrastructures. The use of test sites in Trondheim, Norway, Winchester, UK, Bologna, Italy and Dublin, Ireland provided validation of the methodology, logical functionality and the ICT solutions (Westerheim 2011).

Figure B.2 SMARTFREIGHT Main results structured into categories (Source: Westerheim 2011)

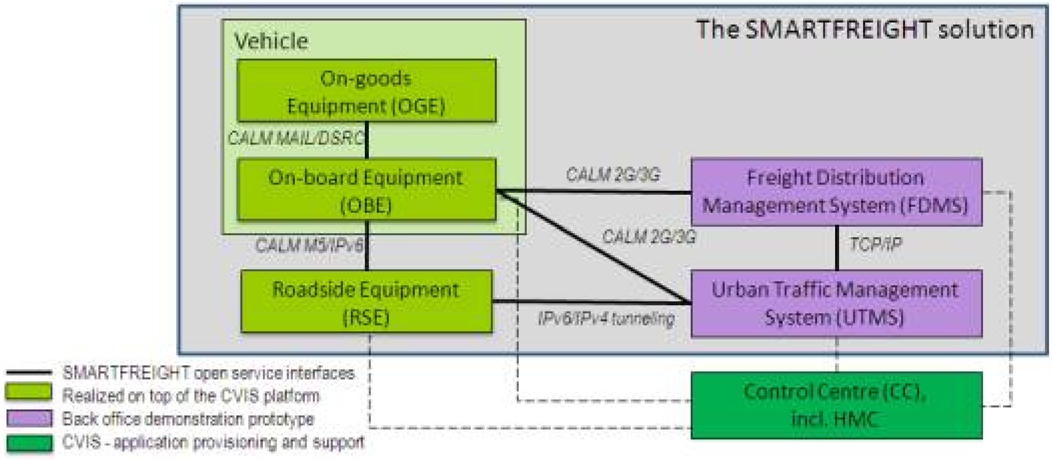


The SMARTFREIGHT framework architecture uses a top-down holistic approach focused on solutions that consider both the needs of the city and the needs of the commercial transport operators. They define a set of generic concepts related to both the transportation network and traffic management strategies. For example:

- controlled areas – priority or access restriction schemes
- pre-booked loading bays
- information checkpoint
- access and priority assignment policy – defines how access rights and priorities are assigned to vehicles based on vehicle properties
- access and priority offer – defines priority and access rights to individual vehicles for a controlled area.

The framework then defines services with APIs that facilitate the exchange of information between urban traffic management systems, freight distribution management systems, vehicles and cargo as demonstrated in figure B.3. A full assessment of available wireless technologies was developed and tested. CALM M5 technology based on WAVE and IEEE802.11p was highlighted as a useful alternative to the public 2G/3G networks. As a dedicated infrastructure for ITS, it provides a more reliable communication channel as it is not susceptible to congestion or other problems inherent with public networks.

Figure B.3 SMARTFREIGHT system components (Source: Westerheim 2011)



SMARTFREIGHT use the ISO family of CALM standards to enable optimal connection between vehicles and infrastructure. The CALM protocols were made available as services by cooperative vehicle infrastructure systems, with SMARTFREIGHT extending this to include CALM MAIL usage over dedicated short-range communication (DSRC). The usage area for DSRC in SMARTFREIGHT is to enable information exchange between the cargo and the vehicle (Westerheim 2011).

SMARTFREIGHT addresses a series of new functions at strategic, tactical and operational levels. This approach provides a firm basis from which urban freight services can be realised, with the support of different communication channels, ICT infrastructure and decision makers.

B1.4 Dublin bus AVLC management system

A recent update to SCATS incorporates an API allowing external applications to interface with traffic signal operation. This has allowed Dublin City Council to utilise their investment in SCATS and a GPS-based bus tracking solution (AVLC) to deliver selective priority service to buses without the need for additional roadside infrastructure. The Dublin public transport interface module (DPTIM) optimises SCATs and AVLC using a low-cost centralised software solution that establishes virtual detection zones across the city to effect priority based on defined parameters (ITS United Kingdom 2016). The new software solution for DPTIM processes data inputs and outputs to/from bus feeds to SCATS, accommodating a comprehensive database management system for processing data received from the buses and stores and manages a geospatial information system that permits map-based displays to be provided (ITS United Kingdom 2016)

The Dublin bus AVLC management system provides a service interface for real-time information VM data feed which contains the position of each in-service bus in the fleet approximately every 20 seconds. Data on whether the bus is in congestion, free flowing or loading passengers at a bus stop is also contained in this data feed, which is mapped to display the latest status of the locations of the public transport vehicles. The application also allows virtual detectors to be mapped out and used as hot spots and detector points within the road network. These virtual detectors can be configured for specific route/journey patterns with individual threshold values such as queuing time, the number of buses located within the geospatial area of a detector, or an acceptable journey time. If real-time values of these thresholds are breached, the application calls a command on the SCATS/API to execute priority commands. The new application being used in Dublin delivers a centralised network response to bus problem locations, not just an individual junction response but to corridors and city-wide routes via multiple junction adjustments (ITS United Kingdom 2016).

