Strategic electronic monitoring and compliance of heavy commercial vehicles in the upper North Island

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Contents

Executive summary

Around 84% of internal New Zealand freight is carried by road. Overloaded heavy commercial vehicles (HCVs) can cause significant extra wear and tear to our bridges and roads. This additional wear and tear is not paid for by those overloading their vehicles, with the asset costs being passed on to other road users and ratepayers. Gross overloading can also damage our roads and lead to asset failure with consequential economic loss and the potential to cause injury or even death. This report addresses the following:

- The New Zealand government seeks more efficient and safer road freight movements; however, measures taken to increase HCV productivity including high productivity motor vehicles (HPMVs) should ideally have corresponding monitoring and compliance systems to ensure negative impacts such as increased asset wear are effectively managed.
- Official statistics show that present day annual costs of all truck-related fatalities, highway repairs, local road repairs and health costs add up to over $2.6 billion nationally.
- NZ Transport Agency (NZTA 2011a) statistics show that currently around 8% to 10% of New Zealand HCV trips are overloaded.
- There is currently a wide range of other types of HCV non-compliance including safety and road user charges revenue evasion.
- NZTA (2011a) statistics show the rate of overloading offences detected at a single automated NZTA weigh-in-motion site (Drury) is around 110,000 per annum, although these statistics include some HPMVs.
- NZ Police statistics show the national rate of Commercial Vehicle Investigation Unit (CVIU) HCV inspections is 90,000 individual vehicles per annum (estimated 50,000 HCV combinations). Each inspection takes 20 to 30 minutes.
- Therefore, even if the entire national CVIU enforcement force was permanently sited at the Drury weigh-in-motion site, they could not deal with all the overloading offences at that site.
- CVIU inspections are vital in dealing with non-compliance. Under current procedures, however, CVIU inspections of HCVs, many of which are found to be compliant, result in 45,000 hours unplanned reduction in national supply chain productivity and result in an estimated additional 180,000 litres of diesel per annum.
- Police and Ministry of Transport (MoT) statistics show the current probability of an HCV being inspected by CVIU roadside inspections is one inspection every two years or 44,000km.
- This means the probability of a CVIU inspection on each 10km trip undertaken by a transport operator is 1 in 4400 (0.02%) – this offers little if any incentive to comply.
- HCV operators that do comply can run the risk of being ‘undercut’ by other operators that have lower levels of compliance, such as overloading vehicles or exceeding work-time hours. Therefore any compliance model needs to specifically target the minority of operators who are the most evasive, deliberate and systematic in non-compliance. Anything less will not achieve the objectives.
- HCV operators may be motivated to cut costs by reducing compliance levels in order to stay in business with many suffering losses and a national average 2010 profit margin of 1%.

- There is anecdotal evidence that HCV drivers are being pressured not to comply by some transport operators. On an individual basis when given the choice of being paid or losing your job one might expect the former to take precedence.
- Therefore the authors suggest education will not be effective overall. Significant improvement in enforcement methodology and strong economic incentives to comply are required to create any real effect.

This research into strategic electronic monitoring offers the opportunity of a cost-effective approach to the issues outlined above. It requires a new paradigm of thinking, strong political will, commitment and significant investment. In the words of Albert Einstein 'The significant problems we have cannot be solved at the same level of thinking with which we created them'.

The NZ Road Transport Forum, the 'authoritative voice of the road transport industry', seeks effective, targeted enforcement, and a system that makes transport operators fully accountable for their policies and actions. The failure of government transport policy to provide those elements, has played a significant part 'in giving economic advantages to delinquent transport operators who have deliberately compromised safety and operated illegally' (Audit New Zealand 2005).

NZ Police, the NZTA and road-controlling authorities share the common goal of increasing HCV compliance for various reasons. Deliberate non-compliance normally results from the necessity for economic survival or from greed. Education and alternative compliance regimes normally fail in either circumstance.

A safe system approach requires action to minimise identified risks and this paper identifies safety risk.

This paper addresses each issue, proposing a strategic network of automated evidential-grade electronic monitoring and direct enforcement sites (SEM). SEM sites are capable of continuously detecting a wide variety of offences and directly holding operators accountable, primarily while an HCV is moving.

SEM would also enable the NZ Police CVIU to operate significantly more efficiently in identifying, checking and targeting the worst offenders; making them pay for the asset damage they are responsible for rather than having that cost shared among all those who pay road user charges.

Transport operators who elect a cooperative partnership (voluntary electronic data sharing) approach with the NZTA will demonstrate their commitment to safety and compliance. In return they may experience alternative enforcement intervention if any non-compliance is detected on their vehicles, and may be authorised to bypass active weigh sites on the majority of occasions. There may be further benefits.

The proposed model improves private sector productivity, improves the effectiveness of public sector agencies, improves freight data for planning purposes, reduces costs and delivers strong value for money. To achieve this will require firm political commitment and support, significant investment, expert private sector programme direction, along with a range of enabling law, policy and business process changes. These are all realistic and achievable in a relatively short timeframe.

As what is proposed is a new system, involving different parties, it is vital that the view or position of one stakeholder does not take precedence over another; the balance is delicate and interests of all parties can feasibly be met if progress is firmly and impartially directed. Failure to follow the proposed model, or removal of any one component will risk failure of the entire proposition.

This paper can provide an outline and the basis for change but continued expert private sector advice will be required to successfully achieve implementation. There is a significant risk of failure if expert private sector expertise is not applied to ensure that the interests of all parties are met. Development by committee is unlikely to achieve the goals in a timely manner. It is almost certain that if the interests of all parties are not precisely met, the overall approach will fail.

This research outlines a significant change opportunity which the authors recommend is progressed further to achieve full implementation. It is a new paradigm of thinking for New Zealand and is not NZTA policy or that of the New Zealand government.

Abstract

This research report on the strategic electronic monitoring of heavy commercial vehicles (HCVs) was prepared by Traffic Design Group in 2011–2012. The aim of the research was to provide a conceptual framework within which technology systems could be operated at strategic, tactical and operational levels. The goal is to improve national productivity, by maximising efficiency for transport operators and enforcement staff alike, improving road safety, improving protection of road and bridge assets and creating a fairer economic environment through greater compliance with HCV legislation.

Overloaded HCVs create significant additional wear and tear, damage and even reduce the economic lift of New Zealand's roads and highways. Overloaded vehicles do not pay for the additional tonnes they carry, leaving the considerable extra maintenance and renewal costs to be unfairly borne by operators who pay their correct share of road user charges. Overloading of vehicles beyond the legally allowable weight can also compromise the vehicle's body, brakes, chassis, wheels and/or engine.

Currently 84% of freight travels by road within New Zealand and the volume is predicted to double.

The aim and recurring theme throughout this research report is improving the efficiency and effectiveness of the fundamental enforcement process, which is to identify, process and release or escalate.

1 Introduction

1.1 Background

Optimising supply chains is crucial to New Zealand's long-term success. Connecting New Zealand (MoT 2011a) stated that 'Moving our freight and people as safely and efficiently as possible, with a minimum of hold ups, is vital to speeding up economic growth'. The New Zealand Productivity Commission (2012) found that 'the government has an important role in gathering and disseminating freight information. More information on freight in New Zealand – collected and made available on a regular basis – would have considerable value and help freight organisations make better individual and joint decisions. It would also help stakeholders monitor performance, and policy-makers design and evaluate policies and regulations'.

An efficient freight industry with access to cost-effective transport is vital to New Zealand businesses being internationally competitive. Upton (2008) states that heavy commercial vehicles (HCVs) transport 84% of internal New Zealand freight. HCVs also account for 7% of the total distance travelled on New Zealand's 200km of motorways and 11,000km of highways. There are a further 83,000km of local roads including Auckland Transport's 7000km.

Large trucks are often perceived with some nervousness by the general public, both in New Zealand and internationally. Because of their size, truck crashes regularly result in serious injury and fatalities, regardless as to what or who caused the crash. Associated media coverage can also reinforce this perception.

Road transport offers a high level of security and resilience following natural disasters and other events when compared with other modes. This was demonstrated following the recent Christchurch earthquakes which effectively closed both the port and the adjacent rail network.

Past studies indicated that the trucking industry and members of the public could gain substantial economic benefits through increased truck sizes and heavier loads, thereby reducing the trips required to move New Zealand's freight. A high productivity motor vehicle (HPMV) regime was introduced to New Zealand in 2010. This current regime permits larger and/or heavier HCVs on routes that are suitable to carry the extra loads. HPMVs, unlike overloaded vehicles, are trucks that have been certified to carry the additional loads and pay higher road user charges. Currently HPMVs operate without continuous monitoring or measuring systems for route or weight compliance. As a result, HPMV compliance (or otherwise) and net benefits cannot fully be understood. There is anecdotal evidence of HPMV non-compliance.

Increasing road freight volumes, increased HCV weights and the introduction of HPMVs have made it timely to look at how we can ensure we get the most economic value out of our pavements and bridges, ensure transport operators pay the appropriate amount for their use of the roading network, and ensure that the NZ Police Commercial Vehicle Investigation Unit (CVIU) has the best tools available to provide effective and equitable enforcement of legal load limits and road user charges. NZ Police have reported difficulty enforcing these using current methods.

1.2 Relevant characteristics

The MoT 2011 vehicle fleet composition spreadsheet[1] shows that out of a total New Zealand fleet of 3.24 million vehicles, 111,000 are HCVs. HCVs travel a total of 2563 million kilometres annually; an average of 23,300km per HCV. Road user charges data indicates there are a further 60,000 unpowered heavy trailers travelling 1210 million kilometres; an average of 20,000km per year per trailer.

Weight limits are intended as safe maximums for the majority of our bridges and are the basis of road asset wear calculations. The gross weight of a vehicle is used to determine road user charges under New Zealand's mass distance road user charges system.

NZTA telemetry data for 2011 (NZTA 2011a) shows that 8% to 10% of all HCV combinations on New Zealand highways are overloaded, operating in excess of the maximum permitted weight limits.

One continuously operated NZTA telemetry site at Drury (Auckland) detected 124,500 overloaded vehicle combinations in 2011. Four other NZTA telemetry sites detected a further 125,500 overloaded HCVs. Yet under the current system, enforcement action against any of those operators to disincentivise their overloading behaviour is limited. This is due to the current time-consuming physical enforcement process and finite CVIU staff resources. Overloading is just one of many forms of non-compliance that is impacting on the economic life of New Zealand's roads, creating a safety risk and reducing the overall economic efficiency of freight movements.

The NZ Police CVIU is responsible for HCV enforcement but has finite staff resources to stop and inspect the 171,000 HCVs and trailers nationally. HCV enforcement inspections each take around 20 to 30 minutes with some taking 60 minutes or more; resulting in around 90,000 individual HCV inspections annually. Many vehicles that are inspected are found to be roadworthy and compliant, yet their freight delivery schedule has been disrupted by the legitimate CVIU inspection. While they are inspecting vehicles that are found to be compliant, CVIU officers are unable to inspect other passing HCVs that may turn out to be non-compliant. Inspections of compliant vehicles, therefore, pose significant cost to freight supply chains, and reduce the time available to the police to focus on non-complaint transport operators. These together have a negative impact on the efficient movement of freight and the wider New Zealand economy.

It is apparent that current HCV compliance measures are resource intensive and the likelihood of random detection of a specific instance of non-compliance is very limited for this reason; yet some operators pass weigh stations frequently and are inspected regularly. The consequences of detection rarely outweigh the short and medium-term financial benefit available to HCV operators who elect deliberate non-compliance. Many operators who do intentionally comply are penalised by repeated enforcement inspections.

Hardware and communications for one high-speed strategic electronic monitoring (SEM) site (as described in this report) can be installed for around $250,000 with a design life of around 10 years. Additional one-off costs are required to set up a 'back office' capable of processing the data nationally to maximise efficiency and effectiveness.

An automated direct enforcement approach SEM can readily make a significant difference by maximising detection of non-compliance and holding non-compliant operators accountable even when no enforcement staff are present. When enforcement staff are present they are able to operate much more efficiently and

[1] Available from www.transport.govt.nz

effectively, because SEM is able to identify vehicles that are non-compliant. Changes to implement SEM require strong political support, an investment commitment, expert private sector programme direction, law changes and business process changes. Absence or removal of any one of these elements risks programme failure.

1.3 Research objectives

This research report forms the basis of best practice possibilities for near real-time collection and processing of relevant HCV compliance data. The focus is on what is currently technically feasible, with a view to future improvement of national freight productivity and smarter regulation through automation of a wide range of HCV safety and compliance checks on moving vehicles. The current economic environment, legislative, policy and funding limitations do not constrain the technical focus of this report; indeed the report offers a basis for change in these areas.

Purpose: To develop a framework for a safe and efficient method of electronic monitoring of heavy commercial vehicles on key freight routes within the upper North Island. The upper North Island was selected by the NZTA due to the significant concentration of freight movement in the region surrounding Tauranga, Hamilton and Auckland.

Knowledge gap: There is currently no framework for monitoring real-time HCV movements and the degree to which they are compliant. The current process of monitoring and compliance checking is resource intensive and not as effective as other models.

Parameters specific to this project: This project looks at developing a framework that will provide for a safer and more efficient method of monitoring and ensuring the compliance of HCVs. The focus of the work is in the upper North Island. The project investigates the potential use of electronic devices such as weigh-in-motion sites, automatic number plate recognition and other devices and systems to provide for more efficient and effective monitoring and compliance activity. These proposals will promote improved efficiency and safety through:

- monitoring vehicles while in motion, to ensure compliant operators are able to keep moving and ensure more efficient freight movement
- delivery of more targeted enforcement for vehicles identified as potentially non-compliant
- ensuring improved management of state highway and local road sets
- improved monitoring of heavy vehicle movements on key freight routes.

The framework has taken into account the implementation of changes to legislation, such as road user charges (RUC) and the introduction of high productivity motor vehicles (HPMVs).

The authors have developed a framework that provides:

- better information regarding the movement of freight
- better tools with which to manage and develop the road network (local and highway)
- improved asset management outcomes
- better enforcement

- a more efficient and equitable outcome for the transport sector, including transport operators; and for identifying opportunities to use data collected to support intelligence analysis.

1.4 Research output

This report provides the first step in developing a customer focused approach to the application of intelligent transport system (ITS) technologies along with the parallel data, information and business intelligence to enable improved monitoring of HCV operations in Auckland, Waikato and Bay of Plenty, supporting key policy objectives:

1 Economic growth and productivity

2 Achievement of strong value-for-money

3 Improved road safety, contributing to a safe system

4 Equitable outcomes for the transport sector.

1.4.1 Economic growth and productivity

More efficient supply chains will be enabled through improved understanding, identification and generally authorising those HCV operators with safe and compliant vehicles to continue their journeys with a minimum of delay. Streamlining the regulatory monitoring process will reduce costs to all freight transport businesses. Informing compliance activities will also focus and optimise the use of enforcement resources where, when and with whom they are most effective.

1.4.2 Achievement of strong value-for money

Strong value for money will be achieved by:

- reducing or eliminating current enforcement-related delay to compliant HCV operators
- optimising enforcement resource allocation, linking strategic, tactical and operational levels in compliance, enforcement and planning activities
- limiting state highway and local road asset costs caused by overloading
- ensuring road users pay the appropriate RUC for their use of the network
- providing better traffic information to road controlling authorities to improve planning, investment and asset management decisions.

1.4.3 Improved road safety, contributing to a safe system

Road safety will be improved by providing a wider, continuous or regular view of HCV compliance and physical safety issues. Accurate, timely information will enable improved operational decisions on physical vehicle checks, road maintenance, mitigating risks to reduce the overall occurrence of crashes.

Correspondingly, continuous monitoring will incentivise HCV operators to consistently manage their drivers and deploy their vehicles in a safe and properly loaded condition, reducing crash risks.

The general condition of vehicles using the highway will be improved. Arnold (Road Transport Forum) confirms that HCVs and trailers may be out of safe specification under normal circumstances within 20,000km. On the basis that some HCVs travel 500,000km per year, as determined by Upton (2008), some vehicles will require scheduled maintenance every two weeks and indeed some fleets already schedule servicing at this frequency.

1.4.4 Equitable outcomes for the transport sector

- Providing evidence-based business intelligence to correctly inform targeted enforcement of non-compliant transport operators by the CVIU.
- Justifying less frequent enforcement stops for those operators who demonstrate compliance.
- Promoting economic advantage for those operators who invest in continuous compliance in partnership with the NZTA.

1.4.5 Research output summary

The research output offers a new paradigm for New Zealand. The framework will safely, effectively and efficiently monitor HCV activity without the requirement for onsite enforcement staff. It is a highly effective, repeatable and scalable ITS framework. The recommendations deliver the most effective mechanism for optimising continuous compliance at acceptable levels of accuracy and consistency. It is again emphasised that this research report is not NZTA policy. Policy/law changes and significant funding are all required before a SEM system may be implemented.

1.5 Methodology

1.5.1 Research methodology

As part of this research paper, a comprehensive literature review was undertaken, describing a wide range of operational and future compliance methodologies within New Zealand and internationally.

The literature review considered the capability of numerous technology components, and their degree of use, as well as the system architecture options and the international policies adopted by various government agencies.

A particular component of the literature review assessed the potential and validity for the adoption of international systems and practices within the New Zealand environment.

The literature review was circulated to the peer reviewers and the NZTA Steering Group members for discussion. The comments received were incorporated and developed into a draft research paper. This was subsequently issued to the peer reviewers and Steering Group members for further comment.

1.6 Report structure

The NZTA project sponsor requested the authors to maximise the usefulness and effectiveness of this research paper by addressing a wide range of non-technical audiences. Therefore this report departs to some degree from traditional NZTA research papers in its structure and presentation. The report is structured as follows:

The **executive summary** is intended for a range of audiences including senior policy makers.

Chapter 1 contains the **introduction** to the background, research objectives and outcomes.

Chapter 2 describes the **current compliance model.**

Chapter 3 describes the relevant **policy and law.**

Chapter 4 describes the options surrounding strategic **operational concepts.**

Chapter 5 describes the more detailed **system components.**

Chapter 6 describes the r**ecommendations** to advance the SEM.

Chapters 7 and 8 contain the international **literature review** as this is considered to have a more technical focus and be of reduced interest to policy makers.

The report structure is shown below. This is replicated at the beginning of each chapter to allow the reader to easily identify their position within the document.

✦ Introduction ✦ Current compliance model ✦ Policy and law ✦ Operational concepts ✦
System components ✦ Recommendations ✦ Literature review ✦

The report structure is such that chapters 2 and 3 are primarily intended for policy makers while chapters 4 and 5 are primarily intended for senior management and operational teams.

2 Current compliance model

✦ Introduction ✦ **Current compliance model** ✦ Policy and law ✦ Operational concepts ✦ System components ✦ Recommendations ✦ Literature review ✦

2.1 The operational transport environment in New Zealand

Transport operators operate in a highly competitive environment governed by a raft of transport, taxation, environmental and health and safety legislation that is too complex for all but skilled experts to comprehend. The few that can grasp the wide range of requirements normally have expert training, a skilled support team and years of experience.

The NZ Police (2011) *Annual report* shows around 110 CVIU staff inspect just under 90,000 individual vehicles nationally; a rate of 818 vehicle inspections each per year per staff member. This approximates to an average of one inspection of each heavy vehicle every two years or every 44,000 kilometres. In reality, many of these inspections are conducted on the same vehicles at more frequent intervals while other HCVs are rarely inspected, if ever.

This means the probability of an HCV being inspected by Police on any specific 10km trip is one in 4400 (0.02%) and evidential detection of overloading under the current inspection system is even lower.

The volume of trucks operating on New Zealand's road network and the finite number of enforcement staff is one of the key limitations in the existing compliance model. For example, even if the entire national CVIU staff was placed at the Drury weigh station site (south of Auckland) during 2011, a maximum of 75% of weight offences at that site may have been detected. If the CVIU was given 10 times as many staff the national inspection rate might increase to an average of one check per 4400km or five inspections per vehicle per year providing sufficient full-time coverage for perhaps seven sites. While a tenfold increase in inspections would have an impact it would still be insufficient to make the required change. The costs to Police and to national productivity would be immense. Therefore while Police inspections continue to be vital, it is important to consider alternative approaches to improving compliance.

As a very competitive industry, profit margins for road transport businesses, even those that are run well, are constrained. In order to survive in business, some transport operators are choosing to operate in ways that do not comply with land transport rules and regulations, particularly overloading, avoiding payment of RUC and other decisions that could compromise safety. Because economics is a strong driver of behaviour, for many operators who choose to be non-compliant, education will have little effect in shifting behaviours. The NZTA's own statistics show that 8% to 10% of New Zealand HCVs are overloaded to some degree.

Economic necessity, finite enforcement staff resources, the low probability of detection, receiving a fine and relatively low fines if imposed, can have the effect of incentivising poor compliance with HCV weight limits and safety requirements. Maintaining profitability is a significant motivating factor for operators, which can often result in poor decision making around legal compliance. While many in the road transport industry strive to be legally compliant, there are some HCV operators who choose to overload, operate vehicles with safety defects, drive while excessively fatigued, without the correct class of driver licence (or direct their drivers to do so) and fail to pay their share of RUC. These operators create unacceptable safety risks to other road users, create significant additional costs to the road network (that they do not pay for); gain economic advantage for themselves and disadvantage their competitors.

The NZ Road Transport Forum (as cited in Audit New Zealand 2005) seeks effective, targeted enforcement, and a system that makes transport operators fully accountable for their policies and actions. It said the failure of government transport policy to provide those elements, has played a significant part 'in giving economic advantages to delinquent transport operators who have deliberately compromised safety and operated illegally'.

An operator rating system (ORS) has been partially implemented to identify poor performers, with limited impact on transport operators' behaviour to date. Static rollover thresholds and brake rules have also been introduced since 2005. These developments have not been matched by the development of economic incentives to encourage greater compliance or an increase in the rate and efficiency of compliance checks.

We identify the primary lever to ensure improved compliance as economic.

There is a clear opportunity to provide compliant operators with commercial advantage by quantitatively and qualitatively increasing the frequency and coverage of HCV inspections, while simultaneously making it even more uneconomic for operators who fail to comply, or bypass or avoid inspection sites. This could also include a review of the current penalties in place for infringements of land transport regulations.

The proposed method of achieving the primary change is direct enforcement, generated from SEM as outlined in this paper.

While many SEM technologies are capable of fully automated operation and direct enforcement at high vehicle speed, others require slower speeds. Detailed physical inspections by qualified enforcement staff cannot currently be fully automated. Physical inspections require every HCV to stop and an enforcement officer to be present; however, the system can readily be configured to identify the most suitable candidates.

The information requirements, data quality and algorithms to provide these are significantly more important and more complex than the hardware or technology used to capture that data and develop it into information. There are numerous disparate data sets in existence in the NZTA and MoT, and with local authorities and the private sector. SEM provides an opportunity to link them together for the common good.

New Zealand HCV law permits many potential combinations and exceptions. New Zealand land transport law has constantly evolved during the last decade; introducing an ever-increasing range of possibilities and exceptions; correspondingly introducing significant complexity. During the course of this research a range of HCV drivers, operators, manufacturing engineers and enforcement officers stated to us that they could no longer understand all the legal requirements surrounding HCVs.

If a SEM system is to be implemented, there exists a parallel opportunity to address the question of simplicity by delivering accurate, reliable and specific information to each of these groups, consequentially improving enforceability of HCV law.

2.2 Stakeholder motives

This section sets out a base level of information that is required to broadly understand the motives driving behaviours of the system stakeholders. It is our experience that one group often does not understand the other. Under New Zealand law drivers, operators or owners are all liable for most types of offences and other parties can be held liable for some offences through a chain of responsibility.

2.2.1 Truck drivers

Many truck drivers have a solid understanding of the basics of compliance, but few have been trained as lawyers and many struggle to understand the complexity and finer detail of every HCV-related law.

It may be fair to say that, apart from the enjoyment that truck driving can provide, the majority of employee truck drivers are primarily motivated by two objectives:

1 Obtaining their wages, ie doing what the boss says

2 Getting the job done on time with the minimum of fuss.

In some cases, compliance with the law can be secondary to these objectives. Pressures from employers (perceived or direct) may also place additional burdens on truck drivers, encouraging non compliance.

FIRST Union Transport & Logistics Secretary Karl Andersen said (June 2012[2]) ‘As both the Waikato report and the Policing Advisory Agency study have demonstrated, the pressure on drivers is immense. They work in an industry that drives down their margins, leading them to take risks and compromise the safety of themselves and other road users’. The FIRST Union website[3] (2012) states ‘Fatigue and drug abuse are being blamed for a high number of crashes involving truck drivers. FIRST Union... believes unsafe practises are becoming more common place’. FIRST union represents 27,000 workers in finance, industrial (textile and wood) retail, stores and transport. The Associate Minister of Transport said in the same article that ‘the law was working fine’.

2.2.2 Truck operators and owner drivers

Accepting that there is a wide variety of opinion in the transport industry, two well understood and fundamental operational motive scenarios have been established:

1 Profit motive: Without profit a business will not survive. It is essential to operate a financially viable business. The approaches to achieving this vary and competition is fierce and overall profit margins are low. There is always pressure to carry larger loads and operate longer hours.

2 Safety motive: Ensure that any safety issues are rectified in an acceptable time frame. The interpretation of ‘acceptable time frame’ varies widely from a responsible continuous compliance approach, to a belief that six-monthly certificate of fitness checks will detect any faults, and in some cases deliberate non-compliance.

The NZ Road Transport Forum (as cited in Audit New Zealand 2005) seeks effective, targeted enforcement, and a system that makes transport operators fully accountable for their policies and actions. The failure of government transport policy to provide those elements, it said, has played a significant part ‘in giving economic advantages to delinquent transport operators who have deliberately compromised safety and operated illegally’. The Road Transport Forum New Zealand (RTF) website[4] states that the RTF is the authoritative voice of the road transport industry, advancing the interests of its members and promoting the contribution road transport makes to all New Zealanders’ lives.

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[2] www.voxy.co.nz/business/high-risk-truck-driver-pay-structure-highlighted/5/126949 (Accessed 14 October 2012)

[3] www.firstunion.org.nz/content/call-law-change-stop-unsafe-practises (Accessed 14 October 2012)

[4] www.rtfnz.co.nz/ (Accessed 28 June 2012)

Clearly truck operators have a significant incentive to always assure government officials that they comply fully with the law.

2.2.3 Truck owners

Owners of HCVs have generally invested significantly to acquire their vehicle or fleet of vehicles with some combinations costing nearly $1 million new. It is reasonable to assume that having made such an investment there is a strong motive to maximise the return. There are various approaches to doing so.

Truck owners may be the same as truck operators but in many cases are not. Some operators also set up separate companies or other types of entity to own the vehicle fleet.

2.2.4 New Zealand Transport Agency (NZTA)

The NZTA, as the national operational and funding agency for both highways and vehicles, has a range of priorities relating to HCVs:

- Prevent HCV crashes in line with a safe system approach. The consequence of being involved in a high-speed truck crash is significant, therefore it is vital to reduce the risks.
- Reduce or eliminate road asset damage (as distinct from authorised asset wear).
- Fair and equitable revenue collection (primarily mass distance RUC for HCVs).
- Fair market competition.
- Efficient freight systems supporting national productivity.

Road funding for the construction and maintenance of highways is obtained 100% from the National Land Transport Fund (NLTF) administered by the NZTA.

2.2.5 Road controlling authorities

New Zealand has over 70 road controlling authorities, with the NZTA controlling all motorways and state highways while local authorities (councils) control the other public roads within their local area.

The primary relevant objective of local authorities is to protect their investment in road asset from damage by overweight HCVs. They also promote safety on their network. Funding for local authorities road construction, operation and maintenance is 50% from the NLTF and 50% from local rates.

2.2.6 NZ Police CVIU

NZ Police, as the primary HCV enforcement agency, are tasked with managing road safety and compliance with other laws such as revenue collection, hazardous goods and weight enforcement. It is important to recognise that New Zealand law governing HCVs has always been complex and as such, CVIU enforcement officers are specialist enforcement officers. Some are qualified A-grade mechanics while many have other related backgrounds. The role of the CVIU is to ensure compliance as far as is possible. The Police aim to be fair and impartial in their role.

The broad areas that current checks investigate once identity has been confirmed include:

- vehicle safety compliance
- weight compliance with vehicle maximums
- hazardous materials compliance
- vehicle registration and licensing
- RUC compliance (national mass distance system)
- driver compliance
- operator compliance.

2.3 Enforcement methodology and requirements

The technical content of this report revolves around a fundamental analytical approach to best practice enforcement. This process is common to almost all jurisdictions and is illustrated in figure 2.1.

2.3.1 Identify

Correct identification to an evidential standard is essential, otherwise all other action fails.

The standard of proof required is the criminal standard ‘beyond reasonable doubt’ or greater than 99% rather than the civil standard ‘more likely than not’ (51%) Therefore any electronic identification must ‘authenticate’ identity of the vehicle, driver, owner and operator. This generally requires two factors of identification to be present and is achievable electronically.

Authentication of identity using two or more factors protects (as far as reasonably possible) from misuse of another’s identity and attached liability for non-compliance. Equally it enables a picture to be developed over time to demonstrate a general level of compliance that may result in operator incentives.

Identity of the vehicle, driver, owner and operator are all critical. If electronic systems cannot confirm any one type of identity, a requirement to stop whenever enforcement officers are present will remain. To ensure all can be confirmed, a voluntary data sharing partnership arrangement with the NZTA would enable connection to the vehicle systems and driver identification through an onboard driver licence bar code reader.

2.3.2 Process

The standard roadside inspection process determines whether or not the vehicle, driver, owner and operator are compliant with their legal obligations. Chain of responsibility requirements may involve other parties.

In the standard roadside inspection process, enforcement officers rely on their skills and experience along with team work and judgement to ascertain whether or not a vehicle, driver, operator, freight and owner are compliant. Enforcement officers are unlikely to ever detect every instance of non-compliance. Human nature, along with an easy-going New Zealand culture results in ‘discretion’ being legitimately used for many less serious offences, effectively meaning that fewer of the non-compliance issues detected are likely to be escalated or actively enforced. As a result operators are not always held accountable and a percentage of non-compliance persists.

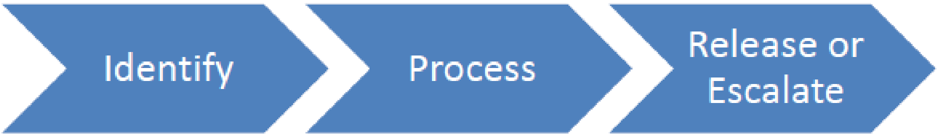
In an electronic process all applicable rules are programmed into the system, which rapidly and accurately ascertains whether or not a vehicle, driver, operator, freight and owner are compliant. The system can readily be programmed to escalate and enforce or require alternative compliance action without any bias. This results in a greater rate of detection of non-compliance, guaranteed escalation and accountability.

2.3.3 Release or escalate

Once the process is complete the vehicle and driver may be released with or without further action.

Any non-compliance may be escalated to ensure compliance before continuing on the journey. Such escalation may include further inspection or further action such as making a vehicle safe, offloading excess weight or a driver taking a required rest break.

Figure 2.1 Fundamental enforcement process



2.3.4 High-speed weighing (non-evidential)

There are a number of high-speed weigh in motion (WIM) telemetry sites operational throughout New Zealand which were originally installed solely for statistical purposes. The data from these sites is now available to enforcement officers.

Two sites have associated automatic number plate recognition (ANPR) cameras and three sites can be accessed near real time by enforcement staff as screening devices. Legal restrictions, the physical locations and the accuracy levels present issues in using these sites for enforcement purposes. This effectively requires NZ Police to continue stopping each HCV that is to be inspected. The NZTA also routinely sends operators warning letters.

Vehicles detected as being over the weight limits at these sites are often unable to be stopped due to insufficient enforcement staff and lack of suitable sites and inspection facilities in which to stop them. Current New Zealand law limits diversions away from planned routes.

2.4 Current NZ Police inspection process

The current New Zealand inspection and enforcement process relies substantially on stopping and physically examining as many HCVs as CVIU enforcement staff can inspect. New Zealand law permits the use of 'All trucks stop' signs in electronic or physical form and it is an offence for drivers of HCVs (including buses) not to comply with such a sign. Alternatively a hand signal or direction to stop, using flashing lights and siren on a patrol vehicle may be used.

CVIU enforcement officers inspect HCVs, their drivers, operators and freight. These checks provide existing legal linkages to owners and chains of responsibility to other parties.

Critical to the success of any check, is confirmed (authenticated) identification of the vehicle, driver and operator. Such identification ensures correct attribution of liability for the results of the checks.

Some cursory screening is conducted relying on the anecdotal knowledge, experience and skills which most of the enforcement staff possess.

This business process involves lengthy, generally untargeted inspections of documentation, vehicles and loads, the majority of which are generally compliant. While enforcement staff are busy and/or inspection sites are unmanned, many non-compliant HCVs will pass by. For example, Jones (2008) identified that in the UK environment, 94% of identified offenders could not be processed at one site while staff were operating due to lack of staff and site resources.

Each New Zealand vehicle inspection takes around 20 to 30 minutes and 90,000 inspections are conducted per year by the CVIU. While it is accepted these checks are vital, many of the vehicles and drivers are found to be compliant. The net total effect of all compliance checks on national supply chain productivity amounts annually to approximately:

- 45,000 hours unplanned reduction in national supply chain productivity
- 180,000 litres of diesel (estimated at 2 litres per hour idle time and 2 litres to accelerate 44 tonnes from a standstill to 90km/h).

There is also the wear and tear on HCVs and indirect costs including supply chain delay and increased emissions.

New Zealand weigh stations and sites are generally situated at the nearside of the roadway (rather than the centre). This arrangement is acceptable for vehicles travelling in one direction but poses risk for HCVs travelling in the opposite direction.

In order to stop and inspect a vehicle travelling in the 'opposite' direction, HCVs must cross oncoming traffic twice, once for inspection and once for departure with an inherent safety risk.

In one New Zealand case at Plimmerton, the original weigh station exists adjacent to the northbound carriageway. There has never been sufficient enforcement staff to permanently operate the station.

To reduce the safety risk a newer station has been constructed directly opposite, adjacent to the southbound carriageway. The cost of duplication of facilities is in the millions of dollars and the net effect is splitting the available staff resource.

Unlike many other jurisdictions, New Zealand does not currently have either indoor inspection facilities or inspection pits to readily permit detailed under-vehicle inspections and keep enforcement staff dry in wet weather.

Figure 2.2 New Zealand weigh station (Plimmerton northbound)

Irrespective of the enforcement staff resources and/or the facilities available to them, the fundamental enforcement concept: identify, process, release or escalate is still applied.

2.4.1 Acquiring identity

Conventional New Zealand enforcement methods require sighting and handwriting all details of the driver, vehicle, owner and operator onto a triplicate paper form. This process dramatically improved in terms of both operational accuracy and efficiency in early 2012. CVIU staff now generally use a handheld device to collect all data directly and electronically.

The device is fitted with imaging software that scans the barcodes present on New Zealand driver licences, operator transport service licence (TSL) labels (see figure 2.3 below) and vehicle labels (including RUC licences) when these are presented to enforcement officers. Each device is also fitted with GPS sensors to populate the location and time fields (when GPS coverage is available).

In the existing enforcement situation, driver identity and operator identity can only be determined once a vehicle has stopped and an enforcement officer requires these details.

Figure 2.3 Bar codes on driver licence (left) and operator transport service licence containing ID information

2.4.2 Automated process

Once key identity fields (driver licence number, vehicle registration number, operator licence number) have been acquired by the handset (see figure 2.4 below) from the relevant bar codes (or using optional manual entry) remote databases are directly queried. The results of the database queries auto-complete most of the required fields on a virtual form in the device.

This leaves the enforcement officer to physically inspect the vehicle and enter any remaining details onto the virtual form during a safety and compliance check before direct entry from the device onto a remote database.

Further details of the basic safety and compliance checks are contained in appendices A and B along with a comparison of the information available to an enforcement officer, an operator and a SEM system.

Figure 2.4 NZ Police CVIU hand-held device with imaging and data entry capability

2.4.3 Weighing options

There are three fundamental situations where HCVs are currently weighed evidentially and collectively; these are referred to as ‘roadside inspections’ for the purpose of the ORS.

2.4.3.1 Weigh stations

A dedicated weigh station facility has permanent HCV weighing facilities, an office and other facilities. In New Zealand these stations are currently government owned or operated, many equipped with electronic or fold-out signs on approach directing ‘All trucks stop’ along with low-speed bending plate WIM (see figure 2.5).

There are dedicated weigh stations in the upper half of the North Island at Stanley St (Central Auckland), Drury (South Auckland adjacent to the Southern Motorway), Nielsen St (South Auckland in a large industrial area) and Rotokawa (Rotorua). Of these, Stanley St is the most often used due to operational issues with the two other Auckland stations and fewer staff located in Rotorua. There are 10 such sites around New Zealand.

Figure 2.5 Low-speed WIM at Plimmerton Weigh Station (south) – 20m concrete approach and departure pads

2.4.3.2 Weigh pits

An inspection at a dedicated weigh 'pit' site constructed with sufficient space for HCVs to safely exit and re-join the roadway with flat approach and departure pads to/from a recessed pit into which portable scales may be placed to form a level surface (see figure 2.6 below). There are well over 100 such sites around New Zealand as they are cheaper to build and do not generally contain any permanent equipment.

Figure 2.6 Weigh pit HCV inspection, using portable static scales

2.4.3.3 Routine inspection

Routine HCV inspections take place where there are no facilities present (see figure 2.7). Weighing is optional using portable scales along with 'ramps and dummies' to elevate all axles to the same height as the scales, providing a level weighing surface. This requires a flat road with sufficient width for other traffic to pass. This method of weighing is the most time consuming, taking between 20 and 90 minutes for experienced staff. In some instances, arrangements exist with nearby certified commercial weigh bridges to use their facilities.

Figure 2.7 Routine HCV inspection with no fixed facilities

During peak periods, conventional weigh stations and inspection sites all over the world tend to exceed maximum capacity, either requiring more HCVs to enter than can be processed, or missing a percentage altogether. One UK example cited by Jones (2008) demonstrated that only 6% of overweight vehicles were able to be inspected at one site, although enforcement staff were present and operational throughout the whole period.

Inspection site operators are routinely forced to close inspection facilities while back-logs of HCVs are cleared. This sometimes results in drivers of overloaded or non-compliant trucks purposefully following a group of other trucks to avoid any requirement to stop for inspection.

The key constraint that emerges yet again is the number of enforcement staff.

2.4.4 Resulting actions

When a vehicle, driver, owner, freight and any associated issues detected during the enforcement process have been identified and properly processed the vehicle can generally be released to continue on its journey.

Those vehicles that cannot be released (with or without an offence notice) face an escalation process to deal effectively with any serious safety, gross overloading or other issues that have been identified. In almost all circumstances, escalation will require human intervention from trained enforcement staff. Escalation may be a lengthy process; however, this is a delay that compliant operators are unlikely to face.

2.5 International HCV compliance operations

On the international stage, there are a range of operational models in place as briefly described below. Further details about their operation and the technologies used are contained within the literature review in chapters 7 and 8.

USA – The USA uses high-speed pre-screening systems upstream of low-speed/static inspection facilities. The high-speed pre-screening sites detect HCV weight, registration number and a handful of other vehicle characteristics before directing potentially non-compliant operators into the low-speed/static facility for more indepth inspections. Throughout the USA, PREPASS and NORPASS are the most common systems to allow compliant vehicles to pass; however, two states use their own systems which perform in a similar way.

UK – The UK Vehicle and Operator Services Agency's (VOSA's) VIPER system was developed by the Weight and Safety Partnership/Project WASP. This incorporates high-speed ANPR and WIM technology screening vehicle weights in advance of inspection sites at 14 motorway locations across the UK. Jones (2008) states that in the UK, the electronic VIPER screening system has resulted in a 700% improvement when compared with traditional methods of targeting non-compliant operators.

Czech Republic – The Czech Republic is leading international practices by operating a high-speed monitoring site at Zlin which is certified to automatically and directly issue infringement notices for overweight non-compliance in the absence of staff (direct enforcement). The CROSS system at this site uses high-speed WIM linked to an ANPR system. A further provider is certified by the Czech Republic to set up direct enforcement systems.

Australia – The Australians use a series of pre-inspection sites where HCVs are required to leave the highway, using a dedicated approach lane to weigh stations while automated screening checks are performed. Drivers are required to slow to around 30km/h with a 30m spacing. Those vehicles that are not assessed as a compliance risk are permitted to continue back onto the highway by way of a variable message sign.

Europe – Mainland Europe is currently working towards a direct automated enforcement model through the ASSET project, funded through the European Commission. Equipment trials in several countries are proving successful and are likely to be incorporated into future direct enforcement operations.

2.6 Potential benefits of improved compliance

The current New Zealand government focus on productivity and reducing the cost of regulation is particularly relevant and applicable to this subject matter. Present day annual costs of truck-related fatalities, highway repairs, local road repairs and health costs add up to over $2.6 billion nationally.

1 HCVs are involved in around 10% of New Zealand's road fatalities with an annual social cost of $865 million (MoT 2012). It is accepted that HCV drivers or faults with their vehicles are the cause of all of these fatal crashes.

2 It is internationally recognised that road wear caused by cars is insignificant in comparison with that caused by HCVs. Overloaded HCVs are responsible for disproportionately greater road wear and damage, depending on the condition of the road. MoT's (2011b) *Briefing to the incoming Minister of Transport* stated that around $2.2 billion was spent annually on maintaining and renewing road infrastructure and this figure was projected to increase to $3.4 billion for 2012/13. Reported annual national highway maintenance and repairs cost $539 million added to local road costs totalling $900 million (Brash 2010). Maximising protection of such a valuable road asset is critical to wider economic success.

3 Diesel emissions are recognised in the preamble to the 2007 Vehicle Exhaust Emissions Rule as 'significantly more harmful to humans than petrol emissions' (NZTA 2007) with conservatively estimated associated social costs of $310 million per annum (accounting for premature mortality alone). Added to these costs are hospital admissions and treatment for injuries and health issues, cancer, bronchitis and related illness, lost work time, supply chain delays and decreased productivity.

Environmental and health effects of excessive emissions and tyre rubber wear cannot be ignored. Lost work time and premature death significantly decrease national productivity.

4 The health effects of vehicle emissions were revised in the HAPINZ report released in July 2012. The figure in that report for health effects was much higher (due to different assumptions) and as at 2010 was estimated at $941 million per annum for all vehicles.

These topics are discussed in more detail in the literature review.

3 Policy and law opportunities

✦ Introduction ✦ Current compliance model ✦ **Policy and law** ✦ Operational concepts ✦
System components ✦ Recommendations ✦ Literature review ✦

Given the outline of the current state in sections 2.1 and 2.2, it is clear that our current operational compliance methodology is not working. The clear intention of conducting this research was to lead New Zealand to a new way of thinking about road damage and compliance. Chapter 4 onwards and the appendices contain more technical details.

In summary of the previous sections:

- The New Zealand government seeks improved safety and productivity; however, to ensure the effective management of our road and highway assets there is an opportunity to develop corresponding HCV monitoring and control systems.
- Official statistics show that present day annual costs of truck-related fatalities, highway repairs, local road repairs and health costs add up to over $2.6 billion nationally although not all of this can be attributed to HCVs.
- NZTA statistics show that currently around 8% to 10% of New Zealand HCV trips are overloaded.
- There is a wide range of other types of non-compliance including safety and RUC revenue evasion that the current compliance model is unable to minimise.
- NZTA statistics show the rate of overloading offences detected at a single automated NZTA WIM site (Drury) is around 110,000 per annum although some of these are HPMVs legitimately operating at higher mass.
- NZ Police statistics show the national rate of CVIU HCV inspections is 90,000 individual vehicles per annum (estimated 50,000 HCV combinations). Each inspection takes 20 to 30 minutes.
- Therefore, even if the entire national CVIU enforcement force was permanently sited at the Drury WIM site, it could not deal with all the overloading offences at that site.
- CVIU inspections are considered absolutely vital in dealing with non-compliance; however, CVIU inspections result in 45,000 hours unplanned reduction in national supply chain productivity and up to an estimated 180,000 litres of diesel per annum.
- Police and MoT statistics show the current probability of an HCV being inspected by CVIU roadside inspections is one inspection every two years or 44,000km.
- This means the probability of a CVIU inspection on each 10km trip undertaken by a transport operator is 1 in 4400 (0.02%). This offers little if any incentive to comply.
- There is anecdotal evidence that some transport operators pressure HCV drivers not to comply. On an individual driver level, if given the choice of doing what an operator instructs or in many cases risking losing your job, one might expect the former to take precedence.

- HCV operators may be motivated to cut costs by reducing compliance levels in order to stay in business. According to research by Waikato University for the Road Transport Forum, in 2010 each stock truck was running at a loss of $8248 a year and the national average profit margin was 1%.
- HCV operators that do comply can run the risk of being 'undercut' by other operators that have lower levels of compliance, such as overloading vehicles or exceeding work-time hours. Therefore any compliance model needs to specifically target the minority of operators who are the most evasive, deliberate and systematic in non-compliance. Anything less will not achieve the objectives.
- Therefore the authors suggest education about compliance will not address the root cause of the issue. We suggest strong economic incentives to comply are required to create any real effect.

This research offers a cost-effective approach to many of the issues but requires a new paradigm of thinking, strong political will, commitment and significant investment. Supporting policy, law, systems and business process changes are all required. This paper can provide an outline and the basis for change but continued expert private sector direction will be required to successfully achieve implementation.

There is a significant risk of failure if expert private sector direction is not applied to ensure that the interests of all parties are met.

Scope exists to use the same technology to directly automate HCV identification and offence-processing at high speed for many offences; or to semi-automate using pre-screening or virtual WIM followed by enforcement staff intervention. The identified issue of finite enforcement staff and the Drury example, in our opinion clearly answers this question.

Any fully automated or semi-automated option will further reduce the time delay to operators by generally releasing those that invest in compliance and elect a data sharing partnership with the NZTA; while actively identifying and escalating those that do not wherever possible.

Escalation may be fully automated for a wide range of non-compliance with direct action, remotely by one operator monitoring and communicating with multiple sites, or following current practice, requiring non-compliant operators to wait until enforcement officers are physically present. Again we suggest the finite staff resource combined with the volume of offending answers this question.

This research promotes productivity through maximum automation including direct action, issuing warnings or notices electronically for non-compliant operators, letting them continue in some circumstances where non-compliance is of a minor nature. More serious incidences will always escalate according to the processes, rules and parameters that are yet to be developed in line with yet to be determined political, practical and legal constraints.

Due to the already identified constraint of staff resources, this paper focuses away from traditional business process and mobile sites. It focuses instead on automated virtual site selection, along with modified site design criteria to maximise efficiency for those sites where enforcement staff may be present at times.

It is accepted that these concepts challenge the current way of thinking; however, in the words of Albert Einstein 'The significant problems we have cannot be solved at the same level of thinking with which we created them'[5].

[5] www.quotationspage.com/quote/23588.html

In considering the above requirements, technology is already available to perform almost all current CVIU functions, screening, and issuing offence notices as appropriate. The CVIU will always be required to conduct detailed physical inspections, target those non-compliant operators who are most evasive, to check areas where the volume of HCV traffic does not warrant electronic systems and to investigate the inevitable serious crashes involving HCVs. It is envisaged that SEM will make the CVIU more efficient, effective and productive, make the industry more compliant and make compliant operators more profitable.

New Zealand law requires that all evidence of non-compliance must reach the criminal standard of proof 'beyond reasonable doubt'. As such it is essential that all systems used to gather evidence in place of enforcement officers must reach the same standard. This is a fundamental requirement for SEM.

3.1 Government policy

The key land transport impacts that are directed by the New Zealand government in the *Government Policy Statement on Land Transport Funding 2012/13 – 2021/22* are improved productivity, improved safety and strong value for money. Over and above these impacts there are other additional priorities including more efficient freight supply chains and reductions in the adverse environmental effects from land transport. The government's transport priorities can be delivered through the following outcomes:

- Reducing the additional road wear that overloaded trucks cause to the road asset.
- Reducing or almost eliminating the delays to compliant HCV operators, supporting and enhancing a more effective supply chain.
- Increasing the ratio of non-compliant HCVs which enforcement staff inspect to 100% at most SEM sites.
- Denying unsafe and overloaded HCVs and fatigued HCV drivers the use of New Zealand's roads until they are compliant.
- Addressing the HCVs that generate the most dangerous emissions will result in improved health and a significant reduction in both fuel consumption and health costs.

3.2 Cooperative partnership and integrated approach

HCV operators who elect to share data in transparent partnership with regulatory agencies, may in the future be able to bypass the majority of traditional inspections. This system works in other jurisdictions such as the USA, Australia and UK. The data which operators and drivers elect to share will be similar in nature to that already collected during a physical enforcement check. This will include accurate driver identity and work time details.

It is accepted that these might otherwise attract privacy concerns. In return, those drivers and operators will experience little or no delay during the majority of checks, which will increase operational efficiency, fuel efficiency and travel time reliability while decreasing emissions.

Brakes cannot be tested at high speed, but can be checked at slow speed. The engine management system can also be interrogated remotely to provide a view of any brake defects.

Alcohol, drug detection and detailed mechanical inspection will require the HCV to stop. These issues require enforcement staff, despite onboard capability in some advanced HCVs to report faults and detect alcohol. The objective is to physically inspect those HCVs and operators that show the highest rate of non-compliance.

At every opportunity, the system will identify and promote operator accountability for those HCVs posing safety risks, undue damage to the road network and unfair economic advantage.

Supply chain, freight logistics and transport systems do not operate in isolation. They are all part of a very complex global system. Improvement to business process relies on change in organisational structures, the legal framework, funding, policies and political commitment. The initial area the research seeks to promote is the willingness to change expectations and behaviour of those involved in the transport industry; to support common goals of safety, efficiency, economic growth and prosperity.

Truly *integrated approaches* are the best differentiator. Such integrated approaches ultimately need to be applied across New Zealand and beyond. Central government, the NZTA, local authorities, transport and technology industries, employees, processes, core and support functions, and even supply network partners and customers need to be fully aligned and synchronised in order to build New Zealand's capability, creating and maintaining sustainable competitive advantage.

The aim of combining and empowering intelligence within vehicles, transport infrastructure and government agencies charged with law enforcement, planning, supply and maintenance of our road network is dependent on wider acceptance that these means are necessary to improve overall productivity, create a safer road environment with lower repair costs, a healthier air environment and a fairer economic environment.

3.3 Identified law changes

Whichever form it takes, the concept of a new SEM system will require law changes to ensure that the system delivers the benefits it is capable of. The majority of these law changes are associated with privacy, acceptance of tolerance and the 'chain of evidence' used to prosecute offenders.

3.3.1 Privacy and identification

Privacy is a potentially contentious and currently poorly defined issue in relation to the identification of vehicles and their drivers. This extends to some degree in relation to owners and operators.

The Land Transport Act 1998, section 113A, permits enforcement officers to require, to inspect and to take copies of all records including work time logbooks.

The Land Transport Act 1998, section 114 (3), permits enforcement officers to require drivers to:

1. Give his or her full name, full address, date of birth, occupation, and telephone number, or such of those particulars as the enforcement officer may specify
2. State whether or not he or she is the owner of the vehicle
3. If the driver is not the owner of the vehicle, give the name and address of the owner or such particulars within the driver's knowledge as may lead to the identification of the owner.

Drivers can be arrested by the enforcement officer if they fail or refuse to provide these details or give false or misleading details.

The Land Transport Act 1998, section 145, permits evidence obtained from approved vehicle surveillance equipment such as speed cameras and toll cameras.

The Land Transport Act 1998, section 149, permits enforcement officers to give evidence on a driver's statement relating to the identity of the employer of that driver or a matter that is or ought to be specified in a logbook.

Voluntary data sharing is an option promoted by this report to deal with such privacy issues; a specific empowering law would create a formal exception to the Privacy Act and create clarity on the topic of electronic identification of drivers in moving vehicles and of the vehicles themselves along with their associated owners.

Given that existing powers require an HCV to stop and the driver to speak with enforcement officers, it is anticipated that many operators and drivers will agree to cooperate voluntarily and disclose these details electronically without stopping.

The Privacy Act 1993, section 6, principle 11(e) (under review), broadly permits automated numberplate recognition for the purpose of upholding the law.

A clear law defining and empowering electronic monitoring and identification of HCVs, their drivers, owners and operators would assist greatly.

3.3.2 'HCV law'

Recent discussions between the authors and industry engineers, transport operators, HCV drivers and enforcement officers presented a common opinion that New Zealand's laws relating to the use of HCVs are unnecessarily complicated. As a whole the rules and regulations governing HCV operations are difficult to comprehend for many in these groups. There is room to streamline HCV regulation, or to use technology to simplify it for the end user.

The requirement to introduce law changes to support the implementation and operation of the SEM system presents the opportunity to update/amend the existing laws associated with the general use of HCVs within New Zealand. It is recommended that a review is undertaken which will ultimately result in a clearer definition of heights, weights and permissible characteristics so that transport operators and HCV drivers fully understand the legal constraints within which they work. Some of the key areas of HCV law which are particularly challenging are as follows:

1. Vehicle Mass and Dimension Rule
2. Worktime and Logbooks Rule.

3.3.3 Chain of evidence and identity

Current identification of those individuals charged with offences relies primarily on an enforcement officer (and supporting witnesses) giving evidence of the individual's involvement in an alleged offence.

Exceptions already exist for parking, speeding, red light violation and a limited range of other traffic offences, such as avoidance of toll and specific access payments where the registered owner is held liable unless the driver is identified.

There are further exceptions for identification of HCV owners based on driver statements and operators based on the operator licence displayed at the time a vehicle is inspected. In each case, an enforcement officer is required to give evidence of identity gained by these methods.

A clear legal framework would be required to permit electronic identification of drivers, vehicles, owners and operators; to confirm that those identifications formally support the criminal standard of proof for associated offences in the absence of any enforcement officer and to provide assurance that the evidence is admissible and will be afforded the same weight as evidence given by an enforcement officer.

It is recognised that electronic systems will not be able to accurately read the number-plates of some trailers, particularly those trailers that are between a truck and trailer and/or trailer-combination, such as a B train. Law changes would be required to permit any detected offending relating to those trailers to be attributed to the towing vehicle without the accompanying current requirement to prove the registration number of the trailer.

3.3.4 Chain of responsibility

A significant incentive for compliance and for improved cooperation would be achieved if the chain of responsibility laws was widened to include direct liability being attached to owners and operators of all vehicles and all sites dispatching or receiving freight on HCVs, including site management.

This may be drafted in such a way that it would be a valid defence if the owner could demonstrate that they took all reasonable steps to avoid overloading and safety issues.

In the UK, this chain of responsibility extends to the 2007 Corporate Manslaughter and Corporate Homicide Act in circumstances where fatalities occur.

3.3.5 Alternative compliance model

In the proposed system there is an option for operators who elect a cooperative partnership (data sharing) with regulatory agencies to demonstrate their commitment to compliance. It is envisaged that this model ideally operated by an independent trusted third party data aggregator, will enable the SEM system to remotely access onboard vehicle systems and obtain driver ID, onboard weight data, engine management data and RUC data.

In return for this type of partnership, some international jurisdictions permit compliant vehicles to bypass weigh sites.

There is clear scope in the proposed model to develop an alternative compliance model as an incentive. For example if:

- an operator is participating in the data sharing scheme and is demonstrating a consistent track record of continuous compliance across the range of offences detected
- a safety or revenue offence is detected by the electronic system (out of character) but not an overloading offence

Then in place of offence notice(s) the operator may be given an electronic requirement to remedy the issue and drive through any SEM site within a set period to demonstrate compliance.

3.3.6 Penalty levels

The current infringement notice regime does not provide any significant economic disincentive to HCV non-compliance. When dealing in millions of dollars, a few hundred dollars or thousand dollars pale in comparison. While more frequent, direct enforcement will improve the current scenario, very significant penalties including impounding of vehicles may be considered for those who are shown to evade detection or be repeat offenders.

3.3.7 Offence automation and deviation from route

Current New Zealand law (section 125 of the Land Transport Act 1998) is based on the presumptions that:

1. Any HCV will be stopped for inspection and measurement by an enforcement officer.
2. Any offence notice will be issued by an enforcement officer.
3. Any driver is innocent until proven guilty and therefore there are limits to the distance that an enforcement officer can require a driver to deviate from their route for the purpose of enforcement weighing by more than 5km (effectively 2.5km in each direction) unless the enforcement officer believes that the driver has attempted to avoid detection.
4. The driver of a heavy motor vehicle or goods service vehicle must, whenever directed by a sign displaying the words 'All trucks stop' or by an enforcement officer, stop the vehicle and keep it stopped so that an enforcement officer may determine whether or not to take any action under subsection (1) or to complete the exercise of any other power conferred on an enforcement officer by this Act.

The system will provide either direct evidence of an offence in most scenarios and good cause to suspect that an offence has been committed in others. This determination may be permitted by Gazette notice or rule.

3.3.8 New electronic offences, detour and avoidance

Further to the discussions above, new offences would be required to deal with vehicles detected using detour routes, bypassing sites without electronic authority or failing to comply with electronic directions of the system or directions of a remote operator.

These directions may include a new way of thinking, such as presenting the vehicle for inspection at a certificate of fitness testing station the same day, within seven days or within 28 days at the expense of the operator and significant economic disadvantage such as mandatory impounding of unsafe or overloaded vehicles that have detoured, bypassed or avoided SEM without authority.

It is critical that non-compliance offence penalties are of sufficient magnitude that the incentive on the HCV drivers is to drive across the SEM sites, comply fully with all directions of electronic signs, in vehicle devices, and local or remote operators.

A suitable incentive may readily be provided by mandatory 14-day impounding of vehicles and mandatory seven-day HCV driver licence or operator licence suspension, effective immediately upon the driver being spoken to by enforcement officers. This level of penalty is justified on the basis that some New Zealand transport operators have been known to threaten drivers with dismissal or ‘stand down’ if they fail to operate outside the law (for example, work excessive hours or carry excessive loads).

3.3.9 Tolerances

It is a fact that any weighing system and most measurement systems have an inherent degree of inaccuracy. The method of dealing with the inaccuracy may be the difference between evidential grade and screening grade WIM.

Evidential high-speed WIM equipment may not be as accurate as low-speed WIM. However the trade-off for permitting most vehicles to continue without stopping may require an increase on the current tolerance levels. Such an increase may be in the order of a 10% tolerance but would need to be determined during field trials of any equipment used. This would permit automatic prosecution of weight offences at highway speed on suitably certified equipment.

A second level may be determined (at a lower tolerance) when enforcement staff are present to direct an evidential weigh based on information supplied by the system.

A two-tiered or multi-tiered approach is likely to promote a higher level of compliance while promoting fairness and removing any doubt when solely electronic evidence is used.

3.3.10 Summary proceedings

Consideration may be given to making all offences detected by SEM infringement offences carry a significant pre-determined penalty (many already are infringements). This would minimise the initial effect of significant increases of offence notices on the judicial system.

While current law requires a person to obtain electronic evidence from a system, then provide that evidence to the judge as a witness, an alternative scenario may be contemplated for electronic HCV offences where an individual requests a hearing.

The judge may be supplied with a standard electronic report including photographs describing the allegations. Defence evidence may also be lodged in electronic form. The judge would only call human witnesses if considered necessary. This would speed the judicial and administrative process for all parties enabling both Police and transport operators to continue business under most circumstances.

Current law around service of infringement notices might be modified to include electronic service by the system directly to last known email addresses, smart phones and other electronic media. Proof of service would also require consideration.

3.3.11 Judicial notice

It is recognised that judges may be reluctant to take notice of purely electronic evidence, particularly if identity is questioned. It is recommended that consideration be given to a law requiring judges to admit electronic evidence of this nature and to place full weight on electronic evidence unless there is evidence beyond reasonable doubt to the contrary.

3.3.12 Data sharing

Significant productivity and cost gains may be made by sharing the data from infrastructure such as high resolution cameras with a wide range of authorised parties with legitimate purposes. Legg (Washington State Department of Transportation (WSDoT)) states that when the data becomes available a wide range of people will request access. This also supports an 'all of government' approach. Currently there are numerous potential legal restrictions to data sharing even though the data may be obtained by cameras and other equipment in a public place.

A law supporting data sharing at different levels would enable effective and efficient use of infrastructure. It is recognised equally that significant care should be taken to prevent industry operators from obtaining specific data about the routes taken, frequency of occurrence at a site, weight, cargo types carried and other such data relating to their competitors.

3.3.13 Data issues

Consideration may be given to legislation around data ownership, custody, stewardship, storage, hosting and retrieval.

3.3.14 Freight only lanes

The economic incentive to cross a SEM site may be achieved using freight only lanes at sites where congestion is frequent and traffic is stop start. Suitable requirements around departure from the freight lane would need to be in place.

3.3.15 Congestion charging

SEM sites are capable of being used as a general congestion charging cordon. For example in Auckland, the type of connectivity required for SEM sites would readily lend itself to shared use. Laying out SEM sites in a full cordon around the central city would also maximise the ability to check each HCV entering and leaving Auckland. This consideration is not built into the current site list but is readily achievable as a cost-saving option. Congestion charge cordons are rarely viable as a sole use system.

4 Operational concepts/options

✦ Introduction ✦ Current compliance model ✦ Policy and law ✦ **Operational concepts** ✦ System components ✦ Recommendations ✦ Literature review ✦

4.1 Overview

SEM systems are capable of collecting evidential-grade HCV, driver, operator and owner compliance information, primarily without any requirement to slow from normal operational speeds. SEM builds on the international concept of virtual weigh stations (VWS) and appendices A and B examine the broad range of non-compliance that can feasibly be detected. Evidence of HCV activity will inform and underpin planning processes and decisions, improving productivity (efficiency and effectiveness) of road freight movements; enhancing safety, security, equity, resilience, compliance and health for all parties; minimising excessive damage to the road asset; accurately measuring network performance; enhancing future policies and law; and ultimately leading to improved compliance and improved national productivity.