This system in Dublin has provided greater visibility of issues and incidents on the network, enabling timely and appropriate reactions to be made, leading to a significant reduction in queuing times and improved journey predictability (ITS United Kingdom 2016).

B1.5 Cooperative intelligent transport system trial, New South Wales

The Illawarra region in New South Wales, Australia, is currently the test bed for the only large-scale cooperative intelligent transport initiative (CITI) dedicated to heavy vehicles in the world. In addition to the published literature cited in the literature review (see section 3.4.1), the research team engaged with Data61's technical lead for the project. Data61 is an ICT research organisation with significant transport experience. They are the technology partner for CITI and provided useful additional information.

The CITS technology is very new; essentially in the preproduction phase at the time of writing and not ready for deployment yet. There are few suppliers (five to six worldwide) of the hardware devices with only two tenders received for the NSW trial. The infancy of the technology means it only just does the job required and multiple issues have arisen including positioning inaccuracy. Currently the actual position of a vehicle and the reported position of the vehicle is plus or minus about seven metres. This means a significant number of false collision warnings are generated. An example of this is the inability to differentiate which lane a vehicle is in, so two trucks travelled side by side in individual lanes are reported as colliding. There is currently no obvious way forward to solve these issues. The lack of accuracy of basic GPS is expected to be addressed in the next few years with the provision of additional (augmented) signals.

The CITS trial involved engaging with three transport companies and developing a value proposition for their businesses in order to improve uptake in use of the technology. Emphasis needed to be placed on the productivity gains as drivers consider they have all the technology needed to be safe drivers.

Data is currently being collected from the trucks and infrastructure, but the analytics to determine the nature of any change in safety or productivity of freight vehicles has not been completed. Careful consideration of the impact on other vehicles will need to be factored in, along with the potential political aspect of prioritising commercial vehicles over other vehicles.

A key learning from the trial has been how pre-market the technology is and whilst the ability for vehicles to talk to each other and infrastructure is currently separate from automated vehicle technology, in the future these two areas will need to be able to combine. The CITI provides a platform to learn about communication to improve vehicle productivity, but more in preparation for automated vehicles.

Land Information New Zealand is cooperating with Geoscience Australia in delivering the trial. It will improve the accuracy of GPS and other satellite navigation systems, so accurate positioning information can be received anytime and anywhere across New Zealand.

The two-year project will test two new satellite positioning technologies including next generation satellite-based augmentation system and precise point positioning, which will provide positioning accuracies of several decimetres and five centimetres respectively.

Appendix C: Glossary

AADT	annual average daily traffic
AMA	Auckland Motorway Alliance
ANPR	automatic number plate recognition
API	application programme interfaces
AVLC	automatic vehicle location and control
CALM	communication access for land mobiles, ISO standard
CCTV	closed circuit television
CITI	cooperative intelligent transport initiative
CITS	cooperative intelligent transport system
CO	carbon monoxide
DoS	degree of saturation
EEM	NZ Transport Agency *Economic evaluation manual*
EROAD	EROAD is a fully integrated technology, tolling and services provider.
ERUC	electronic road user charge
FHA	Federal Highway Administration
FRATIS	freight advanced traveller information systems
GIS	geographic information system
GNSS	global navigation satellite system
GPS	global positioning system
HERE	a company that provides mapping data and related services
HGV	heavy goods vehicle
ICT	information and communication technology
IEEE 802.11p	an approved amendment to the IEEE 802.11 standard to add wireless access in vehicular environments (WAVE), a vehicular communication system.
INRIX	a global software as a service data as a service company which provides Internet services and mobile applications pertaining to road traffic and driver services
ITS	intelligent transport systems
LaMiLo	(or LAMILO) lastmile logistics
LGV	light goods vehicle
LOS	level of service
M5	CALM M5. The ISO 21215 standard that incorporates WAVE (WAVE PHY/MAC is the IEEE 802.11p standard)

MAIL	CALM media adapted interface layer
MCV	medium commercial vehicle
MoT	Ministry of Transport
N_2O	nitrous oxides
NOP	network operating plan
RUC	road user charge/s
SCATS	Sydney Coordinated Adaptive Traffic System
SH	state highway
T2	a lane that can be used by vehicles with two or more occupants
TOC	traffic operation centre
TREIS	traffic road event information system
VMS	variable messaging sign
WiM	weigh-in-motion
2G	second generation global system for mobile network
3G	third generation global system for mobile network