The electronic monitoring technology options outlined in this paper enable a wide range of highly accurate and systematic automated safety and compliance checks, enforcement officers could not reasonably be expected to conduct during a detailed 20-minute inspection.

The implementation of a SEM system should consider and satisfy the following fundamental rules:

1 The system will eliminate or minimise the requirement for any human intervention while ensuring that enforcement officers can readily access and understand the information near real time – any time any place using any internet enabled device.

2 The system will make each end user task as simple, or simpler, than the current process with an improved result.

3 The system will maximise use of a minimum number of standardised evidential grade technologies, systems and processes. The intention is to ensure a readily scalable architecture that may simultaneously be used for other authorised purposes, including those outside the current research scope.

4 Existing hardware, weigh sites and communications systems should be used wherever possible to maximum advantage.

5 Each site will have different requirements and subtle variations in layout. For example urban sites prone to stop start traffic require a different layout than free-flow motorway sites.

6 The system will contain sufficient avoidance detection to ensure that HCV operators do not prefer to bypass, avoid or evade SEM sites.

Building on international experiences, in order to introduce a SEM system to New Zealand, there are four high-level concepts of operation which may be implemented. These are identified below.

1 Direct automated enforcement

2 Automated inspection with targeted intelligence driven enforcement

3 Electronic screening with low-speed/static inspection

4 Existing operational regime.

The concepts identified above are placed in hierarchical order in terms of ability to address the issues faced by New Zealand. The direct automated enforcement model is the most effective and productive. If the political will exists, it delivers the greatest benefits and a maximum return on investment.

The other two models require identical equipment and will form part of the direct enforcement model. As stand-alone options they are significantly less effective because the level of compliance remains constrained by the finite number of enforcement staff.

The existing operational regime (no change or do nothing option) is the least sophisticated and as already demonstrated is inadequate in providing the functionality and levels of service necessary to ensure a high level of compliance in national freight operations. The current regime is not taking full advantage of technology and systems that would readily assist in reducing undue wear to the road asset, and safety and adverse public health risks.

The four operational concepts are described in further detail in sections 4.2 to 4.6 below.

4.2 Direct automated enforcement

Direct automated enforcement is a system concept that uses the data from SEM to assess an HCV, driver, operator and owner and their associated characteristics (attributes) against a range of specified criteria (laws) and tolerances (parameters).

The operator/driver/owner of a vehicle operating outside a specified range automatically receives infringement notices for the identified offences, similar to the way in which infringement notices are issued to the registered owners of vehicles caught speeding at fixed and mobile speed camera sites. The automated issue of infringement notices ideally requires no Police enforcement resource.

Direct automated enforcement requires roadside technology that can identify the vehicle and assess its key identifiers (registration number(s), driver licence number, operator TSL number and characteristics (attributes), eg weight, speed, height, width, length at high speed in the normal operational environment. The system is capable of:

- querying existing databases to obtain compliance information (refer appendices A and B)
- identifying specific offences from known parameters and issuing infringement notices
- identifying other characteristics where non-compliance may be inferred but cannot be confirmed in the high-speed environment
- storing all data in a readily accessible format that is available in different forms at different levels of security to authorised user groups.

The vehicle characteristics which the system can identify are reliant on the deployment of suitable roadside technology that is capable of accurate measurements for particular components. Local controllers, including databases at each site, store key data for each vehicle, query remote databases near real time and store key identification material in a central national database.

Querying remote databases enables accurate determination of a wide range of other relevant compliance data. Those operators electing a data sharing arrangement will make their GPS, RUC, engine management and driver ID data available to the database at the time of each query.

Direct automated enforcement using SEM requires a network of infrastructure, power, communications and a comprehensive back office system capable of processing all data at evidential grade (for offence purposes) while building a 'history' of characteristics about New Zealand's HCV fleets.

Direct automated enforcement is not capable of detecting complex mechanical faults and other subtle conditions. These are likely to continue to require inspection by a skilled and suitably qualified enforcement officer. However, the SEM is able to act as a decision support system, identifying the vehicle, suspected area(s)/issue(s) when enforcement officers are present.

It also acts as an intelligence system identifying those operators who are generally compliant and those who are not.

All high-speed sites can readily be monitored and managed remotely and simultaneously by enforcement staff sited in a single, suitably equipped, control room. This caters for the situation where some vehicles will be required to stop until they comply.

Where high-speed sites are located upstream of suitable static or low-speed inspection facilities, the driver of any non-compliant or suspect HCV can be required to enter the static/low-speed inspection site for further investigation, such as thermal imaging to assess evenness of brakes, or if staff are present a detailed mechanical inspection.

System performance and on-going transport operator performance is clearly measured by key performance indicators including detection rates for each type of offence. This offers significant intelligence to CVIU about the compliance of New Zealand's fleets.

The concept of direct automated enforcement requires a shift in the paradigm of thinking. The roadside infrastructure becomes the 'enforcement officer'. The SEM network and evasion detection systems make avoidance or detouring economically unviable for even the most determined offenders.

The implementation of direct automated enforcement requires significant political commitment and will need to take place in conjunction with law changes. The most significant law changes will be the authorisation of evidential grade high-speed WIM systems and the authorisation of direct issuing of infringement notices, based solely on information recorded by the roadside systems and the associated databases.

Direct, continuous detection and automated processing of all possible non-compliance offers dramatic efficiency, safety and productivity improvements when compared with current enforcement capability.

4.3 Automated inspection with targeted enforcement

Automated inspection with targeted enforcement employs the same equipment, techniques and processes as the direct automated enforcement operational model. It requires a reduced policy imperative using the system as an intelligence tool and needs enforcement staff to take any action. It also forms a natural part of a direct enforcement system and provides local screening (see section 4.4).

This is a significant improvement on the current enforcement model; however, it is unlikely to deliver the cost benefits of the direct enforcement model because it continues to rely entirely on the finite pool of enforcement staff.

A significant intelligence base would be established for the New Zealand fleet that would enable more targeted enforcement to maximise the productivity of enforcement staff by enabling attention to be given to the vehicles and operators identified as having the poorest compliance record. This data might also be authorised by law for entry into the ORS.

Automated inspection with targeted enforcement would still require a range of law changes.

As the automated inspection with targeted enforcement operational concept largely relies on identical roadside and back office infrastructure, the costs to implement each system are largely the same. The only realistic reason to choose this concept would be as an intermediate step (progressing toward direct automated enforcement).

4.4 Electronic screening with low-speed/static inspection

Electronic screening with low-speed/static inspection is a localised concept using identical roadside equipment to previous options. The functionality identifies HCV issues at high speed, upstream of an inspection facility and provides secure enforcement access on any internet enabled device.

This can operate with limited policy changes. It is only of any use when enforcement staff are present at the site. The remainder of the time the investment is not utilised.

HCVs detected as having issues are signalled to enter the low-speed facility for further inspection.

In the event that the low-speed inspection facilities are unmanned, or the high-speed electronic screening system is not located upstream of a low-speed inspection facility, mobile systems such as smartphones and laptops may be used by enforcement officers to inform physical inspections at the roadside or safer location.

The information gathered by the electronic screening system may only be used to target a particular vehicle near real time because the data is not transferred to a remote central database.

Electronic screening with low-speed or static inspections may require limited law changes.

Using a lower specification of equipment is feasible but would result in the identification of fewer offences or suspected offences.

4.5 Existing operational regime (no change)

The existing operational regime (refer to section 2.4 for further details) requires intensive manual intervention. Enforcement staff undertake physical inspections with limited technology support. This business model is readily avoided, time consuming and lacks reliable operational intelligence. It also relies on a ratio of enforcement staff to known offending that is clearly identified as inadequate.

4.6 System summary

Fully automated systems can operate effectively on a continuous basis, detecting, recording and issuing automated notices for a wide range of offences without any staff constraint.

Therefore a fully automated direct enforcement system offers significant improvement on the current level of safety issues, overloading and compliance with a wide range of offences.

Automated systems generate a significantly improved strategic view of compliance, impartially identifying those transport operators who are generally compliant and those who are not. This information could be useful to both allow greater targeting of enforcement resources as well as provide more even coverage of data for the ORS, when safety-related offences are detected.

The first three system concepts outlined above use the same equipment but the success of each operational concept is unlocked by the political will and the necessary funding, policy and law changes required to make it happen.

Table 4.1 below highlights the key differences between the four operational concepts outlined above.

Table 4.1 Operational concept summary

System functionality	Direct automated enforcement	Automated inspection with targeted enforcement	Electronic screening with low speed/static inspection	Existing operational regime
Automatic issue of infringement notices	✓			
Significant intelligence gained about the New Zealand fleet. Maximised effectiveness of enforcement staff through targeted enforcement	✓	✓		
Electronic screening. Maximised use of enforcement staff at inspection sites	✓	✓	✓	
Random inspections				✓
'Return' on CVIU enforcement officer's effort	Not constrained by staff	High	High	Very low
Estimated percentage of actual non compliance detected and dealt with	Maximum effect	Low but more strategic effect	Very low estimated 1%	0.04%

Automated systems will readily perform high-volume enforcement tasks, providing an evidential basis that supports decisions to target particular operators, vehicles, times and locations.

Automated and semi-automated systems are initially, and probably in the longer term, unlikely to be able to effectively deal with deliberate, systematic, calculated evasion of inspection sites, particularly in rural and low volume areas. This dictates an on-going requirement for enforcement staff.

It is not suggested that automated direct enforcement systems result in a reduction of enforcement staff requirements; instead direct enforcement systems offer improved efficiency, effectiveness and focus of enforcement officers.

4.7 SEM site selection

4.7.1 System wide

The position of SEM sites relative to major freight routes and proximity to potential avoidance routes are key factors in operational success. The placement of SEM sites should pay particular attention to the locations and route choices adjacent to industrial areas, the ports and rail hubs. Failure to manage or eliminate all possible avoidance routes will always reduce the on-going operational effectiveness of WIM sites because many non-compliant operators will tend to use them.

A widespread network of SEM sites will generate significant information about the movement of HCVs on key freight routes. This data can be used to understand more about New Zealand's 'freight task' and assist with planning for the future. A widespread network may also identify further compliance issues whereby specific vehicle, drivers or trailers appear to be detected in two or more discrete locations in which it is physically impossible for that to occur (ie using the identity of another).

Four potential operational environments have been proposed for SEM sites. These are:

1 On approach to NZ Police/NZTA weigh stations and inspection sites

2 Strategic sites on approach to bridges, at congestion or toll cordons and on the open road with emphasis on key freight routes where there is limited economic scope for avoidance

3 At the entrance to ports, inland ports and major rail freight terminals, air freight terminals and refuse collection centres. At this type of location the site operators have their own reasons for installing facilities and may be interested in sharing costs and data

4 Sites where major freight operators and other parties wish to demonstrate compliance and/or partnership with the NZTA.

It is anticipated that all HCVs will be required to follow designated routes in the close vicinity of SEM sites. Appendix D drafts a potential list of sites for consideration.

4.7.2 Site-specific factors

For high-speed SEM sites, the road on approach (>100m) is ideally smooth, straight, free flowing and with good lane discipline. The WIM sensor should be flush with the surface to avoid bumps or changes in levels, as each of these affects the downward force of the vehicle and movement of loads (particularly bulk liquid) within a vehicle.

For SEM sites where stop start traffic may occur, the location of the facility with respect to the carriageway and direction of travel is a key consideration. Currently there are no methods for weighing HCVs in a stop start environment although one is currently under development.

There is no single correct answer in a stop start environment and careful consideration will need to be given on a site-by-site basis. We have introduced the concept of freight lanes as an incentive for operators; these would both enhance freight productivity and provide an incentive to cross the SEM sites at those locations.

4.8 Site layout

Inspection facilities can be located in a number of locations. Appendix E provides a representative sample of schematic arrangements.

Locating the inspection facility on the nearside of the carriageway is the considered the safest arrangement. An HCV will turn left into and out of the facility. This, however, fails to account for the operational reality that New Zealand has insufficient funds to build dual weigh stations either side of the highway at each location. Even if sufficient funds were available, there is insufficient enforcement staff to operate the existing weigh stations continuously and a tenfold increase in enforcement staff would still be insufficient. Therefore we suggest serious consideration of the alternatives.

Operational reality is that HCV traffic travelling in the opposing direction to the majority of New Zealand weigh stations are required to turn right into and turn right out of the station, crossing the opposing traffic flow twice and accelerating with traffic approaching on the left (blind) side.

Internationally, some facilities are located on dual carriageway roads within the central reservation between the two opposing carriageways. This allows a single inspection facility to be used for HCVs travelling in both directions without any direction change manoeuvres.

The disadvantage with this arrangement is that HCVs are required to access the facilities from the right lane at modest speeds and on leaving the site, traffic will be on the left (blind side) of the HCV. However, entering a central reservation facility will be safer than the current arrangements where HCVs are required to cross opposing vehicular movement, often at highway speed.

The NZ Police CVIU currently makes irregular use of weigh pits at over 100 existing locations on a mobile basis. The environment required for mobile inspection will depend on the tools and techniques used. Within this report mobile units that might complement an infrastructure-based SEM framework were identified; however, high-speed portable WIM is not currently available.

Mobile sites have not received significant attention due to the ongoing requirement for enforcement staff to operate the systems and the identified fact that the finite number of enforcement staff is the major constraint to increased inspections.

5 System components

✦ Introduction ✦ Current compliance model ✦ Policy and law ✦ Operational concepts ✦ **System components** ✦ Recommendations ✦ Literature review ✦

5.1 Overview

The system components are the 'building blocks' that permit a SEM system to operate. Further detail at a slightly more technical level is available in the literature review.

Any information system may be logically broken down into the categories of inputs, processes and outputs. This breakdown communicates basic operational principles.

The inputs to any system involve the data that is to be used. This is the area that non-technical people tend to focus on because it contains the visible, tangible hardware. Data capture generally forms the least challenging and often the least costly part of a system. As a best practice rule data should be collected 'once only' for each instance.

The system process may essentially be considered by non-technical people as a 'black box' inside which the data is processed to make meaningful information. The process and the required communications normally involve the greatest complexity and often the greatest cost. They also pose the greatest risk if the architecture and rules are not optimised.

The output is information delivered through as many 'channels' as may be required. For SEM the channels are likely to include variable message signs, email, SMS, secure internet and computer screens.

An observed phenomenon in international examples is that the user interface is not able to be configured by the end user. As the end user is the most important part of any system it is considered vital to provide the best possible experience. Therefore we recommend a user configurable widget-based graphic user interface.

5.2 Recommended system inputs

There are a number of key HCV attributes and characteristics that need to be ascertained by the SEM system. The compliance data itself is of paramount importance; however, metadata such as the time, date and place at which that data was obtained is necessary to develop evidential grade information.

The literature review (chapters 7 and 8) covers a great deal of potential options in terms of technologies and systems from which the preferred options were elicited.

Appendices A and B describe the data that is required in further detail.

5.2.1 Data capture

Table 5.1 below briefly demonstrates some of the data requirements to enable the operation of a SEM system. Appendices A and B provide significantly more detail. If SEM systems are introduced which do not capture all requirements, they will still offer benefits and efficiencies, but these will not be maximised.

To put these characteristics into context, each has been assessed against its potential capability (which is specific-technology dependent) to be determined by the following systems. It is assumed that each system (high-speed, low-speed and manual) has access to the relevant evidential-grade databases in order to make data associations. The table categorises each characteristic as obtainable at either evidential grade (EG) or preliminary inspection (PI).

1 High-speed SEM site (not requiring manual inspection by an enforcement officer)

2 Low-speed SEM site (not requiring manual inspection by an enforcement officer)

3 Manual inspection by enforcement officer.

Table 5.1 Data capture characteristics

Entity/attribute	Data	High-speed SEM	Low-speed SEM	Manual inspection
Vehicle	Tractor unit, individual trailer(s), dimensions	EG*	EG*	EG
Driver	Licensing, vehicle class, speeds, working hours, fatigue, performance, alcohol and drugs, safety belt use, 'track record'	EG**	EG**	EG
Operator	Licensing, ORS, 'track record'	EG**	EG**	EG
Owner	'Track record'	EG	EG	EG
Freight	Freight description, load content, hazardous material	PI	PI	EG
Certificates	Loading compliance, fitness	EG	EG	EG
Permits	Indivisible loads, HPMV	EG	EG	EG
Weight	Axle, group axle, gross vehicle, combination	EG***	EG	EG
Revenue	Licensing, registration, RUC (distance, payment, accuracy, tampering)	EG**	EG**	EG
Vehicle parameters (mechanical and electrical)	Brakes, tyres, lights, wipers, steering, bearings, suspension, exhaust, emissions, load security	EG**	EG**	EG

* Middle trailers in a combination cannot visually be identified and a database association may potentially be required, dependent on the policy direction.

** Requires in-vehicle electronic driver licence ID/electronic RUC/engine management system linkages to fleet management systems and cooperative data sharing, alternatively requires each vehicle to stop for inspection whenever enforcement staff are present

*** Relies on law changes to make high-speed WIM admissible in evidence and requiring judicial notice to be given to the results.

Table 5.1 above is a high-level overview which demonstrates some of the characteristics that are required to be determined and the broad capability of the different data collection mechanisms. Appendix B compares the data that may be obtained by a physical enforcement inspection with the data that is available to HCV operators and the data that may feasibly be collected by an automated system. It demonstrates that the vast majority of required data can be collected using a 3D camera with image processing, a high-speed evidential-grade WIM site, data from the engine management system and electronic driver information along with near real-time database queries and associations.

Slow-speed thermal imaging and an under-vehicle camera capture further data; notably the thermal imaging is capable of detecting brake issues, bearing issues and tyre tread depths.

Among SEM's strengths is that it can potentially detect safety belt and mobile phone use in HCVs where these are exceptionally difficult for operational enforcement staff to detect.

5.2.2 Recommended data capture technologies

Our recommended SEM sites consist of two primary high-speed technologies and associated avoidance detection systems:

1. An evidential grade high-speed WIM system (requires New Zealand law changes) is currently employed only in the Czech Republic using quartz Piezo sensors. A European standard has been developed and another system aiming to meet that standard is under development using strain gauge sensors. It is our opinion that a suitable preliminary enabling method is to increase the tolerance used at high-speed WIM sites.
2. 3D cameras equipped with infra red and colour capture can be coupled with image processing software to obtain a wide range of data described in the literature review and appendices A and B.

We also recommend that at weigh stations further low-speed (and/or static) equipment is installed:

- under-vehicle thermal imaging cameras with automation software
- under-vehicle high-resolution cameras with automation software.

5.2.3 Avoidance systems

A percentage of operators will always attempt to avoid detection, and in doing so may use routes that are unsuitable for trucks. This is the experience internationally in relation to toll and enforcement systems and it is also the personal experience of one of the authors.

It is vital therefore to ensure that any HCVs bypassing, avoiding or evading a SEM site are automatically detected and that the economic consequence of doing so outweighs the penalties that would have been imposed if the HCV had passed a SEM site.

Closed-circuit television equipment should be installed on each potential avoidance route and connected to the 'back office' to enable processing and direct enforcement. Where the route is 'popular', consideration should be given to installing a new SEM site.

A stated aim for the system is that it does not encourage operators to choose unsuitable routes instead of inspection.

5.3 Process

The introduction of SEM requires a comprehensive near real-time evidential grade information system for enforcement purposes.

The authors recommend this is best developed, operated and maintained by specialist private sector providers, for a wide range of reasons, to meet the needs of all parties. We do not propose to detail the complexities of the databases, database management systems, interfaces, applications, supporting infrastructure, communications requirements or business process in this report.

The functionality of the back-office system required to operate a SEM framework will depend on the system's approved operational concept.

Our recommended approach is to maximise the use of an automated process in order to minimise the amount of repetitive manual process. A direct automated enforcement system will be required as a minimum to:

- authenticate the identity of the vehicle, driver and operator, and derive the identity of the owner
- authenticate the time, date and place of each record
- identify freight commodity where possible
- authenticate any detected instances of non-compliance
- associate all attributes for each record with the relevant identity
- generate exceptions for manual processing when this cannot be achieved
- interface with other expert systems such as the motor vehicle, transport operator and driver licence registers and be continuously available to perform near real-time queries
- interface with third party fleet tracking providers to obtain driver and vehicle data when authorised
- issue infringement notices and emails
- have sufficient resources to verify challenges and/or disputes
- identify and manage all system faults and maintenance.

The requirements described above represent a significant investment in the introduction of SEM. We strongly recommend that this is structured as a standalone system in a third party environment for many reasons including building the trust of operators and eliminating political considerations between government agencies that might otherwise host the system.

The processing of data into information at this scale relies on expert guidance and a well thought out architecture including:

- information processes at site level and system level (databases, database management systems and applications)
- infrastructure requirements at site level and system level
- information output requirements at site level and system level
- communications requirements at site level and system level
- interface requirements
- graphic user interfaces and usability.

The authors recognise that ensuring coordinated development of these architectures falls within the scope of a programme director during an early phase of an implementation programme.

Therefore in the following diagrams we have provided an indicative sample of the architecture in information and infrastructure views. This demonstrates the complexity involved for those with limited previous exposure to national systems and to provide a starting point.

Figure 5.1 High-speed information architecture – site level

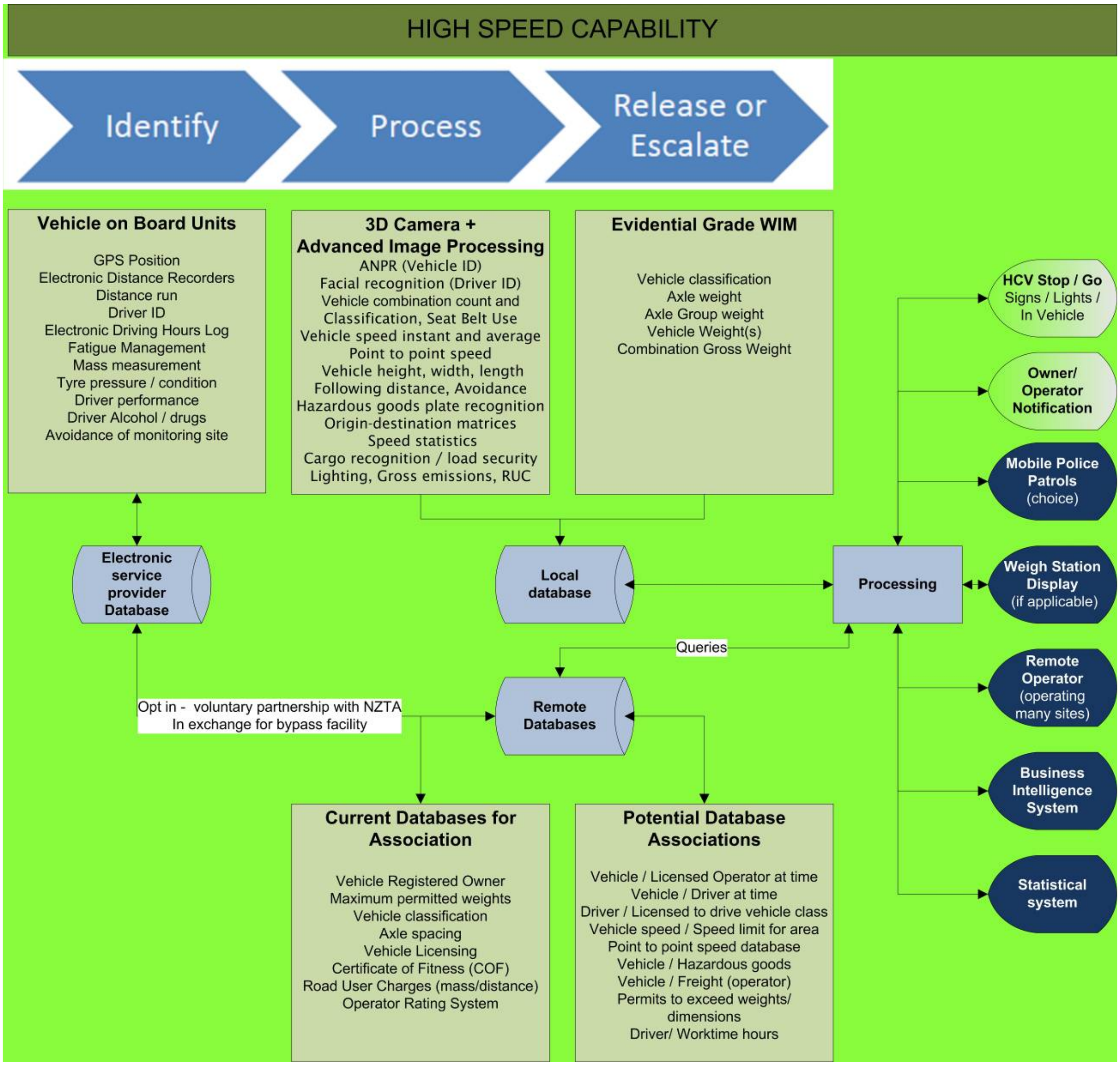


Figure 5.2 Low-speed information architecture – site level

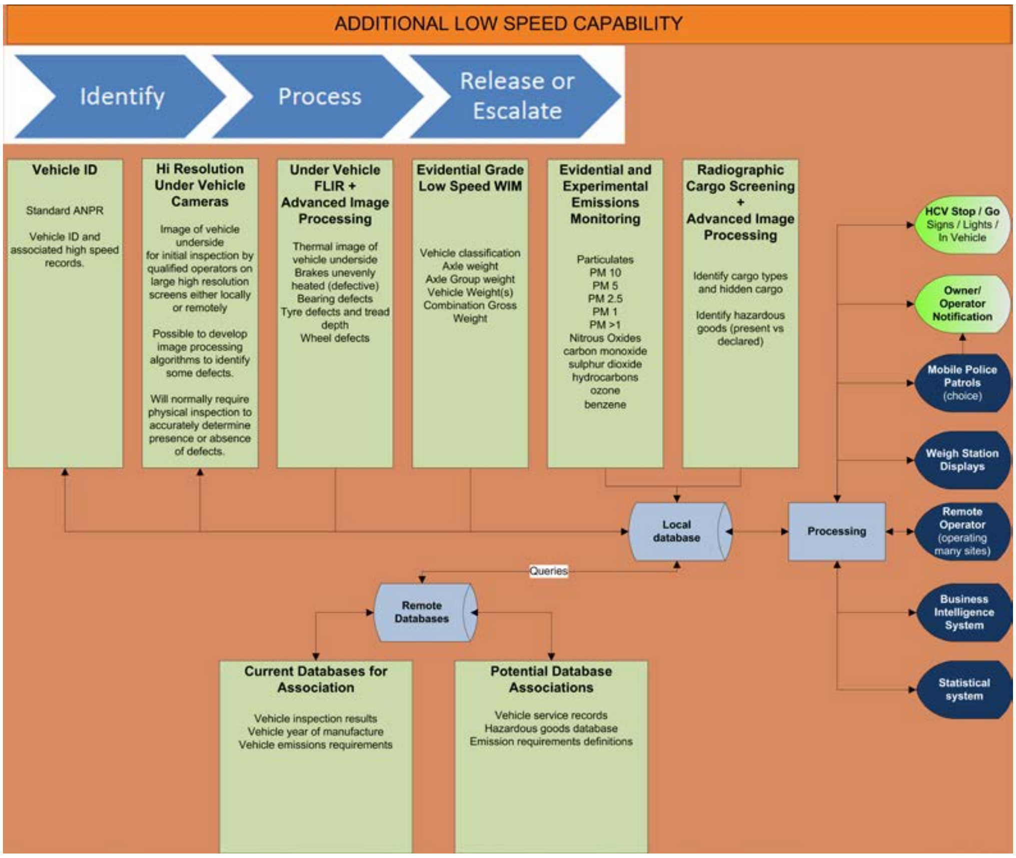
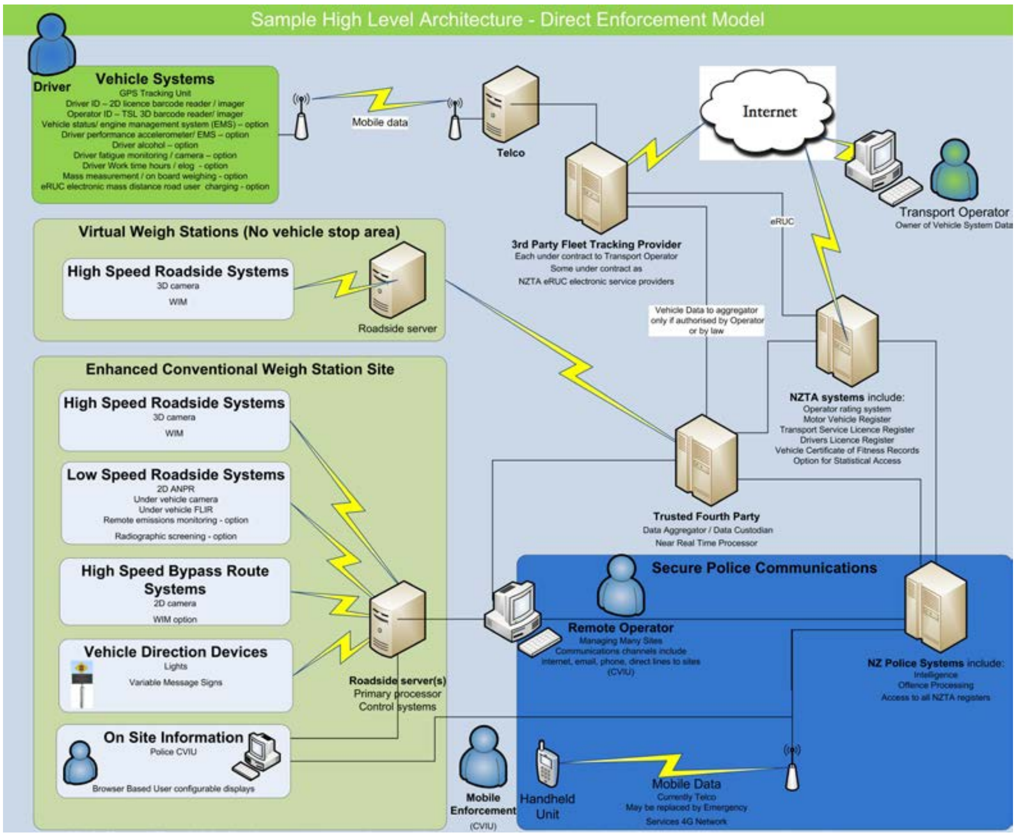


Figure 5.3 System-wide sample architecture – national level



5.4 Outputs and distribution channels

There is a wide range of outputs which the system may deliver. The key concept is to collect the data once only (for each inspection record) and develop it into a range of information for various purposes. This is delivered through a range of channels including the following:

Operator rating system – the use of high-speed SEM sites will establish the continued compliance or otherwise of licensed operators and the majority of the HCVs operating within the upper half of the North Island. Without high-speed SEM it will take many years to establish the same knowledge. More even coverage and ongoing information on safety-related offending will dramatically improve the accuracy of the ORS.

Automated infringement notices – (if the direct automated enforcement model is used) infringement notices can be automatically issued to drivers, owners or operators (or to all three subject to policy/law change).

Notification to the driver – after passing a high-speed SEM, in-cab systems could advise a driver of authority to bypass a weigh station, advise a driver of a particular issue, require a driver to proceed directly to an inspection facility within a specified time frame; roadside variable message sign(s) may be activated to direct the vehicle into an inspection facility.

Weigh station display – after a vehicle has passed a high or low-speed SEM site, the data obtained will be available for local and/or remote operators to view.

Notification to the operator and/or owner – automated email alerts will be sent to owners or operators of the vehicle, communicating exceptions (existing or possible issues).

Mobile Police patrol – mobile Police patrols will be able to connect to the system via secure internet to view local events near real time. The use of well informed mobile units in a range of locations may also assist in improving the perception that offenders can and will be detected, wherever they may be.

Business intelligence and statistical information – the systems will be able to collect significant data about the condition and compliance of New Zealand’s fleet and the way in which the national freight task is delivered. Exception reporting, predictive trends and/or statistical analysis can delivered by the system.

5.5 Other potential uses of the framework

The NZTA might generate significant value by extending the scope of the SEM framework to deliver wider transport management and other benefits. The following policy options may be considered:

- light vehicle compliance and incentive schemes enhancing safety
- congestion and emission charging cordons
- high occupancy toll (HOT) lanes
- freight lanes.

5.5.1 All of government approach

In considering an all of government approach the SEM system might potentially be used to deliver part of the data set at a level agreed and authorised between all parties, or alternatively authorised by law. If such an involvement was considered co-funding might also be discussed with the following groups:

1. Port owners for WIM at port entrances could compare stated weight with loading records. Most fees are based on tonnage and a chain of responsibility might apply.
2. NZ Customs for WIM and freight identification at port entrances could compare stated weight with loading records, hidden freight, overloading or abnormally light loads might provide an indication to conduct more thorough checks. The images from an inspection system similar to airport security screening would prove invaluable to Customs.
3. NZ Police could detect all unsafe vehicles (expired warrant of fitness (WoF)) and those without current licensing. SEM might also be used in the detection of stolen vehicles and to assist with other serious crimes.
4. Fisheries could ensure that the use of New Zealand's fisheries resource was sustainable by detecting vehicles that were already of interest.
5. Immigration could detect the presence of people inside shipping containers if an inspection system similar to airport security screening was implemented and could monitor vehicles of interest.
6. The Ministry for Primary Industries (Agriculture) could monitor the movement of live stock and livestock carriers particularly when travelling to or from controlled zones. SEM could be used to supplement the current electronic livestock tracking project.
7. The National Institute of Water and Atmospheric Research (NIWA) to research data about diesel vehicle characteristics and emissions. Supporting future policy to reduce harmful effects to humans.

6 Summary, conclusions and recommendations

✦ Introduction ✦ Current compliance model ✦ Policy and law ✦ Operational concepts ✦
System components ✦ **Recommendations** ✦ Literature review ✦

6.1 Summary

This report has described the current enforcement regimes, the current level of non-compliance, identified the key constraints, notably the finite number of enforcement staff and the limited potential to improve compliance levels using current methods. It also describes the key drivers for each main group of participants that are crucial in addressing the compliance issues.

The literature review in the following sections contains a more in-depth technical view of a range of technology and systems options that were considered. Some options, eg dedicated short range communications (DSRC) were not included because New Zealand uses existing alternatives. Introduction of DSRC would only increase the cost of compliance to operators.

The literature review follows this section for the reasons explained in section 1.6.

The successful implementation of technology, new business process and law changes at the recommended scale is a finely tuned, highly complex and costly undertaking with a high associated risk. Yet it is readily achievable if expert private sector programme direction and implementation is mandated and full cooperation is received from various government departments.

Removal of any identified requirement will almost certainly result in failure to meet the required outcomes for all parties and the consequences are likely to be failure to achieve the proposed outcome of any implementation programme.

Any implementation should make the manual task that it replaces simpler, or as simple, for the end users, including HCV operators, NZ Police CVIU, local authorities, significant freight terminals and the NZTA. This means that the minimum business requirements of each group must be met and data must be shared at authorised levels rather than solely focusing on the requirements of a single agency.

A cooperative approach to policy, architecture, roles, politics and issues is pivotal to achieving success.

The system specification must exceed the initial cost and performance of visible technology components such as cameras, electronic signs and WIM. The real focus is on the more significant overall architecture, the underlying system rules and processes, supporting applications, communications, ongoing power, maintenance and staff requirements, both roadside and back office.

The real value that such a system might deliver is the development of data into evidential grade information and the development of this information and inferences into business intelligence for various purposes.

The research has met the primary brief of identifying the technologies that are available for strategic electronic monitoring of heavy commercial vehicles and assessing each in terms of the New Zealand environment.

Proper implementation of technology can readily achieve the stated aims of improving the efficiency and effectiveness of HCV enforcement, improving freight productivity for transport operators and reducing undue wear on the road asset.

The strongest value for money is identified as being achieved from the simplest robust system that provides the most information and is capable of operating autonomously and continuously for the majority of enforcement tasks.

6.2 Conclusions

1 New Zealand is arguably at a measurable crisis point in terms of HCV non-compliance. 8% to 10% of HCV trips are overloaded and the probability of any 10km trip by an overloaded vehicle being detected in an enforcement stop is one in 4400 (0.02%).

2 The level of wear HCVs cause to our national road asset, particularly bridges is significant; however, RUC are collected to allow for this. Damage by overloaded HCVs is exponentially and unacceptably greater. The scale used to calculate road wear is the fourth power rule. (Twice a specific weight causes 16 times the damage.)

3 NZ Police observe that the existing infrastructure is not keeping pace with the increasing volume and mass of HCVs.

4 Experience suggests that loading, safety and environmental outcomes are likely to worsen in response to financial pressure during times of economic downturn.

5 The New Zealand government has made some progress in HCV safety since the 1996 review of truck safety. A significant reduction in rollovers has been made with introduction of static rollover thresholds (SRT), the current implementation of an ORS has led to some improvement in HCV standards and a current review aimed at simplifying the vehicle testing and licensing regime may lower the cost of compliance.

6 The net effect of HCV crash costs, time costs, fuel costs, undue road asset maintenance and repair costs, vehicle maintenance costs and health costs is reduced national productivity – an estimated rate of $2.6 billion annually.

7 Operators of non-compliant HCVs gain significant financial advantage, unfairly placing safety and financial burdens upon others in many ways including the following:

   a Operators of HCVs who neglect maintenance are likely to operate unsafe vehicles, often with defective brakes, tyres and excessive emissions. The result is an increased safety risk to all road users and health risk to those in the region.

   b Operators of deliberately overloaded HCVs can charge lower prices, gain higher profit or both. The result is unfair competition with otherwise compliant operators.

   c Operators of overloaded HCVs cause excessive road damage and do not pay their fair share of RUC (directly used to maintain New Zealand roads). The result is unfairly placing additional RUC burden on all operators who pay appropriate RUC.

8 The system needs the ability to identify those who overload at far greater frequency and to hold them accountable for the damage they cause with penalties that make the economic risk of non-compliance greater than the cost of compliance.

9 Existing HCV enforcement methods impose undue cost on compliant operators and result in claims of unfairness, particularly where they are delayed for time-consuming manual checks. The current system fails to enable CVIU to focus on non-compliant operators.

10 Increasing the number of HCV enforcement staff is not a viable option to adequately address these issues; the education of HCV operators fails to address the underlying economic driver. Therefore while each has merit, neither is likely to be effective in achieving the required compliance outcome.

11 SEM with inspection site bypass for safe, compliant vehicles and drivers is a means to improve productivity and compliance.

12 Electronic screening sites have proven to be effective compliance and enforcement tools in other jurisdictions. Maximum effectiveness is dependent on maximising process automation, minimising the requirement for human input; locating each site where it is uneconomic or impossible for HCV drivers to detour; implementing systems to detect evasion, accompanied by a detection system with high penalties for avoiding or failing to travel over monitoring equipment.

13 A fundamental shift in thinking is required to achieve the required results, in terms of acceptance that the current methodology is ineffective, implementing policy, law and technology changes to maximise efficiency and effectiveness of compliance monitoring.

14 This research provides a framework in which both new technologies and existing databases can be used at an operational, tactical and strategic level to properly inform decision making; initially in the upper part of the North Island.

15 Strategic electronic monitoring of HCVs will require substantial investment. Early indications (prior to formal economic analysis) suggest very high benefit–cost ratios in terms of reducing undue road asset wear, safety improvements and improved environment/public health.

16 Improved national productivity, asset management, road safety, environmental and health benefits will be achieved with the full implementation of an effective network of fully automated HCV SEM sites. These sites will support automated and direct enforcement providing significantly greater capability at each site than is feasible with traditional enforcement methods and finite staff.

17 Improvements in current freight and transport data quality attributes of timeliness, accuracy, completeness and consistency are required. Improved accessibility to freight, enforcement and strategic planning information is also required. Potential to collect data once and share at authorised levels of aggregation with a wide range of properly authorised parties will add value to the entire transport sector.

An assumption is made that primarily electronic inspections of those compliant operators who elect a cooperative (data sharing) partnership with the NZTA, coupled with evidence-based targeting of habitually non-compliant operators will always justify enforcement action whether by direct electronic, Police CVIU or other enforcement officers as an appropriate response.

The fundamental aim and recurring theme throughout this research report is maximising the productivity, efficiency and effectiveness of the underlying enforcement process by identifying, processing and releasing or escalating. The net outcome is a vital contribution to a high-performing transport system that contributes to economic growth.

6.3 Recommendations

The framework described in this report aims to:

- improve the existing situation where HCV non-compliance is widespread
- implement a coordinated programme of infrastructure implementation, amendments to transport policy and law and a cooperative partnership approach with operators who wish to demonstrate continuous compliance in exchange for greater trip reliability and an alternative compliance regime.

In order to advance this subject matter, realise economic growth and productivity, improve road safety and health, contribute to a safe system and achieve strong value for money, the following primary recommendations are made in terms of business progress:

1. Develop a robust formal economic analysis at site level and at systems level combining technical expertise with highly regarded economic expertise.
2. Ensure political support, ideally from all parties to improve the productivity and safety of our road network and economic fairness for transport operators by improving compliance through the use of SEM and direct enforcement.
3. Appoint a private sector programme director, and a formal project initiation conforming with both Prince 2 and SSC Gateway methodologies. Obtain funding for a proof of concept. Prepare:
   a. a formal concept of operations
   b. a business case supporting a single site installation and proof of concept field trial.
4. Deliver a proof of concept field trial.
5. Analyse the proof of concept and development of a full business case for funding.
6. Develop various architectures and system rules, aligning with HCV law.
7. Simultaneously commence policy work towards amendment/review of HCV law.
8. Develop and enable the remote back-office facilities and systems.
9. Adopt a staged proof of concept in pilot site implementation(s) with local systems and develop a business case based on the results.
10. Implement a network of SEM sites.
11. Initiate the operation of automated direct enforcement systems.
12. Maximise the use of continuous automated SEM systems.

In terms of technical content we recommend using at all SEM sites:

- evidential grade high-speed WIM (the Czech republic is the only jurisdiction to certify evidential grade WIM, the physical device used is quartz Piezo). Ideally the device used will meet the updated international standard OIMLR134. (ROC Systemtechnik[6] has announced a strain gauge matrix network system being developed to meet OIML R134 that will weigh stop start traffic)

- 3D cameras front and rear with advanced image processing
- 2D cameras for side views to confirm axle group classification and on all potential avoidance routes (coupled to ANPR and the direct enforcement system)
- a site controller to gather and store all data for transmission.

At low-speed approaches to weigh stations (also connected to the site controller):

- under-vehicle thermal imaging cameras with advanced image processing
- under-vehicle high resolution cameras with advanced image processing
- a 2D camera with ANPR to confirm identity of vehicles with under vehicle images.

Consideration may be given to:

- working with NIWA to establish experimental measurements of HCV emissions
- using radiographic screening, particularly at sites where customs and biosecurity may be an issue.

A modular and interoperable approach should be taken to any implementation so that the system is future-proofed, can readily be scaled up from the recommended base model and seamlessly exchange data with other systems.

6.3.1 Further brief implementation recommendations

It is recommended that, if implementation proceeds, it should follow a formal systems engineering approach, conforming with both Prince 2 and SSC Gateway methodologies.

It is simple to focus on the visible hardware components consisting of sensors, support structures, communications and output channels, each with graphic user interfaces. Clarity and focus is required on the successful integration of all hardware and the expertise of those that carry out that task.

A systems engineering approach first considers the required outcomes, business requirements and business process, the information output requirements to support those outcomes, the data inputs and information architecture required to develop first the information and then the system rules and algorithms.

Once these are clearly identified, selection of the most appropriate technologies for each site may commence. High-level design is followed by detailed design and implementation.

A systems engineering approach also requires checks at every step to ensure that the design meets the criteria, that outputs are delivered as intended, and that the outcomes are met.

Legg (WSDoT) states from the Washington State experience that the implementation of the back-office processes, the databases, algorithms, and user interfaces to access the databases to permit the

[6] http://rocgmbh.com/ (Accessed 28 June 2012)

identification and flagging of vehicles as candidates for pulling into a weigh station for inspection is, by far, the greater part of the effort, and hence, most of the cost, of implementing prescreening systems. By comparison the field equipment is relatively inexpensive and easy to install. However, in discussing these systems with decision makers, the public, and even the media there is a disproportionate interest in the field equipment, which often leads to confusion about system costs versus their benefit based on what is visible on the roadway.

7 Literature review, part 1 – technology components

✦ Introduction ✦ Current compliance model ✦ Policy and law ✦ Operational concepts ✦ System components ✦ Recommendations ✦ **Literature review** ✦

7.1 Introduction

Changes in the global economic environment have led to government recognition of supply chain/value network leadership and the important role of a highly efficient freight industry in New Zealand maintaining competitive advantage. Improved safety is another key strategic goal.

This literature review provides details associated with the technology components and systems that are already used or may potentially be used by the NZTA to establish a hardware framework for the strategic electronic monitoring and compliance of HCVs.

The scope of this research has been principally concerned with what is relevant, most efficient and technically feasible in terms of improving efficiency, and successfully identifying and checking safety and compliance of HCVs as they travel throughout the upper part of the North Island, to promote targeted enforcement with comparatively short inspection processing time, or alternately if required, rapid escalation to deal with detected offences.

Integrated-system approaches perform well and offer the best value for money. Such integrated approaches ultimately need to be applied across New Zealand and beyond. The government, transport and technology industries, employees, processes, core and support functions, and even supply network partners and customers need to be fully aligned and synchronised in order to build New Zealand's capability: creating and maintaining sustainable competitive advantage.

The ability to capture and compile operational characteristics of moving vehicles in a three-tiered approach; (identify, process, release/escalate); will enable safe, compliant operators to efficiently continue their business with the minimum of disruption. This will enable enhanced asset management, improved road safety, fuel savings, improved travel time predictability and consequential improvement to logistics efficiency and national productivity.

The same information will enable NZ Police to target unsafe and non-compliant vehicles, their drivers and their operators more effectively. Removal of unsafe HCVs from New Zealand's roads will reduce the level of risk to other road users, reduce excessive wear and damage to road assets and minimise the unfair competition that safe and compliant operators currently face. The information will support collection of RUC revenue from those that currently do not pay their fair share, instead imposing additional cost on others. Environmental and social well-being benefits will be obtained through safer, cleaner vehicles on our roads.

The information obtained about vehicle movements could be aggregated and processed to inform a much finer understanding of the activities of HCVs and freight movements on the national network. This in turn will lead to improved planning of transport and land use with longer term benefits.

Achieving these outcomes relies on accurate information systems architecture, appropriate funding, political will, ideally support from all stakeholders, and firm programme direction. New Zealand is fortunate to be starting largely with a ‘blank canvas’ that can be completed with established and innovative technologies.

This literature review has drawn on the experiences from the international arena (in particular the USA, Europe and Australia) as a baseline for relevant opportunities for New Zealand. It logically focuses on the New Zealand environment where five distinct HCV entities: ‘vehicles’, ‘vehicle owners’, ‘drivers’, ‘licensed transport operators’ and ‘freight’ exist.

Any enforcement officer is currently legally entitled to require identity information and conduct a wide range of checks on vehicles, drivers, operators and freight. Most of these checks can be performed electronically, with cost, efficiency and time savings for all parties.

It is accepted that there may be real and perceived concerns around privacy, along with commercial considerations that may constrain some aspects of automated checking. Consent may be required for some personal aspects of automated checking. Law changes or continued requirement to stop to permit an enforcement officer to require the same information are the only real alternatives.

Those operators that realise the benefits of consenting to a fully automated checking process and working in a transparent partnership with the NZTA are likely to realise the greatest benefits.

This paper does not attempt to define the balance between efficiency and acceptability. It focuses instead on a technically realistic and achievable approach to maximise efficiency, safety and productivity.

Accurate identity recognition is the cornerstone of any automated or manual enforcement system. Without accurate identification, issues will be attributed incorrectly and any system will fail. Accordingly this is the beginning of the literature review.

7.2 Establishing identity

Underpinning any enforcement system is the requirement for highly accurate identification of the entities that are being enforced – vehicles, vehicle owners, drivers, licensed transport operators and freight. Once the identity of each HCV is established numerous attributes can be associated for example:

- vehicle attribute(s) including axle configuration, length, weight and dimensions
- vehicle owner including registered owner and legal owner
- driver attributes including licence status, fitness to drive, fatigue level and behaviour
- operator attribute(s) including licence status and liability for any offences
- freight attribute(s) including commodity, weight, origin and destination
- database associations.

Identification of vehicles using two or more observation methods is an important component of electronic vehicle monitoring. Independent verification that two or more vehicle observations are from the same (or different) vehicles independently of number plate identification has a valid place in discounting any challenge to electronic identification (and any associated information). Any exceptions or offences that are attributed to the incorrect identity will cause issues, whether or not the process is automated. Therefore this literature review considers identification first.

7.3 Vehicle identification

Any vehicle identification for automated evidential purposes must be by way of a reliable factor (eg number plate) supplemented by one or more further factors such as a photograph or other electronic means to confirm identity. Vehicle number plates are currently associated on databases with the vehicle's actual 'unique identifier' – the vehicle identification number (VIN). Each vehicle is also associated with the registered owner and other attributes such as axle spacing. The vehicle identification options are:

- automatic number plate recognition (ANPR) – currently used in New Zealand
- 3D image processing – would add significant value
- vehicle 'tag' and dedicated short-range communications (DSRC) roadside 'readers' – New Zealand policy has previously steered away from introducing DSRC to New Zealand in the national tolling project in favour of ANPR. Introduction would result in an increased cost of compliance.

7.3.1 ANPR

ANPR systems use video cameras to capture images and optical character recognition (OCR) processing to recognise and digitally record the number plates of vehicles. One of the key benefits of ANPR is that it removes the need for any additional in-vehicle equipment such as tags and associated transponders which can perform similar vehicle identification techniques. Once plates are in a digital form, a database or databases are required to process and identify any relevant information.

ANPR systems offer two broad system configurations:

- onsite number plate recognition and database processing built into many hand-held and static ANPR cameras with high-speed, low-cost and low communications requirements, or
- remote centralised database processing with lower speed, higher cost and intensive communications requirements.

There are various possible intermediates between onsite and remote processing. The specific configuration is determined by a range of considerations at the time a specific system is designed.

ANPR capture is dependent on the correct set up of camera, lens, illumination, angle of view and configuration. This favours permanent installations, often using more than one camera across multiple lanes and approaches. ANPR cameras may potentially be deployed as part of mobile or temporary systems; however, careful selection of camera, operator training and experience is normally required to optimise image capture.

Properly set up, many ANPR systems can automatically identify in excess of 99% of unobstructed retro-reflective number plates. Retro-reflective number plates have been issued in New Zealand since the late 1980s and are fitted to the majority of the fleet.

The main issues for incorrect identification are associated with poor or reflective lighting conditions, poor environmental conditions (dirt, rain, snow), physical obstructions between the camera and vehicle and the requirement for the number plate to be clean enough to read. Deliberate removal of number plates is a potential issue along with vehicle speed and capture rate in the context of HCV identification for SEM. These are all readily dealt with by stopping and checking any vehicles that cannot be automatically identified.

It is accepted that any combinations of two or more trailers will result in a lack of ability to read the number plates as only one is required to be displayed on each trailer and this is located at the rear of the vehicle, generally underneath the next trailer or in such a position that it is impractical to use cameras to obtain an image.

ANPR costs vary widely depending on the quality, accuracy, system architecture and the system supplier. Some low-end ANPR systems cost as little as $500; however, these are more suited to stationary vehicles. More accurate and robust systems are generally used at high speed; infra red and vandal resistant housing may also be considered.

7.3.2 3D image processing

The primary requirement for advanced image processing is capture and input of high resolution image(s). Currently NZTA highway systems use low resolution analogue cameras along with some digital cameras. These cameras are fit for traffic management purposes but do not support advanced image processing (as required for strategic electronic monitoring).

The use of high resolution cameras and advanced image processing to analyse and provide direct near real-time information output offers significant advantages over other identification methods. These advantages include effectiveness in providing two forms of identification and a wide range of data from a single sensor unit, processing efficiency, timeliness, cost and accuracy.

3D (three-dimensional) images, captured using two or more cameras, permit processing of depth characteristics such as distance and length. This permits accurate calculation of speed, following distance, vehicle classification and a range of other applications.

Figure 7.1 3D camera used in Project Asset in portable tripod mounted and fixed format (courtesy of KRIA[7])

Recent European Commission research (Project Asset[8]) used processing of 3D imaging at highway speed to determine a vehicle's instant and average speed, height, width, length, following distance, hazardous goods plates and number plates on the German A8 autobahn.

[7] KRIA (Knowledge research in imaging applications) website: www.kria.biz/english/index.html (Accessed 17 April 2012)

[8] www.project-asset.com/index1.php?lan=en (Accessed 16 April 2012)

This system is already certified by the Italian Ministry of Transport for evidential-grade speed and red light offence detection. Additional enforcement capabilities include automated evidential standard detection of vehicle colour, safety belt use, excessive emissions, tailgating, traffic access to prohibited roads (HPMVs), traffic travelling the wrong way on separated highways, illegal turning and identification of vehicles of interest to Police that are listed on a database. Current research will include make and model identification from the same image. The system will be operational in Europe from 2013.

Statistical analysis capabilities include origin-destination matrices, vehicle classification and speed on a month/week/day/hour/minute basis if a SEM system is widely implemented.

Figure 7.2 Advanced image processing at highway speed in Project Asset, Germany (courtesy of KRIA)

7.3.3 Vehicle tags and roadside readers

These systems involve the use of electronic tags or radio transponders being issued and placed within vehicles which communicate with roadside infrastructure via DSRC. Tags are widely used in tolling systems and HCV identification systems (outside New Zealand), parking systems and a variety of other applications such as building entry.

Tags exist in read-only, read/write or smartcard formats. A read-only tag contains a fixed identification code which, when interrogated by a roadside-reader device, transmits the code to the reader. The code relates to the identity of the vehicle and/or the identity of the user's account and is normally a 'key field' on a related database.

The commonly used radio frequencies for DSRC are in the 5.8GhZ and 5.9GhZ spectrum allowing maximum line of sight range up to 800m in ideal conditions.

At long range it is possible for multiple vehicles to simultaneously communicate with readers; however, to enable reliable identification of a single vehicle the range is generally reduced to a short range within a single lane. A short range constrains the time available for data interrogation and requires a lower vehicle speed to enable reliable reading. For example, when HCVs are travelling at the highway speed limit of 90km/h (or 25m per second), a 100m range either side of a reader allows a maximum theoretical time frame of eight seconds for all data transactions. In practice shorter times are used to increase reliability.

Read-write tags may be used to receive data from the roadside and store this data directly on the tag or on a separate storage facility such as a 'card'. Smartcards, such as those used in many new generation electronic bank cards, have the capability to handle and process many kinds of data and (potentially) to be programmed to manage a number of different applications. Read-write systems require a reliable, high-speed two-way data communications link with the roadside and more complex onboard equipment. This could potentially replace some of the processing requirements traditionally handled by the roadside equipment but also increases the scope for cyber fraud.

The complications surrounding DSRC tags include a general lack of standardisation (even when tags have the same manufacturer), the cost of tags including database entries; the operational requirement for each relevant vehicle, driver or operator to be issued with tags and to retain and maintain them, and most importantly, the ability to remove, steal and swap tags between vehicles, drivers and operators.

If these issues are overcome, DSRC technology is sufficiently robust, well proven, offers a reasonable level of security, and may potentially be used to wirelessly identify HCVs for electronic inspections.

Tags are inexpensive to produce; however, the commercial reality is that they tend to retail for between $20 and $100 each including database entry. DSRC transponders are also relatively inexpensive, but they require significant supporting infrastructure and back-office databases to operate effectively, particularly at highway speed.

ANPR and DSRC transponders are well established methods of high-speed vehicle identification. Each has inherent weaknesses that will apply to a small percentage of vehicles. ANPR can be implemented with limited cost to the government and no cost to operators. ANPR is the sole method already operational for New Zealand's government-operated toll roads.

Legg advises that Washington State Department of Transport experimented several years ago with 'vehicle finger printing' using acoustic signature, magnetic signatures, and video image profiles. At the time none of the technologies were effective enough to include as a reliable approach to vehicle identification. Each had its unique challenges, from lighting, weather conditions, traffic density and vehicle lane location. Due diligence is therefore required if any of these technologies are to be considered in the New Zealand environment.

7.4 Vehicle classification and complementary identification

Additional technologies may also be used to accurately count and classify vehicles, in some cases including subsidiary identification methods that are not accurate enough to be used alone. The options discussed are:

- inductive loops
- magnetometers
- passive acoustic sensors.

7.4.1 Induction loops

Induction loops are placed in the road surface (typically asphalt in New Zealand) to detect vehicles as they pass through the loop's magnetic field. The simplest detectors simply count the number of vehicles during a unit of time which pass over the loop. More sophisticated sensor systems estimate the speed and length of vehicles and the distance between them. Loops operate at high speed through to stationary vehicles and are typically associated with traffic lights and traffic monitoring, as used in the Auckland travel time system. High-speed WIM and ANPR sites tend to use loops to estimate speed and trigger camera operation.

7.4.2 Magnetometers

A magnetometer is an instrument which measures the strength or direction of a magnetic field. The widespread use of magnetometers in the transport environment is relatively new and primarily focused around their potential to replace inductive loops as effective lower cost traffic detectors for many functions including traffic counts.

Magnetometers are attractive due to their limited maintenance requirements, opportunities for wireless connectivity and their general suitability for use in the transport environment. Due to the ‘fuzzy’ nature of magnetic fields they are not as accurate as loops for performing vehicle classification.

Bullock et al (2008) state that magnetometers are increasingly being deployed for traffic detection in both fixed wired and wireless installations around the USA. Research by Brennan et al (2009) has shown that their performance in this respect is comparable to inductive loops and that they perform most accurately when vehicles continue to move over the detector without stopping.

Figure 7.3 Image of wireless magnetometer (courtesy of Clearview Traffic)

Magnetometers placed in the road surface are capable of measuring the waveform, density and distribution of steel in the vehicle body. By analysing the response from a detector, a unique vehicle ‘fingerprint’ can be generated based on the vehicle’s metallic properties. This technology is already in use at the Missouri I95 weigh site (USA). Enrique Cramer (Intelligent Imaging Systems) advises that the accuracy of this system is in excess of 90% for comparing vehicles on approach to a weigh site with those that enter the site.

7.4.3 Passive acoustic sensors

A vehicle’s speed, width and length may be estimated by jointly estimating its acoustic wave pattern (Cevher et al 2006). A single passive acoustic sensor is used to record the vehicle’s drive-by noise. The acoustic wave-pattern is estimated using three envelope shape (ES) components. These approximate the shape of the received signal’s power envelope. The parameters of the ES components along with estimates of the vehicle engine revolutions per minute (RPM) and number of cylinders are incorporated to form a vehicle profile vector. This vector provides compressed statistics that can be used for vehicle identification and classification.

Noise control cameras are used in New South Wales and Victoria (Australia) and Calgary (Canada) in response to HCV engine compression braking and noisy motorcycles respectively. However, the relevance is minimal in the New Zealand SEM environment.

7.5 Driver identification

At high speed, it is currently feasible to identify drivers only if they are visible to cameras (at facial recognition standard) or if key fields (driver licence number and vehicle registration number) are associated on a database record specific to the vehicle for that journey. That database must also be accessible to the SEM system.

Driver identification is personal information within the meaning of the Privacy Act 1993; therefore, any access to this personal data must either be authorised by law or specifically consented to.

Identifying the driver of a HCV, checking they hold a current and appropriate class of driver licence and inspecting their worktime logbook are key parts of any physical enforcement check.

To add context, whenever an HCV is required to stop (and has stopped), any enforcement officer is lawfully entitled by section 114(3) Land Transport Act 1998 to ascertain the driver’s identity by requiring:

- their full name, full address, date of birth, occupation, and telephone number, or such of those particulars as the enforcement officer may specify
- a statement whether or not he or she is the owner of the vehicle
- if the driver is not the owner of the vehicle, the name and address of the owner or such particulars within the driver's knowledge as may lead to the identification of the owner.

The driver must remain stopped until the enforcement officer is satisfied of their identity. An enforcement officer may require a driver to remain stopped on a road for as long as is reasonably necessary to enable the officer to establish the identity of the driver, but no longer than 15 minutes if the requirement to remain stopped is solely to check the driver’s details.

Likewise there is a lawful authority for an enforcement officer to require production of a driver licence and worktime logbook.

This part of an automated inspection process requires formal driver identification by driver licence number and appropriate checks along with automated access to (yet to be released) electronic worktime logbooks (elogs). Each would need to be associated electronically to a vehicle database accessed directly through the automated monitoring system.

For those industry operators that elect to be part of a collaborative compliance approach, each driver’s permission to access the driver data would be required, ideally accompanied by a law confirming the database linkage as admissible in evidence.

Prior consent would almost certainly bypass any Privacy Act requirements. Lack of consent (in the absence of a law change) would almost certainly result in the vehicle being stopped for driver checks whenever enforcement staff are present. A driver licence plus a second factor (see the bulleted list below) transmitted to a remote database, ideally in conjunction with a GPS position and time is likely to provide an evidential-grade driver identification. Ideally a law change would support this.

Reliable database association between driver and vehicle may be accomplished using one of the following:

- licence bar code scanners
- smart card licences
- facial recognition
- fingerprint locks
- other biometrics.

Driver identification systems validated with a second identification ‘factor’ (multiple systems from the above list) are the most robust. The driver data must then be transmitted wirelessly near real time to a remote location, most likely in association with a fleet management device incorporating GPS position.

7.5.1 Licence bar code scanners

Bar codes are currently printed on the rear of all New Zealand driver licences. Bar code scanning or imaging can readily identify the driver licence number and identity of the holder. The possibility of in-cab driver licence bar code scanning was first identified as an option by Land Transport NZ in 2006 to support the ORS. This is implicitly referenced in James et al (2010) and is currently used in some New Zealand fleets. Properly implemented, this method accurately associates a driver to a vehicle both at the commencement of each journey and during the journey, and reduces the risk of inaccurate driver identification when compared with other methods.

7.5.2 Smart card licences

Smart card licences are used in a variety of jurisdictions (outside New Zealand) to permit accurate and reliable identification of drivers, particularly in the commercial context in jurisdictions where digital tachographs are used. Smart cards are more secure than bar codes because, among other reasons, they are considerably harder to duplicate. As yet New Zealand does not issue smart card driver licences.

7.5.3 Facial recognition

Facial recognition is a feasible possibility using image processing systems and is currently used extensively in the counter terrorism, border control and law enforcement environments in other jurisdictions and in New Zealand border control systems. Facial recognition relies (to a degree) on a formal photographic standard being adopted for all driver licence photographs and appropriate software being installed on the driver licence database.

There are technical difficulties in remotely identifying drivers at highway speed due to the fact that windscreens and vehicle bodies may obscure the driver’s face from many viewing angles. This may potentially be overcome with the use of small in-vehicle high resolution cameras (as used in many smart phones).

It is recognised that formal legal consideration of the Privacy Act is likely to be required prior to commencing facial recognition activity because it would affect all drivers, including those who had not consented.

7.5.4 Fingerprint locks

It is technically feasible to lock vehicles using fingerprint identification; detection equipment is relatively inexpensive and in some cases combines barcode imaging capabilities. Operationally there may be issues with fingerprint identification in the transport environment due to the widespread presence of grease and other substances on drivers' hands as well as possible privacy concerns. Sub-dermal scanning (scanning under the skin) is already used by some electronic systems to overcome this issue.

7.5.5 Other biometrics

A range of other biometric identification methods exist including iris scanning; however, these are considered both less technically feasible in the strategic HCV monitoring environment and in the current policy and political environment. Some fleets use onboard cameras to monitor indicators of driver fatigue through biometric analysis, but this practice is not widespread.

7.6 Operator identification

Given that operator identification is a primary requirement of the ORS, it is highly desirable that accurate operator identification is part of SEM. A law change may be required to ensure evidential-grade electronic association with vehicles.

In 2007 New Zealand had a requirement to display transport service licence (TSL) numbers on the outside of each vehicle. However, in the New Zealand freight industry, many HCVs change frequently between licensed transport operators, particularly in the truck rental and leasing environment. This requirement was discontinued with the introduction of TSL labels that are required to be displayed in each HCV operated under a transport service.

At high speed it is currently feasible to identify operators only if the key field (TSL number and vehicle registration number) are associated on a database record specific to the vehicle for that journey. That database must also be accessible to the SEM system.

The technologies investigated are:

- bar code labelling – already in use
- DRSC tags.

7.6.1 Bar code label

The current New Zealand TSL identification is a bar-coded label required to be displayed at all times as the primary means of evidentially identifying operators for the ORS. A Ministry of Transport review is currently under way on the transport services licensing regime.

7.6.2 DSRC tags

Options exist to reissue all operator identification labels with tags. The USDOT operator identifier uses marking on the outside of HCVs combined with DSRC. This tag system would provide operators with access to specific database fields and require them to update the vehicle record with the relevant TSL number every time a change is made

7.7 Freight identification

Identification of freight and association with vehicles is not currently considered a priority, although it is important for statistical analysis supporting planning activities. The real issues in gathering such information relate first to associating freight to vehicles and second to gaining consent from transport operators to share the information with the government.

While many freight forwarders, transport operators and logistics providers already associate freight with vehicles, this data takes a number of inconsistent forms and is not publicly available. A separate but related NZTA research paper (ART8 – Ongoing domestic freight volume information study) (as yet unpublished) considers this topic in more detail.

The association between vehicle and freight is important to obtain accurate freight volume, commodity and movement data. The 'freight attribute' is incorporated into the data matrix at appendix A.

In practical terms the current New Zealand data is modelled on a physical survey, calculations and inferences. There is significant scope to use SEM to collect significant quantities of freight data and to associate freight commodities with specific vehicles. Further potential exists to include freight data sharing in the partnership approach that some operators may elect with the NZTA.

7.8 Driver process and database association

The SEM system will make use of database associations for a variety of information collation and interrogation.

7.8.1 Driver licence

Once a specific driver licence is recognised by an electronic vehicle system, a database containing the association between driver licence number and the vehicle may be stored on a database. With suitable authority the strategic monitoring system would be able to query the registration number of the vehicle, obtain the driver licence number and conduct further checks that the licence was correct and current for the vehicle combination being driven.

7.8.2 Electronic driving hour logbooks (elogs)

Electronic worktime logbooks (elogs) are an identified opportunity in the New Zealand, Australian and other jurisdictions. Current laws differ from those jurisdictions that require tachographs to record drive time. New Zealand counts any time spent in paid employment as work time and most other time as rest time.

Several possibilities have been discussed and smartphone based elogs are currently being trialled by one company. Current New Zealand requirements permit approved alternatives to paper-based logbooks. Some legal and technical obstacles to fully implementing electronic logbooks may be resolved in coming months.

Ultimately, the automated system would obtain a driver licence number, already required to be associated with the vehicle in the elog, then (with suitable authority) access and check an elog content reducing any requirement for the driver to stop for a logbook inspection.

7.8.3 Driver fatigue and incident monitoring

Fatigue monitoring systems are currently available in various forms generally using cab mounted cameras or algorithms based on other sensors. These processes are well established using various techniques such as monitoring eye movement and monitoring patterns of driver behaviour such as weaving outside lanes, sudden corrective movements or slower reactions that indicate fatigue or higher than normal risk of incident.

Currently there is no specific legal requirement for such systems under New Zealand law and as a result, the uptake of these technologies is not yet widespread in New Zealand. One New Zealand company is currently converting an existing international product for use in a smartphone-based application.

7.9 Vehicle weighing (infrastructure based)

7.9.1 Static weighing

Static weighing requires a vehicle to stop on a weighing system, either axle by axle, groups of axles or an entire vehicle or combination, dependent on the size of the weigh plate and the desired result.

Historically, all weight measurements were made using static scales and these are still used in many applications; however, the drive for increased productivity, efficiency and throughput has resulted in an increased appetite for WIM systems and acceptance of lower accuracy levels in many jurisdictions, including New Zealand.

7.9.2 Weigh in motion

Weigh in motion (WIM) has traditionally been separated out to low, medium and high-speed categories. Some current WIM systems operate effectively with a speed range of 0 to 250km/h. Others remain speed rated for specific purposes, eg portable low-speed WIM (accuracy only obtained at a maximum speed of 6 to 10km/h). Some systems are also classified by class; with class 1 being accurate enough for evidential weighing and class 2 being accurate enough for screening vehicles.

The WSDoT pavement guide identified the benefits of WIM as:

- Processing rate. Trucks can be weighed as they as they travel at high speeds, resulting in a significantly greater number of counted vehicles in a short period of time compared to static weigh stations.
- Safety. The minimisation of static weighing significantly decreases vehicle accumulation at highway lanes leading to weigh stations.
- Continuous data processing. WIM can be performed continuously rather than static weighing, using traffic stream samples. This can eliminate any inherent data bias in static weighing.
- Increased coverage and lower cost. More sites may be monitored with WIM at the same cost.
- Minimised scale avoidance. WIM can monitor truck traffic without alerting truck drivers. This results in more truthful data as overweight trucks are less likely to avoid weighing stations.

- Dynamic loading data. Unlike static weigh stations, WIM can record dynamic axle load information, which can be significantly greater than static load information.

The shortcomings of WIM identified by WSDoT are:

- Less accurate. WIM systems are less accurate than static scales. According to the National Bureau of Standards, wheel load scales are required to have an accuracy of ±1% when tested for certification and must be maintained thereafter at ±2%. The best accuracy obtained with the most expensive commonly used WIM devices is 6% of actual vehicle weights for 95% of measured trucks. Note: This differs from the Austroads (2010) *Weigh-in-motion management and operation manual.*
- Reduced information. Truck information that is easily collected at static weigh stations such as fuel type, state of registry, year model, loaded or unloaded status, origin, and destination cannot be obtained with typical WIM systems. Note: in New Zealand most of these vehicle characteristics are available from the motor vehicle register. Using ANPR to trigger a query on the registration number, loaded or unladen status may be inferred from the tare weight. Origin and destination are not currently collected in enforcement checks. Therefore this shortcoming is not relevant in the New Zealand environment.
- Susceptibility to damage from electromagnetic transients. WIM systems are sensitive to electromagnetic disturbances caused mostly by lightning strikes in the vicinity of the equipment.

New Zealand has numerous bending plate WIM sites operated by Police for enforcement purposes at dedicated weighing facilities. The NZTA also operates various high-speed bending plate WIM telemetry sites. These were originally installed purely for statistical purposes; however, two now have associated ANPR systems that identify which vehicle is weighed, and are capable of communications.

Enforcement WIM sites in New Zealand typically utilise a 20m flat concrete pad either side of a weight sensor strip. With the advent of 22+ metre HPMVs the last axles of these vehicles may not be on the concrete pad.

7.9.3 Data obtained

WIM systems typically record data about the date, time and place of each weigh, sequentially numbered axle (and sometimes wheel) weight, aggregated axle group weight, aggregated vehicle weight, aggregated combination weight, axle spacing and overall length between axles of each vehicle and combination.

Figure 7.4 Image of current New Zealand Police CVIU slow-speed WIM operator screen (Plimmerton Weigh Station)

Statistical WIM sites may also record other location information, for example road, number of lanes, direction of traffic flow, vehicle count number, date and time of vehicle event, vehicle classification and vehicle speed.

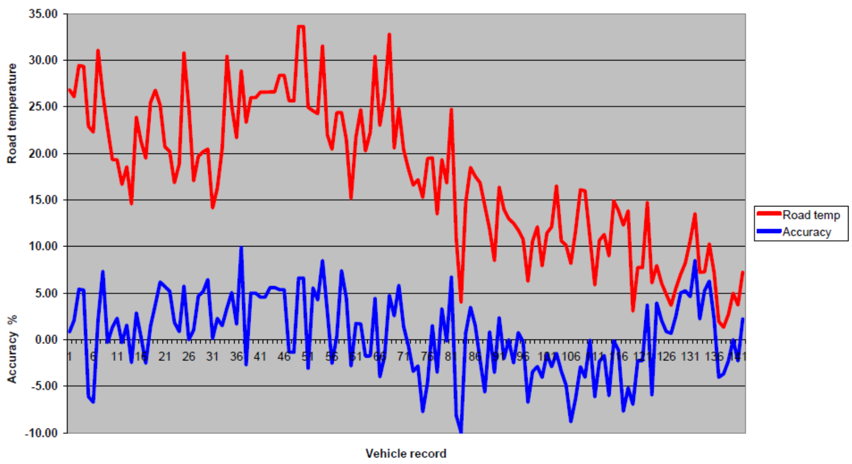
Vehicle classification, count, length and speed may be determined by associated detectors to assist with accurate weight calculation.

7.9.4 WIM lifespan and accuracy – technical requirements

Discussions with David Cornu, Product Manager Kistler (19 March 2012) identify that the lifespan and the accuracy of various types of WIM sensors depend significantly on local conditions including quality of the pavement, traffic and environmental conditions, and the way the systems are tested.

Jones (2008) identifies that the WIM Piezo electric sensors in use by VOSA have different characteristics of output with variations of temperature due to a number of factors, including the type of road surface and the type of resin used for installation. A decision was made to introduce remote monitoring and adjustment of the temperature non-linearity (TNL) curves.

Figure 7.5 VOSA temperature analysis WIM accuracy vs road temperature over six months (courtesy Malcolm Jones VOSA)



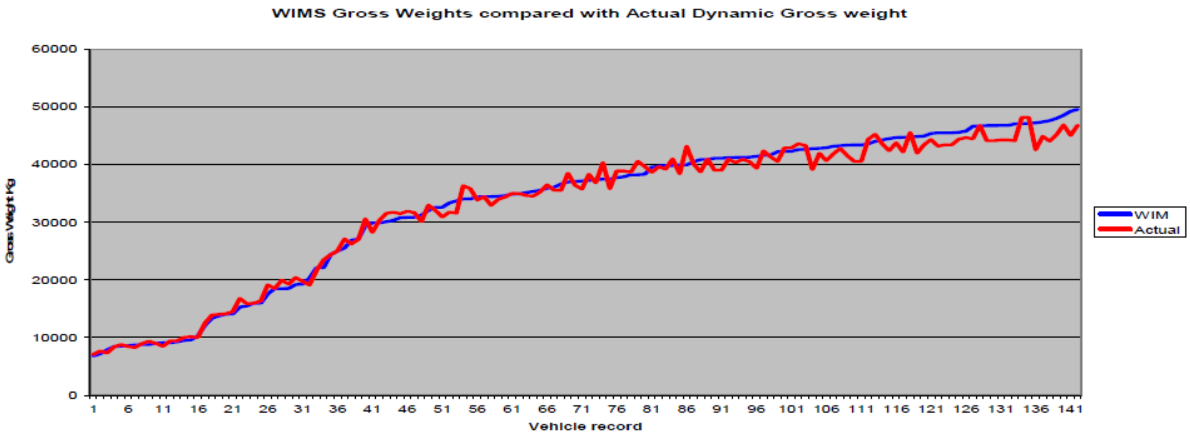
The method employed by VOSA was to monitor the average front axle weight of cars (found to produce the most reliable average weights and offer a high sample rate) and use the average figures to manually maintain and correct the variations caused by temperature change. The actual gross weights obtained from the stopped HGV vehicles were used as calibration reference points; this process was carried out in accordance with guidelines from the WIM manufacturers.

Using the above combination of weight data has enabled a very reliable method of building a unique accurate TNL curve which has provided an increased confidence in accuracy.

Over a six-month period, 100% of vehicles stopped were +/- 10% of evidential weight and 74.2% were better than +/- 5% of evidential weight. The number of overweight prohibitions using the VIPER pre selection system increased from the national average of 24% to 90% demonstrating a significant increase in efficiency.

At the site shown in the graph below, an average of 240 instances of overloading are detected each weekday. Staff and site limitations mean that only 6% of these are able to be processed. This statistic provides strong evidence that a fully automated WIM system offers significant advantages.

Figure 7.5 Daily record of dynamic gross weights vs evidential gross weights in the VOSA system



Transmission of WIM information to smartphones and similar internet enabled devices is commonly used in many jurisdictions. For example, the Netherlands uses a system that transmits photographs of suspect vehicles along with relevant information via the internet. VOSA is trialling transmission of VIPER data to 3G enabled devices such as smartphones and laptop computers; however, UK Government security requirements have slowed the adoption of smartphones for this purpose.

In summary, Jones (2008) states that a 700% improvement has been achieved when compared with traditional methods of targeting non-compliant operators. This is greatly reducing the overweight risk to road safety and road wear.

7.10 Weigh-in-motion equipment types

7.10.1 Strain gauge sensors

There are two types of strain gauge sensors: those mounted on measurement 'bending plates' and those mounted on existing structures.

Most current New Zealand enforcement and statistical weighing facilities are WIM bending plate strain gauges.

7.10.1.1 Bending plates

Strain gauges are permanently attached to the bending plate to create a large measurement area generally 1250mm or 1750mm wide and 500mm long. The bending plate itself, which incorporates the strain gauges, is a vulcanised rubber-sealed unit with a high strength steel plate which is located and secured in a purpose built frame.

The bending plate allows an accurate measurement of wheel load as its whole footprint, typically up to 250mm in the direction of travel, is measured at the same time. The deflection of the plate under the weight of the vehicle produces a strain signal proportional to the load. The signal is amplified to determine the vehicle axle weight.

Kistler advises that bending plates require the installation of a rigid frame into the pavement. In case of flexible pavements (asphalt) this creates a problem with rutting. Such systems are not suitable for direct installation in asphalt pavement. They need concrete pavements or a concrete approach and departure pads as already used in New Zealand.

The ROC Systemtechnik website[9] and media releases state the company is currently developing a WIM matrix network consisting of mini strain gauges that is intended to comply with an international WIM standard (OIML 134) and unlike any previous WIM systems will be able to weigh effectively in stop start traffic.

7.10.1.2 Structure mounted

Strain gauges are mounted directly on to structures (bridges and culverts). Movement in the structures caused by the presence of a moving heavy vehicle is measured directly by the strain gauges. The induced strain is proportional to the weight of the vehicle. Kistler advises that strain gauges can be easily installed and removed which makes it possible to conduct short-term installations, eg to conduct a survey.

7.10.2 Hydraulic load cell sensors

Hydraulic load cell sensors are located in the centre of measurement platforms to assess the weight of vehicles. The measurement platforms can be configured to record axle weights on one side of the vehicle or both. The sensors are highly accurate but the application is best suited to low speeds.

The installation requires reasonable excavation to install the equipment and as a result is relatively expensive.

Kistler advises that load cells require the installation of a rigid frame into the pavement. In case of flexible pavements (asphalt) this will create a problem with rutting. Such systems are not suitable for direct installation in asphalt pavement as they need concrete pavements or surrounds.

7.10.3 Capacitive pad/strip sensors

Capacitive pads/strips use sheets of steel that are separated by a soft rubber dielectric material to form a single unit which is subsequently located and secured in a mounting frame. A voltage is applied across the steel plates and the quiescent capacitance measured. The pressure of a vehicle causes the steel sheet separation to reduce which results in a change in capacitance which is proportional to the load. Capacitance pads can be configured to measure one or two vehicle wheel paths. The latter requires more infrastructure but performs more accurately.

7.10.4 Piezo electric cable sensors

A typical Piezo electric cable (Piezoceramic or Piezo-polymeric) sensor consists of a copper strand, surrounded by a Piezo electric material, which is covered by a copper sheath. The sensor is embedded in the pavement perpendicular to the direction of travel so that the nearside and offside wheels strike the detector at the same time. The sensor produces a charge as a reaction to the deformation induced by the

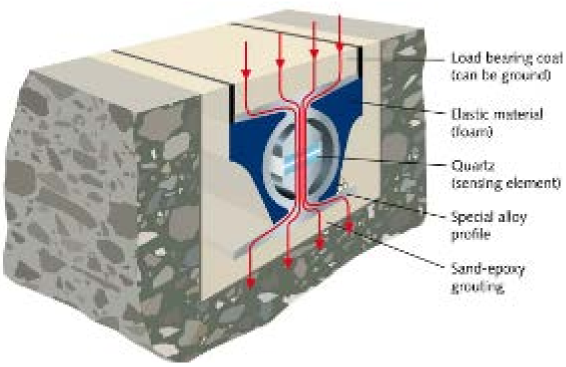
[9] http://rocgmbh.com/ (Accessed 28 June 2012)

tyre loads on the pavement's surface. The Piezo electric sensor's accuracy is practically independent of speed, tyre type, quantity, quality and pressure. The consistency of the measurement accuracy does suffer from a temperature dependency that requires constant compensation as the sensor ages. Besides frequent re-calibration Piezo electric systems require relatively low maintenance activities.

7.10.5 Piezo quartz sensors

The quartz sensing elements are placed in a special alloy profile that will concentrate the vertical forces to the sensing material. This profile is embedded into an elastic material (foam) to eliminate any effect from horizontal forces. The whole WIM sensor is mounted into the road pavement using a special sand-epoxy grouting. This allows a quick installation (four to six hours per lane) and a secure fixation in the pavement. The quartz material has very stable electrical and mechanical properties which means that the sensors are very accurate over time and practically need no recalibration. The sensor's sensitivity is uniform over its entire length. Unlike many other Piezo electric materials, quartz is not pyro-electric, meaning that no electric signal is generated as a result of temperature changes and consequently there are no temperature errors. The sensors can be installed in all kinds of pavements (asphalt, open asphalt, concrete). In case of rutting in asphalt the top layer of the sensors can be ground to fit the road profile.

Figure 7.6 Piezo quartz cross section (courtesy of Kistler)



7.10.6 Additional sensors

In order for the weight measurement to have context, WIM systems must also correctly identify the type of tyre, axle group and axle spacing and ideally each vehicle to establish whether they are overweight or not. Vehicle classification at WIM sites is usually determined by inductive loops, Piezo electric cables, treadle switches or tubes. These systems are installed upstream of the weight sensor at a known separation to determine vehicle speed, vehicle length and classify the vehicle. The 'presence' of a vehicle as detected by one of these systems is often used as a trigger for the weight sensors to commence data collection.

7.10.7 Operations and maintenance

System evaluation and (re)calibration are required on an ongoing basis to maintain the required level of accuracy. NZ Police calibrate and re-certify WIM sites annually. This frequency of system recalibration is required to ensure successful operation and assure public perception.

Besides the periodic calibration of a WIM system, it is important to have a constant data quality control (DQC). The purpose of the DQC is to determine the quality of the data measured by the WIM (eg in the form of a quality index). This quality is important in the detection of errors and disturbances in the system and essential for all applications dependent on WIM data. The quality of analysis using WIM data depends on the known quality of the data.

7.11 Vehicle weighing (portable)

NZ Police use portable electronic scales to obtain weights at any appropriate location. This ad hoc method of weighing is an important tool in the compliance toolbox, but is viewed as a complementary system rather than being part of the SEM framework. Portable static and WIM scales are available.

7.12 Vehicle weighing (onboard – vehicle based)

There are three types of onboard mass measurement (OBM) systems; air pressure transducers (APT), load cells and deflection sensors. Mass information can also be determined through some electronic braking systems although this method is not widely used.

APT are typically accurate to within ±500kgs, although some are more accurate and they measure the variation in air bag suspensions. A larger margin of error may be due to vigorous movements in the suspension systems away from flat roads.

Load cells are typically accurate within ±100–200kg. Sensors are located on each axle group or in specialised positions such as the loading forks of front loading refuse trucks.

Deflection sensors are typically accurate within ±500kgs and they measure the load on the steer axle of a heavy vehicle based on the deflection of that axle.

Each OBM system uses strain gauges as the fundamental measurement device. This common sensor therefore provides a similar level of accuracy to each OBM system.

Formally deployed, OBM systems require high confidence levels in their operation. Cai et al (2009) stated that the nature of these systems make a ‘tamper proof’ system an unlikely possibility. However, evidence of tampering is realistically achievable. A tamper-testing activity was seen to expose vulnerability in commercial OBM systems. Preliminary analysis of the dynamic OBM results suggested that tampering indicators could be developed from the body bounce and/or axle hop frequencies of a vehicle. It is suggested that these would need to sample at a minimum frequency of 24hz to perform accurately.

Large numbers of New Zealand vehicles are already fitted with OBM systems, particularly in the refuse and logging sectors.

The European Project Remove final report on overloading issues recognises there is ‘a singular lack in technical innovation that prevents vehicles from moving whilst overloaded’.

7.13 Engine management systems (onboard)

All engines with electronic engine management require onboard computers to control them. There are numerous variations in terms of data output and capability and each manufacturer tends to vary the system code, even between models. Engine management systems were initially developed to optimise engine systems during driving, to report faults and then permit electronic fault diagnosis through plug in units.

Many HCV engine management systems include control and fault diagnosis for the entire vehicle and for towed vehicles whenever these are electrically connected. The electronic output from these systems offers a wealth of potential data; however, there is little in the way of standardisation.

There is a range of mandatory European HCV engine management interface standards known variously as controller area network (CAN). The physical standards include ISO and SAE standards.

The USA has taken a different approach requiring all vehicles to have an interface providing data on emissions. This range of standards is known as onboard diagnostics (OBD), with commonly known variants OBDII and HD OBD amongst others.

CAN bus is one of five standard protocols used in the OBDII vehicle diagnostics standard. The OBD-II standard has been mandatory for all cars and light trucks sold in the USA since 1996, and the EOBD standard has been mandatory for all petrol vehicles sold in the European Union since 2001 and all diesel vehicles since 2004.

Many US truck and engine manufacturers also comply with the European standards and vice versa due to the global nature of the vehicle market.

Asian manufacturers have different standards in terms of emissions measurement and engine management systems. When selling to the US and European markets, Asian manufacturers are required to meet the locally required standards.

New Zealand does not currently have any requirement for either standard interfaces or minimum available data outputs from engine management systems. Some New Zealand fleet-tracking providers offer interfaces to enable remote monitoring of data via GPS-based systems. This data can include emissions/ fuel consumption for OBDII equipped vehicles along with a much wider range of data including fault alerts, accelerator and brake pedal positions, gear position and a host of other relevant safety and productivity related data. Some of the relevant fields are included in appendix A. This appendix considers the data that may be collected while a HCV is moving in terms of technical feasibility.

7.14 Vehicle safety and compliance

7.14.1 Infrared thermal imaging

Forward-looking infrared cameras use an imaging technology that accurately senses the intensity of infrared radiation emitted from a heat source. The picture that is created is assembled for the static or video output. The thermal imaging camera can accurately measure the temperature of millions of separate points and export the data to a computer for precise analysis.

Thermal imaging cameras are optimally mounted centrally within the roadway surface on an off-ramp lane to a weigh station so that vehicles straddle them on their way to, or within, a low-speed inspection area. The images obtained by the thermal imaging system may be displayed on an operator’s terminal.

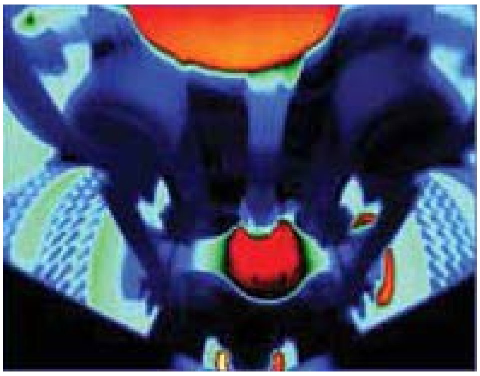
Applied to the transport industry, thermal imaging may be used to assess the condition of a vehicle’s tyres (hot indicating under inflation – and risk of blowout), brakes (out of adjustment) and defective bearings.

Legg advises that thermal imaging cameras are not installed on the mainline because of the severe forces the camera housing would be required to handle from large trucks moving at high speed. Therefore thermal imaging is used for secondary screening at slower speed once a vehicle has already been prescreened and directed into the station.

The system displays images of 'hot' and 'cold' areas. Poorly adjusted brakes or defective brakes will often create a side-to-side heat differential (uneven brake temperature) as shown in figure 7.7 due to one brake either expanding and locking or the ineffective brake not working at all. While some systems require a manual check of the image to establish the integrity of the vehicle, other systems can detect this automatically as the heat signatures for 'healthy' vehicles are predictable to a degree.

WSDoT has installed several forward-looking infrared (FLIR)[10] thermal imaging systems to automatically detect defective truck brakes at several inspection stations with excellent results. Improved safety is achieved through required brake adjustments being made prior to vehicles re-entering the highway.

Figure 7.7 Under-vehicle FLIR image showing uneven brake temperature (courtesy of Bill Legg, WSDoT)



Thermal imaging may provide a sound indication of general maintenance levels when uneven brake signatures are detected.

Traffic Technology Today identifies that FLIR is also used in the European Commission ASSET project to accurately determine tyre depth.

7.14.2 Under-vehicle inspection camera

Tindall et al (2009) completed research for VOSA (UK) including the use of under-vehicle inspection cameras. They identified that slow-speed detection of under-vehicle faults based on camera images is feasible where qualified operators are available.

In many cases remote operators can detect and deal with issues such as the defective (absent) exhaust tailpipe in figure 7.8. It is apparent that under-vehicle cameras are best suited to supplementing a physical inspection and electronically informing transport operator maintenance teams of precise fault details. Following discussions with NZ Police CVIU it is noted that a large screen high resolution display would maximise the ability of qualified staff to detect issues. It is not suggested that under-vehicle cameras would ever replace physical inspection by qualified personnel.

[10] FLIR thermography website: www.flir.com/thermography/americas/us/view/?id=43984 (Accessed 18 April 2012)

Figure 7.8 Under-vehicle camera image showing defective exhaust (courtesy of TRL and VOSA)

7.14.3 Tyre depth and pressure

Maintaining accurate tyre pressure across a national fleet offers significant benefits. The Smartire website[11] states that only 44% of all (US) truck tyres are within 5psi of their recommended inflation and 90% of all tyre failures are a result of under inflation.

7.14.3.1 Benefits of correct tyre inflation

- Stability, handling, braking and performance are improved with obvious safety implications.
- Fuel consumption is reduced. 15% under inflation causes a 1.8% increase in fuel consumption and CO2 emissions, while 20% under inflation causes a 2% increase.
- Tyre wear is reduced in terms of tread and carcass offering cost benefits to the operator.

7.14.3.2 Remote

Tyre depth and pressure can be detected remotely by driving a vehicle over pads at slow speed or alternately through camera-based systems including FLIR. The system units provide immediate readings and show which tyres require inflation and/or replacement. Several options are available, although the majority of tyre sensor pads must be situated indoors.

7.14.3.3 Onboard

Tyre pressures (and in some cases temperatures) can be monitored using electronic valve caps that feed data, generally wirelessly, to an onboard management system. The onboard management system varies and includes dedicated systems and 'add-ons' to GPS systems. Original equipment manufacturer tyre systems generally interface directly with the engine management systems. Both are comparatively new technologies and are in early adoption stages in New Zealand.

7.14.3.4 Smart tyres

Smart tyres are currently under development by a number of companies; they monitor their own tyre pressure and initiate their own inflation process when under pressure. Goodyear has $1.5 million US government funding to develop such a system.

[11] www.smartire.com/cv (Accessed 24 February 2012)

7.15 Vehicle emissions, fuel economy and safety

Excess emissions also indicate poor maintenance; therefore, a high correlation might be expected between HCVs with excess emissions and non-compliance with safety requirements.

Emissions contain the unused hydrocarbons that might otherwise be used to achieve greater fuel economy. Therefore excessive vehicle emissions indicate poor fuel economy. All emissions also have significant effects on human health and mortality.

New Zealand's vehicle emission requirements are primarily contained in the Land Transport Rule: Vehicle Exhaust Emissions 2007. This Rule was initially developed in 2003 following the report of Fisher et al (2002). It contains vehicle entry (import) requirements, a metered test and visible smoke requirements. As HCVs are almost entirely diesel powered, the focus of this review is on diesel emissions from heavy vehicles. The Rule states that 'Diesel emissions are of particular concern because the fine particulates (PM10) produced by combustion of diesel fuel are generally considered to be the most harmful to human health'. As emissions standards have improved, even finer particulates PM2.5 have become an issue.

Recent European standards (Euro 5) have resulted in emissions of much finer particulates PM1 and PM>1 questions are now being asked whether these are even more harmful to humans due to the ability of PM>1 to pass directly into the bloodstream without filtration by bodily hair or tissue.

7.15.1 Land Transport Rule: Vehicle Exhaust Emissions 2007

The Rule identifies that most of the significant health and air quality issues with transport are associated with diesel vehicle emissions. 'Vehicle emissions are a contributing factor to poor air quality, particularly in urban areas, and are known to have an adverse effect on health. Vehicle emissions in this category include carbon monoxide, nitrogen oxides, sulphur dioxide, hydrocarbons, ozone, benzene and particulate matters'.

Because New Zealand is a relatively small consumer of diesel-powered HCVs from diverse markets, a range of emissions standards are accepted by the Rule. Until 2002, Japanese diesel vehicle emissions standards were not very stringent compared with European standards. The Japan 02/04 standard (roughly equivalent to the Euro 3 emissions standard) was the minimum for diesel-powered (existing model) imports to New Zealand from January 2008 to January 2010.

Current compliance options for all new model diesel HCV imports to New Zealand are Australian Design Rules ADR 80/03 and ADR30/01 or Euro 5 or Japan 05; or US 2007. These are considered by the Rule to be equivalent emission ratings although it is accepted that the test regimes are often incompatible and not always directly comparable.

Used, imported vehicles entering the New Zealand fleet are required to undertake a metered emissions test to ensure they continue to meet the emissions standards to which they were manufactured.

All vehicles must be fitted with onboard diagnostic equipment at the time of import if this is required by the emissions standards. For vehicles registered since 3 January 2008 the removal of, or tampering with, emissions control technology is prohibited if it would prevent the vehicle from continuing to be able to pass the same emissions test in place at entry for used vehicles.

A visible smoke test is required at the HCV certificate of fitness (CoF) inspection (generally every six months) to identify badly polluting vehicles. In this test, vehicles must not emit clearly visible smoke when the vehicle's engine is running at its normal operating temperature while idling for five seconds or being accelerated rapidly to approximately 2500 revolutions per minute (or approximately half the maximum engine speed, whichever is lower). This standard may readily be enforced during an onsite physical vehicle inspection and remote emissions detection equipment may be used to alert enforcement staff that particular vehicles should be tested.

On 17 April 2012, Transport Minister Gerry Brownlee announced plans to update the rules setting emissions standards for vehicles entering New Zealand. 'The new standards for new vehicles would mirror those recently agreed in Australia for the introduction of the European standards known as Euro 5 and Euro 6. These standards significantly reduce the harmful emissions from these vehicles', Mr Brownlee said.

7.15.2 The New Zealand HCV fleet

New Zealand HCVs tend to be replaced every five to seven years in transport fleets. Many older vehicles remain operational; particularly in sectors such as farming, where the transport task is secondary to the main business and in marginal transport operations.

Consequently many HCVs currently operating in New Zealand incorporate less sophisticated exhaust emissions control technology than European, Japanese or US vehicles. Bluett (2008) found that operational vehicle emissions tend to exceed test requirements.

Often, the total emissions are dominated by a small number of vehicles with very high emissions. A cost-effective approach may be to identify and target the vehicles with high emissions as an indicator of poor vehicle maintenance, therefore posing a higher safety risk than the majority of the fleet.

7.15.3 Emissions in the upper half of the North Island

Auckland faces air quality problems associated with emissions of pollutants from motor vehicles. Vehicle emissions are responsible for much of the air pollution.

However, there is a general lack of information on the emissions of New Zealand's HCV fleet. Globally there is a lack of information associating operational HCV weight and vehicle age data with measured emissions. This has made it difficult to develop targeted policies to reduce operational emissions and to monitor the effectiveness of any policy that might be implemented. This gap offers significant opportunity for NIWA to lead significant research in association with the NZTA.

There is potential advantage in the SEM environment of high smoke emissions resulting in a detailed safety inspection.

7.15.4 Remote emissions sensing

Remote sensing is one of the most efficient methods of measuring emissions from a large number of vehicles as they are being driven along a single lane. Exhaust emissions are measured in around 0.5 seconds as vehicles pass a sensor creating a system capacity in excess of 2000 vehicles per hour.

A light beam passes through the exhaust plume of the vehicle to a detector. The pollutants discharged from the vehicle's exhaust absorb some of the light beam; the amount of the light remaining is measured at the detector and is used to determine the amounts of pollutants discharged by the vehicle.

Emissions of carbon monoxide, hydrocarbons, and nitric oxide and opacity (uvSmoke, a proxy for particulate emissions) can be detected because they absorb light from different parts of the spectrum.

Figure 7.9 NIWA remote emissions survey at a temporary site in Auckland 2003 (courtesy Auckland Council)

7.16 Vehicle and load profiling

Bridge, power and communication line strikes by over-height vehicles/loads are a persistent problem in New Zealand and internationally. This can lead to the need for expensive bridge repair or even replacement, power or communications outages and consequential productivity losses to other industries.

Over-width loads require drivers to exercise a high degree of skill and care to safely negotiate New Zealand's often narrow and winding road network. There are regular incidents involving collisions with road furniture and parked vehicles. Less frequently motorists collide with over-width loads such as houses, despite in many cases the presence of pilot vehicles, signs, flashing lights and markers on the load. The consequence of this type of collision is often a fatality.

7.16.1 3D Image processing

3D imaging with advanced processing (as discussed in section 7.3.2) is capable of profiling moving vehicles and providing dimensions and other parameters.

7.16.2 Laser profiling

The Transport Data Systems website[12] identifies that some laser profiling systems use an overhead-mounted laser scanner in conjunction with a Doppler radar to automatically determine vehicle classification.

[12] 'An overhead laser scanner and a Doppler radar provide an accurate vehicle profile'. www.transportdatasystems.com/avc_laser_systems.php (Accessed 18 November 2011)

The overhead laser scanner takes vehicle measurements along the length of the vehicle at six-inch intervals as the vehicle passes through the laser profiler. Doppler radar is used to assess the vehicle's speed and determine when the next measurement is required, ie once the vehicle has travelled a further six inches. The system uses the data it has collected to generate a profile of the vehicle which can then be assigned to a particular vehicle category. The system is capable of identifying the presence and dimensions of trailers or other towed equipment.

The system will capture vehicle length, height and width profiles, and its speed. It can be integrated with WIM technology to measure further vehicle characteristics such as axle count, position, weight and the existence of dual tyres.

Other profiling systems are currently being developed including the German PTV AG video-based system used in the ASSET project using lateral 3D cameras and software to provide vehicle identification, classification, speed, profile height and following distance.

Bill Legg (WSDoT) advises that all key weigh stations in Washington State also have over-height detectors on the mainline prior to the weigh station to alert the station if a vehicle is over legal height.

7.16.3 Sniffer technologies

Sniffer technologies are in widespread use for border control. Initially developed to detect explosives on people, they can now be used to detect a range of other substances. A 2011 article on the Homeland Security newswire[13] states that sniffer technologies can detect explosives, chemical agents, toxic industrial chemicals, narcotics, and in addition to the current application (screening people) may be used to screen containers.

These devices are very sensitive and generally hand held, so will require vehicles to stop for inspection.

7.16.4 Radiographic images and electromagnetic images

Freight imaging is widely used in border control systems and several manufacturers offer drive-through inspection systems capable of inspecting freight, providing photo-like images at several aspects at low speed. These can be used for a variety of purposes and can be configured to recognise a variety of substances and items including metallic objects, drugs, alcohol, agricultural products, cash and organic materials such as explosives, even inside moving shipping containers.

Orphan et al state that the vehicle and freight inspection system (VACIS) gamma ray imaging technology provides clear radiographic images (much like x-ray images) of containers, showing the outlines and density of the contents. Over 170 VACIS units have been purchased by the US Government Customs and Border Protection, the US Defense Department and foreign customs agencies for use at freight facilities around the world.

Science Daily reported in an article 'New research could mean cellphones that can see through walls'[14] that researchers at UT Dallas have designed an imager chip that could turn mobile phones into devices that can see through walls, wood, plastics, paper and other objects. Using the new approach, images can

[13] www.homelandsecuritynewswire.com/sniffer-technology-may-replace-detection-dogs (Accessed 6 February 2012)

[14] www.sciencedaily.com/releases/2012/04/120418135306.htm (Accessed 18 April 2012)

be created with signals operating in the terahertz (THz) range using a single lens and a CMOS chip. There is significant future potential for this experimental advance.

Freight imaging offers clear potential, particularly in an all-of-government environment. Freight imaging readily identifies concealed people at international road borders and can be set up to automatically detect a wide range of shapes and densities. One of the New Zealand specific potential applications is in the detection of illicit fisheries including bulk paua (abalone) shipments.

7.16.5 Electronic hazardous goods systems

An electronic hazardous goods declaration system is a viable associated system. The project steering group has requested that this topic is noted, but left to form a separate project.

Essentially a database of hazardous goods information would prove much more effective in achieving safety outcomes than the current paper-based system. Image processing can also readily be programmed to identify and read hazardous goods placards as shown in section 7.3.2.

7.17 Vehicle location and distance measurement

7.17.1 Global positioning system (GPS)

GPS is a space-based global navigation satellite system (GNSS) that provides location and time information in all weather, anywhere on or near the earth, where there is an unobstructed line of sight ideally to four or more GPS satellites. It is maintained by the US government and is freely accessible by anyone with a GPS receiver[15].

In-vehicle GPS-based tracking systems (OBUs) offer a viable option for near continuous strategic monitoring of HCVs.

OBUs offer varying degrees of interface potential with many having the ability to interface with the vehicle engine management system, collect driver identity information and more. Understanding how a vehicle and driver perform at specific locations offers the opportunity to identify ways to increase safety, performance and efficiency. If OBUs were monitored, behaviour patterns on approach to infrastructure based monitoring sites could also be demonstrated.

While GPS systems offer ‘global’ coverage, they suffer from a few issues that can limit their use in particular situations. Tall buildings can result in a canyoning or multipath effect, (bouncing the signal prior to reception). Underground car parks and tunnels can prevent direct signals being received by the GPS unit, again causing issues with recorded position and movement.

Some areas of New Zealand, particularly in the lower part of the South Island, are also prone to lack of constellation (satellite coverage).

Systems which employ more sophisticated analysis of a vehicle’s coordinates are able to resolve more of the data discrepancies which are inherent in this type of system. There have been some false reports of vehicle movements while vehicles were idling due to ‘jiggle’ or ‘wandering’ (McCormack et al 2010). The

[15] Source: Wikipedia website (GPS)

authors have received an independent report that a distance of 80km was recorded over the period of one weekend while a vehicle was parked in an underground Wellington car park. This is normal behaviour for GPS systems under some circumstances (resulting from satellite movement) unless appropriate system filtering is applied.

Several New Zealand companies are at the forefront of GPS developments and offer world leading systems and services which include collection of New Zealand's national mass distance based RUC.

7.17.2 Wheel rotations

The New Zealand RUC system has relied on measurement of distance using wheel rotations since its implementation in 1978. The national interim guidelines require electronic distance recorders (EDR) to continue relying primarily on distance measurements derived from wheel rotations.

7.17.3 Accelerometer

Wikipedia states that an accelerometer device measures the acceleration it experiences relative to freefall conditions and is the acceleration felt by people and objects.

Accelerometers are used in a variety of applications and are built as single, two or three-axis devices to measure magnitude and direction. Three-axis accelerometers are built into many of the more advanced onboard units to gain data for a variety of purposes including rollover and crash detection.

7.18 Release or escalate

When a vehicle, driver, owner, freight and any associated issues detected during the enforcement process have been checked and properly processed the vehicle can generally be released to continue on the journey. This research aims to improve effectiveness and efficiency of that enforcement process through electronic automation.

Those vehicles that cannot be released (with or without an offence notice) face an escalation process to deal effectively with any safety, gross overloading or other issues that have been identified. In almost all circumstances, escalation will require human intervention from trained enforcement staff. Escalation may be a lengthy process; however, it is a delay that compliant operators will no longer face if the SEM system is fully implemented.

8 Literature review part 2: systems and policy

✦ Introduction ✦ Current compliance model ✦ Policy and law ✦ Operational concepts ✦
System components ✦ Recommendations ✦ **Literature review** ✦

This section of the literature review considers international examples of HCV monitoring systems that combine various technologies along with supporting policy in some jurisdictions. The section commences with fully automated weighing and progresses to screening and pre-selection systems.

8.1 Direct automated high-speed weigh stations

Towards the end of 2010, the Czech government announced its plan to allow the use of direct 'evidential standard' HCV enforcement using automatic high-speed WIM linked to an ANPR system. The system measures with an accuracy of ±5% for total weight and ±11% for axle load. In ideal conditions, the system measures vehicle weight to within 3%. One company, Cross[16], has already obtained a certificate to implement direct enforcement on a two-lane road situated in Zlin.

Despite these steps forward, there are still issues surrounding how the equipment will be certified and which organisation will be responsible for the regulations and management of the enforcement operation.

Direct automated enforcement is also the goal of the European Commission ASSET project and is a logical way forward in any jurisdiction seeking to minimise delay to compliant operators.

8.2 Virtual weigh stations

Virtual weigh stations (VWS) operate prescreening technologies but do this in isolation from a weigh station. Instead the system sends the prescreening information or exceptions to enforcement officers who are in the vicinity and have mobile devices capable of connecting to the internet (or other medium).

These sites require far less capital construction then traditional weigh stations and can be located on minor routes that are used to bypass open weigh stations or in situations where it is not feasible to install a weigh station.

In most cases the minimum is a WIM site in conjunction with ANPR cameras (as shown in figure 8.1) with processing and communications equipment to enable enforcement staff to obtain relevant information near real time.

VWS require trained mobile enforcement staff with direct communications permitting access to images and details of HCVs passing the site, along with the proper tools such as portable scales that are required to conduct a more detailed inspection at a suitable downstream location.

VWS are currently of international interest. The two VWS in New Zealand are converted from statistical telemetry sites. Due to current legal requirements they are of limited enforcement use. A few VWS are installed in the USA, and Legg advises that Washington State currently has plans to install two.

[16] www.cross.cz/en/wim-weigh-in-motion/cross-wim.html (Accessed 20 February 2012)

Figure 8.1 VWS on approach to Auckland Harbour Bridge

8.3 Pre-screening and bypassing enforcement sites

Pre-screening is a technique performed in advance of a weigh station on a main highway. In most jurisdictions the high-speed WIM measurements are considered imprecise and are therefore used to screen vehicles identifying those that may have weight issues (rather than using the measured weight evidentially).

By combining vehicle identification data, mainline (high-speed) WIM data, associated detection system data and (where available) associated driver and operator data, compliance information held on remote databases can be queried, vehicles can be checked automatically and many may be permitted to pass the weigh station at high speed.

Vehicles identified for an escalation process are directed electronically (USA) or manually (UK) into weigh stations to proceed over certified evidential standard scales. In Washington State these are static scales.

Traffic Technology International states that the European Union ASSET project recognises the advantage of direct enforcement. In May 2010 the project set up a test site on the German A8 federal motorway with ANPR and high-speed, high-precision WIM and 3D camera with recognition of vehicle identification, dimensions and speed. The German system uses a manned sorting station between the WIM site and the inspection site to instruct non-compliant HCVs and cars to stop.

Jones (2008) states that in the UK over a six-month period to 2008 an average of 240 overweight alerts per weekday were recorded. Due to staffing and check site limitations, the site was, on average, only able to process 6%. This statistic provides strong support for consideration of a direct automated system.

8.3.1 UK

The UK Vehicle and Operators Services Agency (VOSA) VIPER system was developed by the Weight and Safety Partnership/Project WASP. This incorporates high-speed ANPR and WIM technology at 14 motorway locations across the UK. These locations are 10 to 15km in advance of weigh stations. Jones (2008) states that the project was characteristic of a targeted approach to weight enforcement, and aimed to better identify potentially offending vehicles, while letting responsible companies get on with their business.

ITS International[17] states that during trials, VIPER achieved a 700% improvement in identifying 271 overweight vehicles with 100% success rate and prohibiting 204 of those vehicles. In addition to this, 52 drivers were prohibited for serious breaches of their driving hours, and 44 prohibitions were issued for various mechanical defects demonstrating a linkage between offences. Overall accuracy of the high-speed equipment was found to be in excess of 95%.

Figure 8.2 UK VOSA VIPER from the camera gantry (courtesy of ITS international)

8.3.2 Electronic screening in the USA

Several electronic screening systems (PREPASS, NORPASS and two other individual state systems) operate in the USA providing almost complete coverage.

The PrePass website[18] states that PrePass is an intelligent transportation system that electronically verifies safety, credentials and the weight of commercial vehicles at participating state highway weigh stations, commercial vehicle inspection facilities, agricultural facilities and ports of entry. Cleared vehicles may proceed at high speed, eliminating the need to stop. That means greater efficiency for shippers and improved safety for all highway users. There are currently 301 sites across 29 states plus Washington DC. NORPASS operates in seven states while Oregon operates 'Greenpass' and the FMCSA website shows that North Carolina has a similar scheme.

Installation of the basic PrePass equipment at many state inspection facilities is funded by a not-for-profit public-private partnership HELP Inc and provided to states without the use of public funds. Operators who

[17] www.itsinternational.com/features/article.cfm?recordID=4046 (Accessed 6 February 2012)

[18] www.prepass.com/Pages/Home.aspx and www.prepass.com/aboutus/Pages/AboutUs.aspx (Accessed 18 February 2012)

voluntarily participate, fund the system paying monthly service charges. HELP Inc is governed by a Board of Directors comprising an equal number of state official and motor carrier directors.

Legg advises that both ANPR and transponder tags are used for mainline high-speed vehicle prescreening. Trusted carriers, ie those that value legal operations and have very good safety records tend to prefer the transponders which provide a more formal registration of their vehicles for prescreening. Washington State automatic licence plate recognition (ALPR) systems read both natural and infrared light and have infrared flash units. This permits them to operate at night and allows character recognition even when the plates are significantly dirty.

8.3.3 British Columbia Canada – Weigh2Go BC

The Weigh2GoBC website[19] states a similar system operates in British Columbia, Canada, with a random report percentage meaning some trucks that are passed by the system are still required to be checked.

8.3.4 Australia

Australia operates a network of inspection sites. On approach to inspection sites, HCVs are required to leave the highway and use a dedicated approach lane while automated screening checks are performed. Drivers are required to slow to around 30km/h with a 30m spacing. Those vehicles that are not assessed as a safety risk are permitted to continue back onto the highway by way of a variable message sign. This system typically takes around four seconds to evaluate a vehicle combination and provide a green signal to those drivers who are permitted to bypass the inspection site. The evidential weigh site is fully covered with separate covered inspection pits to the rear of the evidential weigh facility.

Figure 8.3 Marulan Weigh Station (southbound), NSW, Australia after the screening lane

Hassall advises that prescreening sites are commonly included in new Australian freeway projects.

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[19] www.th.gov.bc.ca/weigh2GoBC/ (Accessed 29 March 2012)

8.4 Other current semi-automated enforcement

Full automation of most offence processing is constrained by policy decisions and law. These are based primarily on the perception that erroneous issue of a single notice would reflect poorly on any automated system and reduce credibility. However, manual systems are also prone to error.

8.4.1 Red light cameras

Automated red light cameras have been widely used for many years in New Zealand and internationally, both in fully and semi-automated offence notice issuing versions. A vehicle’s presence on inductive loops situated beyond the stopline triggers the red light camera to photograph the offending vehicle when the signals are on red. The photographs are manually reviewed so that the licence plate can be recorded for enforcement purposes.

8.4.2 Speed cameras

Automated static and mobile speed cameras have been widely used for many years in New Zealand and internationally, both in fully and semi-automated offence notice issuing versions. Image processing (as authorised in Italy) might readily be applied to eliminate the existing requirement for induction loops and radar-based mobile systems.

Figure 8.4 Dedicated static speed camera, SH1, Wellington New Zealand

8.4.3 Work time hours

Safe T cam HCV monitoring gantries exist across several Australian states, (Queensland, New South Wales, Victoria and South Australia). The Safe T cam system is set up to automatically enforce driving hours.

European systems monitor driving hours using digital tachographs while New Zealand currently uses paper-based worktime logbooks. Semi-automated electronic logbooks (elogs) are under consideration in both Australia and New Zealand although differing approaches have been adopted.

8.4.4 High productivity vehicles

The Australian Intelligent Access Programme (IAP) involves monitoring of vehicles that are permitted to exceed weight and dimension restrictions on certain routes in some states including Queensland, New South Wales and Victoria. Vehicle movements are continuously monitored using a GPS tracking system that detects and reports non-compliance. Despite continuous monitoring, non-compliance with routes is still detected.

New Zealand currently permits authorised vehicles to exceed standard weight and dimension criteria under a HPMV scheme without any electronic monitoring. The only requirement readily observed by enforcement staff is display of an 'H' plate at the front and rear of the combination.

The result of the New Zealand scheme, under current arrangements, is that any vehicle displaying an H plate would need to be stopped by an enforcement officer to check permit conditions and compliance with those conditions.

Hassall comments from the Australian programme IAP that 'deferring implementation of such a system is likely to increase future resistance as one-off entitlements become accepted as 'rights' under the relevant policy settings, disqualifying increased monitoring as the basis for managing those entitlements'.

8.4.5 Road user charges

The New Zealand eRUC system monitors mass distance-based RUC using distance detection supplemented by GPS. Exceptions are detected by the approved service providers contracted to the NZTA and any suspicious behaviour has to be reported to the NZTA.

8.5 System output

All systems deliver some form of output to end users. The graphic user interfaces range from complex bespoke application screens to fully customisable browser-based screens. Such systems are capable of generating email or text message alerts.

Output hardware includes traffic signals, variable message signs, computer screens, remote laptops, smartphones and mobile phones enabling people to interact with the system at the appropriate level.

8.5.1 Information

All systems collect raw data from a range of sensors and process that data into meaningful information for the end users, ideally close to real time.

In the case of the UK VOSA system, Jones (2008) states that the VOSA 'alert' client displays all WIM and ANPR information within 10 seconds of the generation of each weight record. This enables VOSA operatives at the check-site control room to identify target vehicles and evaluate whether or not the vehicle should be stopped and examined at the check site (up to seven miles from the detection site). The user interface is shown in figure 8.5 and includes the following information:

1. A complete photo overview of the vehicle (for rapid identification and information to be relayed to stopper), eg in the screen shot below, Black Scania 3 + 3 Curtain side Artic.

2 A number plate image, used for stopper information and for comparison with the VOSA technical database and other targeted databases stored in the system which can identify as a 'hit' against the relevant database, eg a vehicle out of test. This also permits storage in an intelligence database.

3 Operator compliance risk score.

4 Which lane the target vehicle was in.

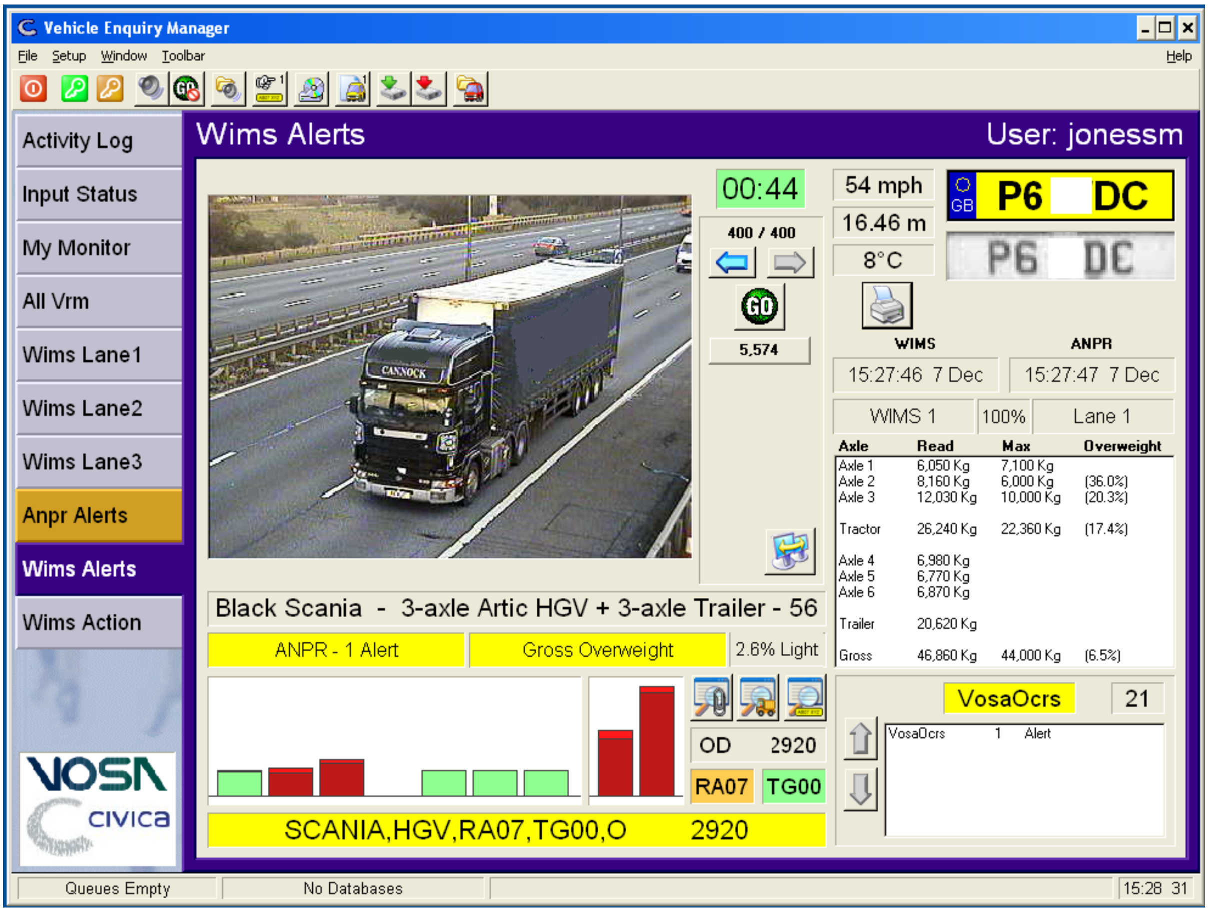
5 Weights of individual axles and calculated gross weight. Both weighed axle information, in kgs compared against pre-programmed parameters and a quick identification bar style graph, ie red is more than 8% overloaded, amber is overloaded but below threshold trigger, and green is within limits.

6 Speed of vehicle.

7 Length of vehicle.

8 Date and time of identification, and time since identification (this helps the operator relay to the stopper the vehicle's potential location after identification and before interception).

Figure 8.5 VOSA screen shot (courtesy of Malcolm Jones, VOSA)



8.5.2 Business intelligence

A few systems go to the next level and combine information and inferences (sometimes contained in system rules) to develop business intelligence. Business intelligence is predictive rather than of an evidential standard, for example high emissions levels indicate a lack of maintenance and may be used to identify vehicles that warrant further safety investigation based on the inference that a lack of engine maintenance more likely than not indicates a lack of overall maintenance.

8.6 Avoidance

Some drivers will elect to use alternative, sometimes unsuitable routes to avoid inspection. Many jurisdictions have severe penalties for bypassing or avoiding weigh facilities.

Avoidance of weigh stations (and toll charging points) whether or not these are automated is an issue in New Zealand and internationally, wherever such opportunity exists. Avoidance often poses safety risks with overloaded and unsafe vehicles using narrow routes and traversing bridges that may be unsuitable for HCVs.

This can be dealt with in many ways including ANPR monitoring with automatic financial penalties. The location of any facility must consider siting away from, or installation of detection equipment on all economically viable alternative routes.

In the Australian semi-automated HCV inspection environment, ANPR cameras are placed on the mainline highway and prohibited alternative routes to detect any avoidance of the screening system. Offence notices are issued using a semi-automated process based on the images.

8.7 Automatic issue of offence notices

Regardless of jurisdiction, offence notices can only be issued for evidential standard measurements of weight or other parameters. The required evidential standard in each jurisdiction is a matter of policy and law, normally including acceptable tolerances for each scenario.

It is technically feasible to automate many processes including the issue of offence notices. Many nations, including New Zealand operate semi-automated processes for a wide range of HCV, speeding, red light, toll evasion and other offences. Full automation is feasible for the majority of offences subject to enabling law changes and acceptance that there will be some error, albeit, fewer errors than the existing manual systems.

Significant efficiencies may be gained (subject to law changes) by automatically detecting offences and generating notices for offences that can be verified to evidential standard. Practical considerations may require continued human verification of some notices.

8.8 International policy

The public perceives that large trucks pose a significant risk to safety in New Zealand. Legg confirms this perception is strong in the USA. Media reports indicate the same perception in many other jurisdictions. Legg states that this perception is continually reinforced in USA by the spectacle of large truck crashes and the media attention that they attract.

Statistics in New Zealand and the USA show that although the rate of truck crashes is lower than other vehicles, the severity of these crashes is higher due to the sheer momentum involved with heavy vehicles travelling at any speed.

Legg states that the overriding justification for truck prescreening and compliance monitoring in the USA is to improve safety. The cost of infrastructure damage as the overriding justification for pursuing prescreening and enhanced enforcement and monitoring was not found to be an effective approach in gaining support for these programmes in the USA.

8.8.1 USA commercial vehicle information systems and networks (CVISN)

The CVISN[20] website states that the CVISN programme is a key component of the Federal Motor Carrier Safety Administration's (FMCSA) drive to improve commercial motor vehicle safety. The CVISN programme supports FMCSA's goals by:

- focusing safety enforcement on high-risk operators
- integrating systems to improve the accuracy, integrity, and verifiability of credentials
- improving efficiency through electronic screening of commercial vehicles
- enabling online application and issuance of credentials.

The website identifies the following overall goals:

- Improve safety and productivity of motor carriers, commercial vehicles and their drivers.
- Improve efficiency and effectiveness of commercial vehicle safety programmes through targeted enforcement.
- Improve commercial vehicle data sharing within states and between states and the FMCSA.
- Reduce federal/state and industry regulatory and administrative costs.
- Wherever automated screening is used it permits enforcement staff to focus on high-risk vehicles, operators and drivers. Not only does this greatly improve the operation of weigh stations and inspection sites, but it is of considerable benefit to the trucking industry as a whole, shifting the balance of competition by reducing or eliminating wait times at weigh stations for compliant operators, cutting fuel bills and emissions in the process.

[20] www.fmcsa.dot.gov/facts-research/cvisn/index.htm

9 References

Audit New Zealand (2005) *Progress in implementing key recommendations of the 1996 Transport Committee inquiry into truck crashes*. Accessed 22 May 2012. www.oag.govt.nz/2005/trucks/part3.htm

Austroads (2010) Weigh-in-motion management and operation manual *AP-T171/10.* New South Wales: Austroads.

Bennett, P, C Han and J Luk (2010) Weigh-in-motion management and operation manual. *Austroads publication no. AP–T171/10*.

Bluett, J, W Fisher, G Kuschel and S Xie (2003) On-road remote sensing of vehicle emissions in the Auckland Region. *Auckland Regional Council technical publication no.198*. Accessed 27 March 2012. www.arc.govt.nz/albany/fms/main/Documents/Plans/Technical%20publications/151-200/TP%20No_198%20%20On-Road%20Remote.pdf

Bluett, J, K Dey and G Fisher (2008) *Assessing vehicle air pollution emissions (new assessments of vehicle air pollution and health effects using advanced on-road remote sensing technology)*. NIWA client report: CHC2008-001 for Department of the Environment, Water, Heritage and the Arts (DEWHA) Clean Air Research Programme (CARP) - project reference number 36 (Australia).

Brash, D (2010) *National Land Transport Programme 2009–12. National overview, mid term update*. Accessed 18 April 2012. www.nzta.govt.nz/resources/national-land-transport-programme/2009-2012/

Brennan, T, DM Bullock, CM Day, H Premachandra and JR Sturdevant (2009) Operational evaluation of wireless magnetometer vehicle detectors at a signalized intersection. *Transportation Research Board of the National Academies paper 10–0007*.

Brownlee, G (2012) *Proposed changes to vehicle emissions rules*. Accessed 18 April 2012. http://feeds.beehive.govt.nz/release/proposed-changes-vehicle-emissions-rules

Bullock, DM, JM Ernst, AA James and V Krogmeier (2008) Recommended tolerances for magnetometer orientation and field calibration procedure. *Transportation Research Board of the National Academies paper 09-0202*.

Bullock, DM, JM Ernst and JV Krogmeier (2011) Acceleration estimation and signature matching travel time estimation enhancement for standard electromagnetic vehicle detectors. *Transportation Research Board of the National Academies 2243*.

Bureau of Transport and Regional Services (BTRE) (2005) *Health impacts of vehicle emissions in Australia: economic costs*. Working paper 63b. Canberra: BTRE.

Cai, D, LE Davis, C Karl and C Koniditsiotis (2009) A regulatory on-board mass monitoring application for heavy vehicles in Australia. In *Proceedings of the 16th World Conference on Intelligent Transport Systems and Services, Stockholm*, 21–25 September 2009.

Cavanagh, J, M Durand, G Fisher, S Kingham, T Kjellstrom, A Hales, C O'Fallon, M Sherman, R Shrestha and A Sturman (2007) *Health and air pollution in New Zealand*. Health Research Council of New Zealand, Ministry for the Environment, Ministry of Transport.

Cetin,M, CM Monsere, AP Nichols and I Ustun (2011) Key factors affecting the accuracy of reidentification of trucks over long distances based on axle measurement data. *Transportation Research Board of the National Academies volume 2243/2011.*

Cevher, V, R Chellappa, AC Gurbuz, JH McClellan and F Shah (2006) *Vehicle fingerprinting using drive-by sounds*. Center for Automation Research, University of Maryland, College Park, MD 20742.

Council of the European Union (1996) *EU Council Directive 96/53/EC of 25 July 1996 laying down for certain road vehicles circulating within the Community the maximum authorized dimensions in national and international traffic and the maximum authorized weights in international traffic*. Accessed 20 February 2012. http://eur-lex.europa.eu/smartapi/cgi/sga_doc?smartapi!celexapi!prod!CELEXnumdoc&lg=EN&numdoc=31996L0053&model=guichett

Department for Transport (DfT) (2010) *Engine idling – costs you money and gets you nowhere*! UK: DfT

Fisher, G, D King, S Kingham, T Kjellstrom, A Hales, J Petersen, K Rolfe, R Shrestha, A Sturman and A Woodward (2002) *Health effects due to motor vehicle air pollution in New Zealand*. Accessed 30 March 2012. www.transport.govt.nz/research/pages/healtheffectsofvehicleemissions.aspx

Gormley, J, E Muenchau, V Orphan and R Richardson (nd) *Advanced cargo container scanning technology development*. Science Applications International Corporation, TRB. Accessed 29 February 2012 http://onlinepubs.trb.org/onlinepubs/archive/Conferences/MTS/3A%20Orphan%20Paper.pdf

HAPINZ (2012) *Updated health and air pollution in New Zealand study*. Accessed 7 September 2012. www.hapinz.org.nz/

International Organization Of Legal Metrology (2004) OIML R134 *Automatic instruments for weighing road vehicles in motion and measuring axle loads*. Accessed 2 June 2012. www.weighment.com/standard/rxxx/R134-2-e04.pdf

James, R, J Date and C McBride (2010) Framework for a national intelligent transport systems architecture. *NZTA research report 397*.

Jones, M (2008) Targeted roadside enforcement using WIM and ANPR, Vehicle and Operator Services Agency (VOSA) UK. *Presentation to 5th International Conference on Weigh-In-Motion. HV Paris.*

Koniditsiotis, C (2000) Weigh-in-motion technology. *Austroads publication no. AP–R168/00.*

KRIA SRL (2012) T-EXSPEED Vehicle speed, classification, identification (white paper). Italy.

McBride, C (2007) Unpublished study of 10,000 New Zealand truck crashes attended by the NZ Police CVIU.

McCormack, E, X Ma, C Klowcow, A Currarie and D Wright (2010) Developing a GPS-based truck freight performance measure platform. *Washington State Department of Transportation research report. Final report TNW2010-02.*

Ministry of Transport (MoT) (2010a) *Interim guidelines for electronic road user charges management systems*. Accessed 20 February 2012. www.nzta.govt.nz/resources/road-user-charges/eruc-guidelines/

Ministry of Transport (MoT) (2010b) *New Zealand truck casualties and crashes*. Accessed 10 April 2012. www.transport.govt.nz/research/Documents/Motor-Vehicle-Crashes-2010-Truck-casualties-and-crashes.pdf

Ministry of Transport (MoT) (2010c) *Understanding transport costs and charges phase two – transport costs in freight logistics.* Accessed 3 June 2012. www.transport.govt.nz/research/Documents/UTCC-Transport-and-freight-logistics-final-report-Aug-11.pdf

Ministry of Transport (MoT) (2011a) *Connecting New Zealand*. Accessed 20 February 2012. www.transport.govt.nz/ourwork/KeyStrategiesandPlans/Documents/Connecting%20NZ_online_version_9_September.pdf

Ministry of Transport (MoT) (2011b) *Brief to incoming Minister of Transport.* Accessed 29 February 2012. www.transport.govt.nz/about/functions/BIM2011/

Ministry of Transport (MoT) (2012) *Social cost of road crashes and injuries 2011*. Accessed 10 April 2012. www.transport.govt.nz/ourwork/Land/landsafety/Pages/Thesocialcostofroadcrashesandinjuries2011.aspx

National Institute of Water and Atmospheric Research (NIWA) (2011) *On road sensing identifies the worst vehicle polluters*. Accessed 18 November 2011. www.niwa.co.nz/publications/wa/vol12-no2-june-2004/on-road-remote-sensing-identifies-the-worst-vehicle-polluters

New Zealand Police (2011) *Annual report for year ended 30 June 2011*. Accessed 2 June 2012. www.police.govt.nz/annual-report-2011

New Zealand Productivity Commission (2012) *International freight transport services inquiry*. Accessed 26 April 2012. www.productivity.govt.nz/final-report/1492

NZ Transport Agency (NZTA) (2007) *Land Transport Rule: Vehicle Exhaust Emissions 2007*. Accessed 6 February 2012. www.nzta.govt.nz/resources/rules/vehicle-exhaust-emissions-2007-index.html

NZ Transport Agency (2010) *Economic evaluation manual (volume 1).* Wellington: NZTA.

NZ Transport Agency (NZTA) (2011a) *Annual weigh-in-motion (WiM) report*. Accessed 2 June 2012. www.nzta.govt.nz/resources/weigh-in-motion/docs/2011-wim-report.pdf

NZ Transport Agency (NZTA) (2011b) NZ Transport Agency annual report and the National Land Transport Fund annual report for the year ended 30 June 2011. Accessed 3 June 2012. www.nzta.govt.nz/resources/annual-report-nltf/docs/nltf-annual-report-2011.pdf

Rooke, A (2006) *Project REMOVE final report*. Accessed 18 February 2012. http://iswim.free.fr/doc/remove_final_report.pdf

Teel, MM (2010) *Missouri's smart roadside program.* Powerpoint presentation US.

Tindall, D, A Gelencser, D Naberezhnykh and A Miles (2009) DART Work Package 2; technology evaluation findings report, project record: *TM 48B Development of detection equipment*. UK Highways Agency, Traffic Incident Prevention Team (UK). 66pp.

Traffic Technology Today (June/July 2011) Issue dedicated to WIM.

UK Government (2007) *Corporate manslaughter and corporate homicide act 2007*. Accessed 20 February 2012. www.legislation.gov.uk/ukpga/2007/19/contents

Upton, J, (2008) Best practice in freight transport operations. *Report no. R08/59 prepared for Environment Canterbury*. Accessed 2 June 2012. http://ecan.govt.nz/publications/General/BestPracticeFreightTransportOperations.pdf

Washington State Department of Transport (WSDoT) *Pavement guide design parameters*. Accessed 18 November 2011. http://training.ce.washington.edu/wsdot/Modules/04_design_parameters/wim.htm (since removed)

Appendix A: Relevant technologies and SEM data output - options analysis

The following table is an analysis of a range of automated options to meet business requirements. Colour coding is used to identify those technologies that are recommended:

As a primary option to meet a business requirement - highlighted in green.

For consideration - highlighted in orange.

Not to be considered further in this context at this time - highlighted in red.

Conventional means of identifying drivers and operators are listed in this table due to the recently introduced practice of NZ Police CVIU enforcement officers scanning bar coded labels to acquire these key fields, automatically populating all known information from the source databases.

Table A1 Options analysis of potential technologies

Business requirement	Function/ automated option	Required sensor/device	Operation-al speed	Estimated efficiency /accuracy	Approx design service life	Strengths	Weaknesses/dependencies	Data output
IDENTIFY								
Vehicle identification	Automatic number plate recognition (ANPR) (key field)	High resolution 2D camera(s) + image processing (ANPR) + database access	High	95% – 99%	10 years	All vehicles are required by law to display number plates and these are already fitted. It is obvious when no plate is fitted. May be used to identify all details associated with the vehicle on database(s). Well proven technology.	Relies on front number plate being visible – any time it is not vehicle must be stopped. Will miss all number plates on the first of two trailers due to plate being out of sight. Rear view camera required to read rear trailer plates. Requires law change to attribute offences.	Registration number (key field)
Vehicle identification	Image processing	3D camera(s) + advanced image processing + database access	High	95% – 99%	10 years	Provides an all inclusive solution incorporating ANPR. Image processing may be used for a range of other purposes. Able to detect changes in colour, make/ model, damage and other parameters. Able to provide vehicle count and classification. Able to measure vehicle dimensions and speed. Already widely in use.	3D cameras are significantly more expensive than 2D cameras	Registration number and vehicle image recognition. Speed detection. Vehicle dimensions, classification and count. Capability to add additional features. Capability to be used for all vehicles.

Business requirement	Function/ automated option	Required sensor/device	Operation-al speed	Estimated efficiency /accuracy	Approx design service life	Strengths	Weaknesses/dependencies	Data output
Vehicle identification	'Tags' Short range communications (DSRC, RFID etc)	Transponder (passive or active in each vehicle) Roadside transmitter/ receiver and associated infrastructure	High	99%	10 years	Provide two-factor identification for added identification in circumstances where ANPR cannot read. Could identify operators who elect to 'opt in' to a cooperative scheme with NZTA. Well proven technology already widely in use.	Transponders are not currently fitted to New Zealand trucks and require additional cost of compliance. Transponders may be moved between vehicles and are subject to theft. Infrastructure is required to read the tags and the current cost of installation of roadside infrastructure is high. This may reduce in future years. Requires law change to attribute offences.	Digital ID that can be associated with the vehicle ID and operator ID
Vehicle, driver, operator, freight and owner identification	Image capture, image processing and response.	Law enforcement officer glasses with camera, communications and heads up display + Image processing	Stopped	99%	2 years	Highly portable and hands free Voice command option in the near future Interoperable with all other devices.	Technology is still in early adoption and research phase so is likely to have improved reliability and lower cost in the future.	Vehicle, driver, operator and owner ID.
Vehicle identification	Magnetic finger-printing	Magnetometers	High	90%	10 years	Cheap to purchase, install and operate in comparison with induction loops and perform many of the same functions.	Changes in vehicle load may cause changes in signature. Not widely used for vehicle fingerprinting with exception of Missouri I95.	Digital signature that can be associated with vehicle ID.
Vehicle identification	Acoustic, finger-printing	Microphones and other sensors	High	20% +	10 years or less	Currently used anecdotally by NZ Police without the use of any electronics.	Unproven technology as at 2012.	Digital signature that can be associated with vehicle ID.

Business requirement	Function/ automated option	Required sensor/device	Operation-al speed	Estimated efficiency /accuracy	Approx design service life	Strengths	Weaknesses/dependencies	Data output
Driver identification	Driver identity	Eyesight and driver licence bar code scanner + image processing	Stopped	99%	n/a	Opportunity to match identity with personal knowledge and photograph limits opportunity for identity fraud. Faster than conventional paper only methods. Currently in use by NZ Police CVIU	Time consuming and requires every vehicle to stop.	Driver licence number(key field).
Driver identification	Driver identity	3D camera + advanced image processing with facial recognition	High	98%	10 years	Opportunity to match identity with personal knowledge and photograph limits opportunity for identity fraud. Minimise requirement for drivers to stop. Currently in use.	Privacy concerns may need to be addressed. Some lighting conditions will preclude image capture inside vehicles.	Driver ID. Driver licence number (key field).
Driver identification	Driver identity	In-vehicle driver licence bar code imaging + second factor – image processing and remote data capture	High	99%	10 years	Currently in limited use by some companies but not currently accessible by the NZTA or Police.	Refer New Zealand provisional patent number 595374. (no details available)	Driver licence number (key field).
Driver identification	Driver identity	In-vehicle camera + Image processing and remote data capture and processing	High	99%	10 years	Currently in limited use by some companies primarily for driver behaviour and fatigue management but not currently accessible by NZTA or Police.	Higher level of privacy concerns when image streams are involved.	Driver identity (key field).
Operator identification	Operator identity	Eyesight and option of operator label bar code scanner	Stopped	99%	n/a	Opportunity to match identity with personal knowledge and photograph limits opportunity for identity fraud. Faster than conventional paper only methods. Currently in use by NZ Police CVIU.	Time consuming and requires every vehicle to stop.	Operator licence number (key field).

Business requirement	Function/ automated option	Required sensor/device	Operation-al speed	Estimated efficiency /accuracy	Approx design service life	Strengths	Weaknesses/dependencies	Data output
Driver, operator and owner identification	Database association with vehicle registration number	Requires in-vehicle devices to scan. Driver licence barcode and ideally a second factor ID. TSL (operator) licence bar code. Alternately TSL may be associated by the operator on the NZTA database.	High	95% – 99%	5 years	Opportunity to automate most checks with a high degree of confidence.	Requires accurate database association with the registration number of the vehicle at that time. Requires that database to be accessible to the SEM system near real time. Recommend operator opt in as a component of bypass requirements. Requires law changes to rely on identification.	Driver licence number. Operator licence number. (key fields)
Legal statement about who the owner and operator of a vehicle are	Vehicle ID, database queries to database linking owner and operator at the time.	ANPR + evidential grade database	High	100%	n/a	Evidential linkage of vehicle registration to owner and operator at highway speed limits requirement to stop vehicles with minor operator and owner offences. Currently requires a statement by the driver to the enforcement officer so requires a physical stop.	Requires law change and NZTA system change	Evidential linkage of vehicle registration to owner and operator
Freight identification	E-manifests: database association with vehicle registration number	Requires operator database interfaced with and accessible by SEM near real time.	High	100%	n/a	Enables an automated decision support system. Would enable statistical data collection to assist with transport modelling and planning activities, fuel efficiency and national productivity measures.	Entirely dependent on operator facilitating electronic entry or entering correct details and making the data available to SEM near real time.	Commodity, weight, volume, origin, destination

Business requirement	Function/ automated option	Required sensor/device	Operation-al speed	Estimated efficiency /accuracy	Approx design service life	Strengths	Weaknesses/dependencies	Data output
Freight identification	Freight scanning	Radiographic scanning	Low	95%	10 years	Enables an automated decision support system detecting different freight types. Enables manual observation.	Despite manufacturers safety assurances perception by some parties that radiographic scanning may lead to health issues.	Freight type
Freight identification	Hand-held freight scanning	Sniffer devices	Static	90%	10 years	Detects many kinds of chemicals and hazardous goods. May be used to detect hazardous goods that have not been declared.	May detect traces of previous freight. Not widely used in the road transport/enforcement sector.	Presence of explosives and some hazardous goods.
Freight identification	Freight image processing	High resolution cameras + image processing	High	90%	10 years	Detects many kinds of freight and hazardous goods placards. Enables statistical attribution of freight to vehicles supporting collection of domestic freight volume information. Image processing may be used for other purposes so shared use of equipment.		Freight type
Freight identification	Hazardous goods register	New database available to SEM and emergency service response	High	100%	7 years	The purpose of HAZMAT identification is to enable correct emergency response. Best practice emergency response starts with a 2km perimeter cordon (until the hazardous goods are identified). This is generally infeasible using the current paper based system. Enforcement also currently relies on physical freight inspection and paper documentation.	Deemed out of scope by the steering group. Initiation and implementation of a separate project to describe and develop a near real time HAZMAT database. Also requires law change.	OUT OF SCOPE FOR THIS RESEARCH

Business requirement	Function/ automated option	Required sensor/device	Operation-al speed	Estimated efficiency /accuracy	Approx design service life	Strengths	Weaknesses/dependencies	Data output
SAFETY PROCESS								
Certificate of fitness (CoF)	Database query, association with vehicle registration number	Already associated during CoF/ (light vehicle WoF) checks and stored in NZTA database	High	100%	n/a	Opportunity to automate issue of offence notices to owner for any vehicles that do not have a current CoF or WoF.	Law change required.	COF current or not.
Brakes	Recognition of uneven heating	Forward looking infra red (FLIR)	Low	100%	10 years	Likely to have a dramatic effect on the incidence of brake defects and consequential safety and fuel economy improvements.	Law change required.	Brakes operating evenly or not.
Brakes	ESC on/off	Engine management	High	100%	10 years	Likely to have a dramatic effect on the incidence of deliberate deactivation and inability to connect.	Law change required.	Brakes not operating effectively.
Wheel bearings	Recognition of uneven heating	Forward looking infra red (FLIR)	Low	100%	10 years	Likely to have an effect on the detection of bearing defects and consequential safety and fuel economy issues. Not normally currently checked at roadside due to difficulty in detection.		Defective wheel bearings.
Tyre tread depth, inflation and condition	Image processing of heat signature	Forward looking infra red (FLIR)	Low	100%	10 years	Likely to have an effect on the detection of tyre defects and insufficient tread depth.	Law change required.	Tyre pressure defective and unsafe tyres.
Tyre pressure	Tyre pressure sensing	Onboard tyre pressure monitors	High	90%	2 years	Tyres report their own pressure and alert the driver/operator and potentially enforcement if issues exist. Commercially available and in use in New Zealand.	Requires linkage near real time to a suitably equipped Telematics system and SEM access to that database.	Tyre pressure.
Tyre tread depth, inflation and condition	Acoustic, light and other tyre data processing methods	Plates in road surface and associated sensors	Low	90%	10 years	Likely to have an effect on the detection of tyre defects and insufficient tread depth.	Generally need to be indoors requiring high stud housing.	Tyre pressure defective and unsafe tyres.

Business requirement	Function/ automated option	Required sensor/device	Operation-al speed	Estimated efficiency /accuracy	Approx design service life	Strengths	Weaknesses/dependencies	Data output
Tyre tread depth, inflation and condition	Smart tyres	Smart tyres	High	?	?	Tyres report their own condition and alert the driver/ operator and potentially enforcement if issues exist.	Experimental and not commercially available in New Zealand as at 2012.	Tyre pressure defective and unsafe tyres.
Lights	Image processing	Camera + image processing	High	100%	10 years	Opportunity to automate offence notices for lighting defects.	Lights only generally activated at night.	Defective lighting.
Lighting, brakes, steering, wipers, suspension, exhaust system emissions, weight	Engine manage-ment system	Engine management system Interfaced with in vehicle telematics and communications to remote database	High	100%	7 years	Vehicle reports its own condition and alerts the driver/operator and potentially enforcement if issues exist.	Commercially available Requires linkage near real time to a suitably equipped Telematics system and SEM access to that database. New Zealand law does not currently require standard engine management system data outputs.	Defective vehicles.
Dimensions	Laser height detection	Laser	High	100%	7 years	Opportunity to automate offence notices for excess height. Potential for width and length. Precise measurement.	Law change required.	Excess height.
Dimensions	Image processing	High resolution 3D camera	High	100%	10 years	Opportunity to automate offence notices for excess dimensions. Image processing may be used for other purposes so shared use of equipment.	Not widely used as yet. Law change required.	Vehicle and load dimensions.
Dimensions	Acoustic processing	Doppler radar	High	98%	10 years	Opportunity to automate offence notices for excess dimensions.	Not widely used as yet	Vehicle and load dimensions.
Detailed mechanical and safety inspection	Convention-al	Eyesight and occasional use of tools.	Stopped	99%	n/a	Detailed physical check by properly qualified staff cannot currently be matched by technology	Time consuming and requires every vehicle to stop for 30 to 60 minutes or more.	Detailed report on safety defects.

Business requirement	Function/ automated option	Required sensor/device	Operation-al speed	Estimated efficiency /accuracy	Approx design service life	Strengths	Weaknesses/dependencies	Data output
Certified vehicle components	Reading plates	ANPR + database association	High	99%	n/a	Detailed physical check of numerous plates can be automated by database checks.	Trailer numberplates may not be able to be read for middle trailers in combinations.	Report on certified vehicle components.
Detailed mechanical and safety inspection	Image processing	Under vehicle full HD camera Large format full HD monitor + Image processing and wherever possible physical inspection	Low or stopped	40%	7 years	Enables improved detection of defects through scanning every vehicle in the low speed zone. May be used remotely.	Will never be capable of matching a physical inspection by properly qualified personnel	Image with highlighted areas of concern.
Load security	Image processing	Side and rear cameras + Image processing	High	50%	10 years	Enables improved detection of insecure loading through scanning every vehicle in the high speed zone and may be repeated in the low speed zone for greater precision. May be used remotely	Requires law change	Image with highlighted areas of concern
PERMIT PROCESS								
Permits to exceed standard maximum dimensions	Database query, association with vehicle registration number plus evidential grade GPS positioning	ANPR/WIM/evi-dential standard GPS devices (electronic distance recorders) for position/route	High	100%	n/a	Confirmation of compliance with permit conditions.	Requires new database.	Permit conditions and exceptions.

Business requirement	Function/ automated option	Required sensor/device	Operation-al speed	Estimated efficiency /accuracy	Approx design service life	Strengths	Weaknesses/dependencies	Data output
Permits to exceed standard maximum weights (indivisible loads and HPMV)	Database query, association with vehicle registration number plus evidential grade GPS positioning	ANPR/WIM/evi-dential standard GPS devices (electronic distance recorders) for position/ route	High	100%	n/a	Confirmation of compliance with permit conditions.	Requires new database.	Permit conditions and exceptions.
WEIGHT PROCESS								
Axle, group, gross and combination weights	High-speed WIM	Quartz Piezo	High – potential for evidential grade	95% of vehicles at +/- 5% -10%	10 years	Able to be installed in asphalt. Linear weight profile.		Evidential standard weight.
Axle, group, gross and combination weights	High-speed WIM	Piezo electric cable sensors	High – for screening only	95% of vehicles at +/- 10% – 20%	4 – 6 years			Screening standard weight.
Axle, group, gross and combination weights	High-speed WIM	Bending plate	High – for screening only	+/- 10%	15 years			Screening standard weight.
Axle, group, gross and combination weights	High-speed WIM	Strain gauge	High – for screening only	95% of vehicle weights +/- 6%	15 years	Bennett et al (2010) state that to supply and install a structure mounted strain gauge system as part of a WIM site costs approximately AUS$20K + AUS$14K per traffic lane.		Screening standard weight.
Axle, group, gross and combination weights	Low-speed WIM	Bending plate	Low - evidential grade			Already in use in New Zealand weigh stations as evidential standard weighing devices.		Evidential standard weight.

Business requirement	Function/ automated option	Required sensor/device	Operation-al speed	Estimated efficiency /accuracy	Approx design service life	Strengths	Weaknesses/dependencies	Data output
Axle, group, gross and combination weights	Low-speed WIM	Strain gauge	Low - evidential grade					Screening standard weight.
Axle, group, gross and combination weights	Static scales		Stopped evidential grade	+/-2%	10 years	Highly accurate	Requires vehicles to stop and start axle by axle. Aim of the research is to minimise the time required by keeping vehicles moving.	Evidential standard weight.
Axle, group, gross and combination weights	Hydraulic load cells	Plate above cell	Stopped	+/- 6%	15 years		Kistler advise that they understand hydraulic load cells are no longer in production. Cost approximately $35K + $30K per traffic lane.	
Axle, group, gross and combination weights	Capacitance pad	Plate above cell	Stopped	95% +/- 10%	20 years		Kistler advise that they understand hydraulic load cells are no longer in production due to reliability issues. Cost approximately $35K + $30K per traffic lane.	
Axle, group, gross and combination weights	Onboard weighing (OBM)	Onboard scales and tamper detection systems	High	95%	7 years	Provide constant weight measurement and ability to demonstrate compliance subject to operator agreement.	Onboard mass measurement has been well established in many fleets and has been operational since the 1990s. As yet a tamper detection system is not commercially available; however, OBM may provide a valuable secondary non evidential data source.	Screening standard weight.

Business requirement	Function/ automated option	Required sensor/device	Operation-al speed	Estimated efficiency /accuracy	Approx design service life	Strengths	Weaknesses/dependencies	Data output
Certificate of loading weight compliance	Database query, association with vehicle registration number	Selected weight detection method(s)	High	95%		Checks every vehicle for compliance as distinct from the current occasional checks.	Relies on database accuracy	Compliance with measured weight.
VEHICLE PROCESS								
Annual licensing fee paid	Database query, association with vehicle registration number	Already associated purchase and stored in NZTA database	High	100%	n/a	Opportunity to automate issue of offence notices to owner for any vehicles that do not have a current licence label.	Law change required	Vehicle licensing current or not.
RUC PROCESS								
Distance run	Database query, association with vehicle registration number plus evidential grade GPS positioning	High resolution camera(s) + image processing (ANPR) + database access	High	100%	10 years	Opportunity to encourage uptake of electronic distance recorders for those operators that wish to maximise efficiency and elect partnership with the NZTA by permitting access to the electronic service provider database.	Can only operate at highway speed with vehicles fitted with electronic distance recorders where operators have consented to permit the SEM to query the electronic service provider databases.	Distance run by each vehicle at known SEM positions and date/time.
Payment for distance run	Database query, association with vehicle registration number plus evidential grade GPS positioning	Electronic distance recorder + database access	High	100%	n/a	Opportunity to encourage uptake of electronic distance recorders for those operators that wish to maximise efficiency and elect partnership with the NZTA by permitting access to the electronic service provider database.	Can only operate at highway speed with vehicles fitted with electronic distance recorders where operators have consented to permit the SEM to query the electronic service provider databases.	Revenue paid/unpaid.
Presence and accuracy of distance recorder or electronic distance recorder	Database query, association with vehicle registration number + image processing	High resolution camera(s) left side + Image processing + database access	High	95%	10 years	Can ascertain the absence or presence of distance recorders on all heavy vehicles required to pay RUC.	System rules and parameters require programming for the NZ environment as hubodometers are not required in any other jurisdiction.	Exception report for no distance recorder fitted.

Business requirement	Function/ automated option	Required sensor/device	Operation-al speed	Estimated efficiency /accuracy	Approx design service life	Strengths	Weaknesses/dependencies	Data output
Tampering/ improper function	Database query, association with vehicle registration number + inferential analysis	High resolution camera(s) left side + Image processing + database access	High	95%	10 years	Can identify improper function of distance recorders on heavy vehicles required to pay RUC.	System rules and parameters require programming for the New Zealand environment as hubodometers are not required in any other jurisdiction.	Exception report for abnormal function observed or derived.
Other checks to confirm the RUC licence is appropriate	Vehicle classi-fication, database query, association with vehicle registration number + Inferential analysis	High resolution camera(s) + Image processing + database access	High	95%	10 years	Can ascertain the correct classification and payment of distance against a series of vehicle records.	System rules and parameters require programming for the New Zealand environment as hubodometers are not required in any other jurisdiction.	Exception report for abnormal function observed or derived.
DRIVER PROCESS								
Driver licensing for class of vehicle being driven	Driver and vehicle ID, vehicle combi-nation classifica-tion and weight, database queries + Inferential analysis	High resolution camera(s) + Image processing + database access	High	100%	10 years	Can accurately and automatically ascertain whether a driver is licensed to drive a vehicle or combination of vehicles.	Requires an accurate means of driver identification with constraints as identified above.	Exception report for driver not licensed to drive class of vehicle or combination of vehicles.

Business requirement	Function/ automated option	Required sensor/device	Operation-al speed	Estimated efficiency /accuracy	Approx design service life	Strengths	Weaknesses/dependencies	Data output
Worktime hours (fatigue manage-ment)	Driver and vehicle ID, Vehicle combi-nation classify-cation and weight, database queries + elog+ inferential analysis	High resolution camera(s) + Image processing + database access	High	100% for detected cases	10 years	Can accurately and automatically ascertain whether a driver is compliant or outside driving hours including driving hours under and alternative fatigue management scheme.	Requires an accurate means of driver identification with constraints as identified above. Requires electronic logbooks and SEM access to the supporting database.	Exception report for driver in excess of driving hours
Speed enforcement	Speed detection and point to point speed detection	3D camera + advanced image processing + database access	High	100% for detected cases	10 years	Evidential standard point and average speed detection using image processing, point to point speed detection using the system wide network (matrix). Capable of being used for all vehicles subject to rear facing cameras for motorcycles.	Requires law change.	Speed offences.
Safety belt usage	Driver and vehicle ID, database queries + driver image	3D Camera + advanced image processing	High	98% for detected cases	10 years	Evidential standard safety belt use detection using image processing. Capable of being used for all vehicles unless lighting conditions or camera angle preclude view.	Requires law change.	Safety belt offences.
Safety belt usage	Driver and vehicle ID, database queries + onboard unit with engine manage-ment system connected	High resolution camera(s) + image processing + database access + onboard unit with engine management system connected	High	100% for detected cases	10 years	Evidential standard safety belt use detection using engine management system + image processing. Capable of being used for all vehicles with onboard equipment.	Requires law change.	.

Business requirement	Function/ automated option	Required sensor/device	Operation-al speed	Estimated efficiency /accuracy	Approx design service life	Strengths	Weaknesses/dependencies	Data output
Driver performance	Driver and vehicle ID, database queries + onboard unit with engine manage-ment system or other sensors connected	On board unit with driver ID + engine management system connected	High	100%	10 years	Ongoing analysis of driver behaviour to demonstrate safe and fuel efficient driving habits. Capable of being used for all vehicles with onboard equipment. May potentially be used to voluntarily inform the operator rating system.	May require requires law change. Technology combination not in widespread use.	Driver performance to demonstrate a good track record (non evidential).
Alcohol and drugs	Driver and vehicle ID, database queries + On board unit with camera, alcolock or other sensors connected + inferential processing	On board unit with vehicle and driver ID + sensors for drugs and alcohol connected + camera with inferential processing	High	50%	7 years	Ongoing analysis of presence of alcohol and some drug types.	Unlikely to confirm total absence of drugs and alcohol however this is the same situation as the manual process.	Presence of alcohol or drugs.

Business requirement	Function/ automated option	Required sensor/device	Operation-al speed	Estimated efficiency /accuracy	Approx design service life	Strengths	Weaknesses/dependencies	Data output
OPERATOR PROCESS								
Operator licensing	Licensed/ not licensed	Vehicle ID, database queries to database holding information	High	100%	n/a	Permits high way speed check	Requires new database access for transport operators to associate TSL with vehicle and change as required to their own licences. Requires law change to permit liability based on database record.	Electronic operator ID licensed/not licensed.
Operator rating system	Associate vehicles, drivers owners and any compliance, defects or non - compliance to operator rating system records	Vehicle ID, database queries to database holding information	High	100%	n/a	Permits high-way speed check.	Relies on electronic operator ID.	Operator rating system data input.
Liability for some offences	Establish operator liability to evidential standard	Vehicle ID, database queries to database holding information	High	100%	n/a	Permits high-way speed check	Relies on electronic operator ID. Requires law change to permit liability based on database record.	Operator licensed/ not licensed.
EMISSIONS AND FUEL ECONOMY PROCESS								
Gross emission detection	Identify the 10% of HCVs with highest emissions	3D camera + advanced image processing	High	100%	10 years	Worst 10% of vehicles are responsible for 90% of New Zealand vehicle emissions. Identify visible emissions at highway speed.	Screening only, is likely to require on-site inspection.	Emission level.

Business requirement	Function/ automated option	Required sensor/device	Operation-al speed	Estimated efficiency /accuracy	Approx design service life	Strengths	Weaknesses/dependencies	Data output
Remote emission detection	Identify the 10% of HCVs with highest emissions	Remote emission detectors	Low	100%	10 years	Worst 10% of vehicles are responsible for 90% of New Zealand vehicle emissions. No current in service checks are performed due to insufficient data supporting in service standards at global level.	Two sets of detectors are required at every site due to some trucks having vertical smoke stacks and others having conventional exhausts.	Emission level.
Brakes and bearings	See above	FLIR	Low	100%	10 years	Defective bearings and brakes that are active while a vehicle is moving increase fuel use and emissions.		Temperature to enable reduced fuel use = reduced emissions

Appendix B: Summary ability of the electronic system to meet and exceed current data requirements

This appendix identifies the data that is required for a physical check along with the data that is available to HCV operators and the data that may be collected by an automated system. It demonstrates that the vast majority of required data can be collected using a 3D camera with image processing, a high speed evidential grade WIM site, data from the engine management system and driver elogs along with database associations.

The slow speed FLIR and under vehicle camera capture further data, notably the FLIR is capable of detecting brake issues and tyre tread depths.

The four weaknesses of SEM identified in this analysis are that:

1 Enforcement staff will always be required to enforce the roads, routes and areas not covered by the system

2 Enforcement staff will always be required to target those who deliberately evade detection and those who demonstrate an ongoing course of non compliance

3 Middle trailers in any combination may not be reliably identified for database associations although this could potentially be worked around.

4 Enforcement staff will always be required to conduct detailed mechanical inspection.

Table B1 Ability of the electronic system to meet and exceed current data requirements

Entity	Class require-ment	High level data for SEM	Current static CVIU HCV enforcement check	Available now to operator by various means	SEM =- feasible moving check	Engine manage-ment system	On board unit/GPS + peripherals + back office	3D camera + advanced image processing	WIM + system	2D camera + ANPR	Hi res under-vehicle cameras	Under vehicle FLIR	Remote emissions monitoring	Radio-graphic screening + image processing	Hardware based height detection	Induction loops
1 Inspection	1 Inspect-ion ID	Unique ID number	No	No	Yes											
	Time	Time	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	No	No	No	No	No	No
	Date	Date	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	No	No	No	No	No	No
	Place	Lat/long + descriptor	Yes	Yes	Yes	No	Yes	Yes	Yes	Yes	No	No	No	No	No	No
	Moving/ static final inspection	M/S	S	S	Yes	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
	Offences	Exception alert,	Yes	Partial	Yes	Partial	Partial	Partial	Partial	No	No	No	No	No	No	No

Entity	Class require-ment	High level data for SEM	Current static CVIU HCV enforcement check	Available now to operator by various means	SEM =- feasible moving check	Engine manage-ment system	On board unit/GPS + peripherals + back office	3D camera + advanced image processing	WIM + system	2D camera + ANPR	Hi res under-vehicle cameras	Under vehicle FLIR	Remote emissions monitoring	Radio-graphic screening + image processing	Hardware based height detection	Induction loops
		offence code(s)														
	Offence Notices	Offence Code(s)	Yes	Yes	Yes	No	No	No	No	No	No	No	No	No	No	No
DRIVER	National ID	No NZ requirement														
	Driver ID	Licence number	Yes	Yes	Yes	No	Yes	Partial	No	No	No	No	No	No	No	No
	Driver currently licensed for class of vehicle being driven	Class vs type and weight	Partial	Partial	Yes	No	No	No	No	No	No	No	No	No	No	No
	Details	Name, address, status, etc	Yes	Partial	Yes	No	No	No	No	No	No	No	No	No	No	No
	Driver behaviour	Balanced Score	No	Yes	Yes	Yes	Yes	Partial	No	Partial	No	No	No	No	No	No
	Current speed	Km/h	No	Yes	Yes	Yes	Estimate only	Yes	No	No	No	No	No	No	No	No
	Point-to-point speed	Average km/h between 2 points	No	Yes	Yes	No	Estimate only	Yes	No	Yes	No	No	No	No	No	No
	Worktime hours (fatigue manage-ment)	Work time periods Rest periods	Yes	Yes	Yes	No	Partial	No	No	No	No	No	No	No	No	No
	Alternative fatigue manage-ment scheme	Approved non standard work hours	Yes	Yes	Yes	No	Partial	No	No	No	No	No	No	No	No	No
	Fatigue monitoring system	Camera and driver behaviour system exception report	No	If fitted	Yes	No	Yes	No	No	No	No	No	No	No	No	No

Entity	Class require-ment	High level data for SEM	Current static CVIU HCV enforcement check	Available now to operator by various means	SEM =-feasible moving check	Engine manage-ment system	On board unit/GPS + peripherals + back office	3D camera + advanced image processing	WIM + system	2D camera + ANPR	Hi res under-vehicle cameras	Under vehicle FLIR	Remote emissions monitoring	Radio-graphic screening + image processing	Hardware based height detection	Induction loops
	Alcohol/ drugs	Present/not detected	Yes	If fitted	Yes	No	No	No	No	No	No	No	No	No	No	No
	Safety belt use	Worn/not	Minimal	Yes	Yes			Yes		Yes						
	Mobile phone use	In use while moving/not	Minimal	No	Yes			Yes		Yes						
	Statement as to owner and operator	Confirm-ation of owner and operator	Yes	Yes	Yes law change required	No	No	No	No	No	No	No	No	No	No	No
VEHICLE	VEHICLE ID (s)	VIN	No	Yes	Yes											
	ADMIN-ISTRATION															
	Registration number (ID)	Regno	Yes	Yes	Yes	No	No	Yes	No	Yes	No	No	No	No	No	No
	Details	Make, model, colour, status, etc	Yes	Yes	Yes	No	Only of entered	Yes	No	Yes	No	No	No	No	No	No
	Vehicle registration	Registration plate present	Yes	Yes	Yes	No	No	Yes	No	Yes	No	No	No	No	No	No
	Vehicle licensing	Current licence label	Yes	Yes	Yes	No	No	Capture registration number	No	Capture registration number	No	No	No	No	No	No
	Certificate of fitness	Expiry date	Yes	Yes	Yes	No	No	Capture registration number	No	Capture registration number	No	No	No	No	No	No
	Permits to exceed std maximum dimensions	Dimensions, route, permit conditions	Paper based system	Yes	Yes requires electronic GIS permit system	No	Partial	Capture registration number + all dimensions	No	Capture registration number	No	No	No	No	Capture height	No
	Permits to exceed standard maximum weights	Weight, route, permit conditions	Paper based system	Yes	Yes requires electronic GIS permit system	No	Partial	Capture registration number	Capture weights	No	No	No	No	No	No	No

Entity	Class requirement	High level data for SEM	Current static CVIU HCV enforcement check	Available now to operator by various means	SEM =- feasible moving check	Engine management system	On board unit/GPS + peripherals + back office	3D camera + advanced image processing	WIM + system	2D camera + ANPR	Hi res under-vehicle cameras	Under vehicle FLIR	Remote emissions monitoring	Radio-graphic screening + image processing	Hardware based height detection	Induction loops
	SAFETY															
	Brakes	Adjustment / defects	Yes	Yes	Yes	Yes	No	No	No	No	No	Yes	No	No	No	No
	Certified components	Current certification	Yes	Yes	Yes	No	No	Yes	No	Yes	No	No	No	No	No	No
	Bearings	worn	Partial	Yes	Yes	No	No	No	No	No	No	Yes	No	No	No	No
	Tyres	Condition	Yes	Yes	Yes	Yes	Yes	No	No	No	No	Yes	No	No	No	No
	Lights	Operational, compliant lenses	Yes	Yes	Yes	No	No	Yes if operating	No	Yes if operating	No	No	No	No	No	No
	Dimensions	compliant	Yes	Yes	Yes	No	No	Yes	No	No	No	No	No	No	Yes	No
	Detailed mechanical and safety inspection	All other safety matters	Yes all selected vehicles	Yes	No will always require CVIU	No	No	No	No	No	No	No	No	No	No	No
	WEIGHTS															
	Axle weights	weight	Yes	Yes	Yes	If fitted	If fitted	No	Yes	No	No	No	No	No	No	No
	Axle group weights	Group weight, spacing	Yes	Yes	Yes	If fitted	If fitted	No	Yes	No	No	No	No	No	No	No
	Total gross vehicle weights	Gross weight, spacing	Yes	Yes	Yes	If fitted	If fitted	No	Yes	No	No	No	No	No	No	No
	Gross combination weight	Gross weight, spacing	Yes	Yes	Yes	If fitted	If fitted	No	Yes	No	No	No	No	No	No	No
	Certificate of loading weight	Registration number, axle weights, gross weight, combination weight	Yes paper based	Yes	Yes	No	No	Capture registration number	Capture weight	Capture registration number	No	No	No	No	No	No
	Advanced electronic vehicle data / engine manage-															

Entity	Class require-ment	High level data for SEM	Current static CVIU HCV enforcement check	Available now to operator by various means	SEM =- feasible moving check	Engine manage-ment system	On board unit/GPS + peripherals + back office	3D camera + advanced image processing	WIM + system	2D camera + ANPR	Hi res under-vehicle cameras	Under vehicle FLIR	Remote emissions monitoring	Radio-graphic screening + image processing	Hardware based height detection	Induction loops
	ment															
	Tyre pressure	Tyre pressure	No	Yes	Yes	Yes	If fitted	No	No	No	No	No	No	No	No	No
	Safety belt worn/ not	Exception not worn when moving	If visible	Yes	Yes	Yes	If fitted	No	No	No	No	No	No	No	No	No
	Coupling	Connected/ not	Yes	Yes	Yes	Yes	If fitted	No	No	No	No	No	No	No	No	No
	Fuel system	Exception faulty	No	Yes	Yes	Yes	If fitted	No	No	No	No	No	No	No	No	No
	Steering	Exception faulty	No	Yes	Yes	Yes	If fitted	No	No	No	No	No	No	No	No	No
	Suspension	Exception faulty	No	Yes	Yes	Yes	If fitted	No	No	No	No	No	No	No	No	No
	Trailer	Trailer fleet ID	No	Yes	Yes	Yes	If fitted	No	No	No	No	No	No	No	No	No
	Wheels	Exception faulty	No	Yes	Yes	Yes	If fitted	No	No	No	No	No	No	No	No	No
	Wipers	Exception faulty	No	Yes	Yes	Yes	If fitted	No	No	No	No	No	No	No	No	No
	Bearings	Exception faulty	No	Yes	Yes	Yes	If fitted	No	No	No	No	No	No	No	No	No
	Collision warning	Exception	No	Yes	Yes	Yes	If fitted	No	No	No	No	No	No	No	No	No
	Emissions	Level	No	Yes	Yes	Yes	If fitted	No	No	No	No	No	No	No	No	No
	Exhaust system	Exception faulty	No	Yes	Yes	Yes	If fitted	No	No	No	No	No	No	No	No	No
	Fuel consumption	Fuel use rate	No	Yes	Yes	Yes	If fitted	No	No	No	No	No	No	No	No	No
	ESC	ESC on/off	Visual only	Yes	Yes	Yes	If fitted	No	No	No	No	No	No	No	No	No
	ROAD USER CHARGES															
	Distance run	Registration number, physical distance run	Yes	Yes	Yes if EDR fitted	Yes uncertain accuracy level	required	No	No	No	No	No	No	No	No	No

Entity	Class requirement	High level data for SEM	Current static CVIU HCV enforcement check	Available now to operator by various means	SEM =- feasible moving check	Engine management system	On board unit/GPS + peripherals + back office	3D camera + advanced image processing	WIM + system	2D camera + ANPR	Hi res under-vehicle cameras	Under vehicle FLIR	Remote emissions monitoring	Radio-graphic screening + image processing	Hardware based height detection	Induction loops
	Payment for distance	Registration number licence min/max distance	Yes	Yes	Yes if EDR fitted	No	required	No	No	No	No	No	No	No	No	No
	Distance recorder	Present/ absent	Yes	Yes	Yes with EDR or left side camera	No	No	No	No	No	No	No	No	No	No	No
	Tampering	Exception	Yes	Yes	Yes if EDR fitted	No	required	No	No	No	No	No	No	No	No	No
	Other checks	Registration number vs licence serial no., actual serial no.	Yes	Yes	Yes if EDR fitted	No	required	No	No	No	No	No	No	No	No	No
FREIGHT	Freight consign-ment ID	Unique ID or RFID														
	Freight commodity ID	Commodity	Yes	Yes	Yes	No	No	No	No	No	No	No	No	No	No	No
	Freight consignor ID	Consignor	No	Yes	Yes	No	No	No	No	No	No	No	No	No	No	No
	Freight origin	Lat/long	No	Yes	Yes	No	No	No	No	No	No	No	No	No	No	No
	Freight consignee ID	consignee	No	Yes	Yes	No	No	No	No	No	No	No	No	No	No	No
	Freight Destination	Lat/long	No	Yes	Yes	No	No	No	No	No	No	No	No	No	No	No
	Freight vehicle association	Registration number/ freight ID	Yes	Yes	Yes	No	No	No	No	No	No	No	No	No	No	No
	Freight route	Lat / long waypoints	No	Yes	Yes	No	No	No	No	No	No	No	No	No	No	No
	Freight Status	Pending/ dispatched / delivered	Yes	Yes	Yes	No	No	No	No	No	No	No	No	No	No	No

Entity	Class require-ment	High level data for SEM	Current static CVIU HCV enforcement check	Available now to operator by various means	SEM =- feasible moving check	Engine manage-ment system	On board unit/GPS + peripherals + back office	3D camera + advanced image processing	WIM + system	2D camera + ANPR	Hi res under-vehicle cameras	Under vehicle FLIR	Remote emissions monitoring	Radio-graphic screening + image processing	Hardware based height detection	Induction loops
	Hazardous materials	Class, declaration ID	Yes	Yes	Yes	No	No	No	No	No	No	No	No	No	No	No
OWNER	Vehicle owner IDs	NZTA customer ID														
	Details	Name, address, status, etc	Yes	Yes	Yes law change required	No	No	No	No	No	No	No	No	No	No	No
OPER-ATOR	TSL operator ID	TSL number														
	Operator licensing identification	TSL card	Yes	Yes	Yes new association database required	No	No	No	No	No	No	No	No	No	No	No
	Details	Name, address, status, etc	Yes	Yes	Yes	No	No	No	No	No	No	No	No	No	No	No
	Operator rating system	Star rating	Yes	Yes	Yes	No	No	No	No	No	No	No	No	No	No	No

Appendix C: Benefit and cost indicators

All benefits and costs in this section are identified as potential and indicative only. They are subject to additional scrutiny, development and formal economic analysis by a fully qualified expert economist.

C1 Identified potential benefits

1 Improved delivery of enforcement services by enhancing effectiveness and efficiency:

- a detection of an increased ratio of roadside non-compliance
- b shorter roadside inspection per vehicle period due to many processes being automated
- c improved efficiency and effectiveness of commercial vehicle safety programmes through targeted enforcement
- d focus on high-risk vehicles, operators and drivers improving the operation of weigh stations and inspection sites.
- e shifting the balance of competition by reducing or eliminating wait times at weigh stations for compliant operators, cutting fuel bills and emissions in the process.

2 Improved road asset life:

- a reduced abnormal road asset damage as a result of increased weight compliance.

3 Improved HCV operator productivity and economic fairness:

- a improved supply chain velocity by reducing the total number of compliant vehicles required to stop for enforcement purposes
- b travel time predictability for those in cooperative data sharing partnership
- c driving hours compliance and knock-on effect to next worktime period
- d early detection of faults optimising opportunity for roadside or scheduled repair
- e fairer collection of RUC by reducing unaccountable road damage
- f reducing unnecessary deceleration, idling and acceleration of compliant vehicles
- g reduced wear and tear – not stopping.

4 Improved safety resulting in reduced crashes, fatalities and injuries:

- a monitoring driving hours and driver licensing
- b reduction in braking and vehicle defects
- c reduced incident-related congestion
- d controlling the operation of unpermitted (ie, overweight or oversize) vehicles

  e reduced volume of entry and egress from inspection points. With a reduction in number of heavy vehicles entering and leaving weigh stations other drivers face a reduced collision risk.

5 Vehicles are workplaces and hence improved safety results can impact on ACC premiums and better workplace safety outcomes.

6 Fewer emissions by detection of gross emitters:

  a fuel savings

  b health and environmental benefits (see environmental section below).

7 Improved aggregated HCV data sharing within the NZTA and between local authorities for planning and maintenance purposes.

8 Better data quantity and quality to support road design, bridge/structural design, traffic engineering, and transportation planning efforts, as well as ongoing performance monitoring and evaluation of vehicle size and weight enforcement programmes.

9 Reduce NZTA and industry regulatory and administrative costs.

C1.1 Safety

According to official Ministry of Transport figures each fatal crash in New Zealand has an estimated social cost of $4,204,000 and each reported serious injury crash has an estimated social cost of $765,000.

MoT (2010 b) statistics show that in the previous 10 years there were 7684 reported injury crashes and 659 fatal crashes involving trucks. This equates to an estimated 10-year social cost of $8.65 billion in fatal and serious injury crashes involving trucks or $865 million per year nationally. The current MoT statistics indicate that less than half of all truck crashes can be attributed to the truck driver.

McBride (2007) in a study of 10,000 fatal, serious injury and high-profile New Zealand truck crashes found that around 7% of truck crashes had vehicle defects as a ‘contributing factor’ and around 70% of those crashes with identified vehicle defects involved defective brakes. Brake defects are a significant issue and were involved in around 5% of all truck crashes prior to 2007. It is not known what impact the Heavy Vehicle Brake Rule 2007 or wider use of disc brakes may have had on this statistic.

C1.2 Environmental

Fisher et al (2002) estimated that 399 people above 30 years of age die prematurely each year due to exposure to emissions from vehicles in New Zealand.

Cavanagh et al (2007) found that in Auckland, the non-external mortality increase (averaged for all age groups) for each 10μg/m3 increase of NO2 was 10%, and for each 10μg/m3 increase of PM10 it was 6%. These results support the use of higher risk coefficients in health impact assessments than those produced by short-term time-series studies.

Oregon Department of Environmental Quality[21] calculated that a truck travelling at high speed compared with one travelling at a weigh station emits between 36% and 67% less PM10, carbon dioxide, carbon monoxide, hydrocarbons and nitrogen oxides.

BTRE (2005) breaks down the costs of emissions in the Australian environment.

Cavanagh et al (2007) found the external costs of air pollution can be estimated as costs to the New Zealand health system and economy. The following table is compiled from two tables and we understand that some questions have been raised about these figures; however, they are the best currently available from published research and provide an indication of the magnitude of cost. It is emphasised that care is required in using these figures. Further research on the topic may be available in the near future.

Table C1 Effect cost per New Zealand case at 2007 with 2010 occurrences attributed to all vehicles

	Estimated cost per case 2007	2010 occurrence	Total
Mortality PM_{10} NO_2	$750,000	414	$310,500,000
Mortality CO	$750,000	86	$64,500,000
Cancer	$750,000	22	$16,500,000
Chronic bronchitis	$75,000	541	$40,575,000
Admission (cardiovascular)	$3675	83	$305,025
Admission (respiratory)	$2700	163	$440,100
Restricted-activity day	$92	671,000	$6,173,200
Total			$428,993,325

C1.3 Wider benefits

There are wider supply chain benefits when travel time is predictable – these include the time of support staff, freight handlers and local distribution.

1 The revenue gains from increased compliance practices. With increased perception that non-compliant HCV operators will be detected and penalised by the SEM followed with targeted enforcement, compliance will increase.

2 Travel time savings for compliant truck operators. Operators who are recognised by the automated systems as compliant are unlikely to be stopped. This gives a time saving for the driver and vehicle, very conservatively estimated at $29[22] per 30-minute enforcement stop.

3 More productivity from better targeted policing. Compliant operators will more often than not be able to pass weigh stations without being stopped for a detailed enforcement check. Police will have a sound and unbiased evidence base to focus on targeted enforcement of persistent offenders.

[21] www.oregon.gov/ODOT/MCT/docs/greenlightemissiontest.pdf

[22] Source: NZTA (2010) *Economic evaluation manual (volume 1)* pA4-2. Value of time for heavy commercial driver per hour in 2008 dollars is $23.92 for the driver and $33.43 for a heavy vehicle (HCV Class II). The authors are aware these figures grossly underestimate the real costs to the supply chain.

Wider aspects of network reliability and maintaining free-flow conditions:

1 Drivers of compliant commercial vehicles are able to continue potentially at high speed. With a potential reduction in number of heavy vehicles entering and leaving weigh stations delays to other drivers are minimised and the network becomes more reliable.

Wider aspects of network monitoring and management:

1 Significant benefits may be gained in terms of planning, monitoring and managing the network.

C2 Identified cost estimates

A high-level estimate (HLE) of cost is provided whenever this was readily available from the research material or is known to our team. This HLE is strictly non-binding and indicative for the sole purpose of informing economic appraisal.

Costing of ANPR/WIM sites at a more detailed level is necessary in terms of site-specific detail to meet business requirements. The cost variation site by site in a more accurate budget estimate will study factors such as:

1 Requirements for VWS vs full installations including options for low-speed equipment.

2 Use of existing power and communications facilities.

3 Use of existing infrastructure such as gantries and weigh stations vs new infrastructure.

4 Road resurfacing or levelling where required.

5 Fixed cost component of back-office processing applications, servers, integration and development. This cannot accurately be estimated until a formal architecture is approved. Simpler architectures generally require less power, servers and staff to operate.

6 Projected operational costs including staff, power, communications, calibration and service requirements.

If existing power and communications infrastructure exists and no road levelling is required, a high-level indicative estimate for a complete installation of an evidential grade two lane (same direction) SEM site is estimated as $250,000 per with forward-facing 3D camera, including on site and remote image processing capability along with quartz Piezo WIM. This high-level estimate is indicative only and non-binding.

Table C2 High-level non-binding cost estimates by component (at April 2012 exchange rates to $NZ)

Component	Cost/lane supply and install to existing system	Model cost estimate on proposed 2-lane same direction model in NZ$
Quartz Piezo WIM option	Two rows of sensors approximately $24K + $30K per traffic lane (Source: Kistler)	$84,000
Bending plates WIM option	Approximately $17K + $36K per traffic lane. (Source: Bennett et al 2010)	$89,000
3D camera and advanced image processing	$150k (up to 3 lanes) includes all advanced image processing	$150,000

Component	Cost/lane supply and install to existing system	Model cost estimate on proposed 2-lane same direction model in NZ$
2D camera side view left side		$10,000
2D ANPR camera rear view		$20,000
Option 2 instead of 3D camera	Delivers significantly fewer benefits for less initial outlay in sensors and increased operational/ maintenance costs	
2D ANPR camera	$20 000	$20,000
Induction loops	$20 000	$40,000
Laser height detection	$10 000	$10,000
Low speed – single lane		**Single lane**
VMS to inform/direct HCVs		$25,000
Thermal imaging		$60,000
Emissions sensor		$150,000
Full HD under-vehicle cameras		$10,000
Radiographic screening		N/K

Appendix D: Potential SEM sites

Four potential operational environments have been considered for enhanced targeting of vehicles and enhanced assessment of vehicles once targeted. These are

1. NZ Police/NZTA weigh stations and inspection sites
2. Strategic sites on approach to bridges, at congestion or toll cordons and on the open road with emphasis on key freight routes with limited economic scope for avoidance. Two cordons have been included to prevent any detours – these are north and south of the South Auckland industrial area.
3. Ports, inland ports and major rail freight terminals
4. Sites where major freight operators and other parties such as city council refuse disposal stations and landfills wish to demonstrate compliance and partnership with the NZTA.

It is anticipated that all HCVs will be required to follow designated routes in the vicinity of SEM sites. The list will require significant further consideration and additional sites to establish effective cordons at key geographical constraint points.

It is noted that the cost per site will be added to the cost of the back office and communications. A high-level estimate of costs for the back office is $100 million +/- $50 million. It is possible that a less expensive solution may be achieved. It is equally possible that if a public sector development is elected the cost may exceed $150 million.

D1 Weigh stations and existing inspection sites

Table D1 Proposed sites

Proposed site	Description/comment	Number of sites	Number of lanes	Indicative cost on recommended model
Stanley St Auckland	Situated at the intersection of two major urban freight routes	3 (1 on each approach road)	9	$750,000
Neilson St	Serves Metroport	2 (1 on each approach route)	2	$500,000
Drury		2 (1 on each motorway approach route)	6	$500,000
SH 30 Rotokawa	Eastern side Lake Rotorua	2 (1 on each approach route)	2	$500,000
Weigh pits - to be determined			50	$12,500,000
Total				**$14,750,000**

D1.1 Strategic sites

Table D2 Indicative sites

Indicative site	Description/comment	Number of sites	Number of lanes	Indicative cost on recommended model
Otaika Rd, Whangerai	South of Tarewa Rd covering all lanes	1	2	$250,000
SH1 Northern Gateway Toll Rd	South end	1	2	$250,000
Northshore near Auckland Harbour bridge	Covering all northbound and southbound lanes prior to Esmonde Rd off ramp Note: existing WIM/ANPR southbound	2	5 each side	$1,000,000
SH16 Te Atatu (North Western Motorway)	East of Te Atatu Rd	2	3 each side	$500,000
SH20 Mangere Bridge	(cordon 1)	2	3 each side	$500,000
Church St Penrose	West of Great South Rd	2	2-3 each side	$500,000
Penrose Rd	On approach to rail overbridge	2	2 each side	$500,000
Station Road East Penrose	South of Walls Rd	2	2 each side	$500,000
Walls Rd Penrose	West of Station Rd East	1	1 each side	$250,000
South Eastern Arterial Route	Near Sylvia Park	2	2 each side	$500,000
SH1 Auckland Southern Motorway	Near Newmarket Viaduct	2	3 northbound 4 southbound	$750,000
Great South Road Auckland	North of Abbatoir Lane (cordon 1)	2	2 each side	$500,000
Mt Wellington Highway Auckland	South of Mt Richmond Drive (cordon 1)	2	2 each side	$500,000
Hillside Rd Auckland	South of Panama Rd (cordon 1)	2	1 each side	$250,000
SH1 Auckland Southern Motorway	Near Panama Rd Bridge (cordon 1)	2	3 each side	$500,000
Ti Rakau Dr Auckland	North of Trugood Drive (cordon 1)	2	2 each side	$500,000
Cascades Rd Auckland	South of Ben Lomond Cr (cordon 1)	2	1 each side	$250,000
Botany Rd	South of Cascades Rd (cordon 1)	2	2 each side	$500,000
SH20 Auckland	Near Manukau Station Rd	2	2 each side	$500,000
SH1 north off SH2 Junction		2	2 each side	$500,000
River Rd Tuakau	Near Waikato River Bridge (cordon 2)	1	2	$250,000
SH1 Mercer	(cordon 2)	1	2	$250,000

Indicative site	Description/comment	Number of sites	Number of lanes	Indicative cost on recommended model
East Coast Rd	Kaiaua (cordon 2)	1	2	$250,000
SH1 north of Ngaruawahia	Covering all northbound and southbound lanes	1	2	$500,000
SH1 north off Tirau Junction	Covering all northbound and southbound lanes	1	2	$250,000
Ngati Maru Highway (Kopu - Thames)	SH25 covering all northbound and southbound lanes	1	2	$250,000
SH1 Cambridge	Tirau Rd between Dominion Ave and Shakespeare St	1	2	$250,000
SH2 Tauraunga	Between Bethlehem Rd and Mayfield Lane	1	2	$250,000
SH5 Rotorua	Ngongotaha Rd near Fairy Springs	1	2	$250,000
SH1 Taupo (north)	Bridge over Waikato headwaters (Tongariro St)	1	2	$250,000
SH3 Te Kuiti	North of Te Kuiti	1	2	$250,000
SH1 south of Turangi		1	2	$250,000
Total				$1,275,000

D1.2 Ports, inland ports and major rail freight terminals

Table D3 Proposed sites – require owners' cooperation and agreement, potential to share costs

Proposed site	Description/ comment	Number of sites	Number of lanes	Indicative cost on recommended model
Port of Auckland, Waitemata inbound	Inbound gates	2	4	
Ports of Auckland, Waitemata outbound	At gates	2	4	
Port of Tauranga, inbound/ outbound	At gates			
Northport (Whangerai)				
KiwiaRail Whangerai CT (container terminal)				
Metroport (inland)				
KiwiRail Auckland CT				
KiwiRail Hamilton CT				
KiwiRail Tauranga CT				
Total				

D1.3 Other potential sites

This concept is mentioned as a possibility for future adoption. Major operators may elect to make data from their own gate WIM facilities available to the NZTA to demonstrate compliance, perhaps in exchange for limited secure access to the system to confirm weights, times, locations, compliance exceptions etc relating to their own vehicles and drivers (not others) as they travel throughout the region.

Table D4 Proposed sites – require owners' cooperation and agreement, potential to share costs

Proposed site	Description/ comment	Number of sites	Number of lanes	Indicative cost for recommended model
Refuse transfer stations				
Major industrial sites				
Major logistics providers				
Total				

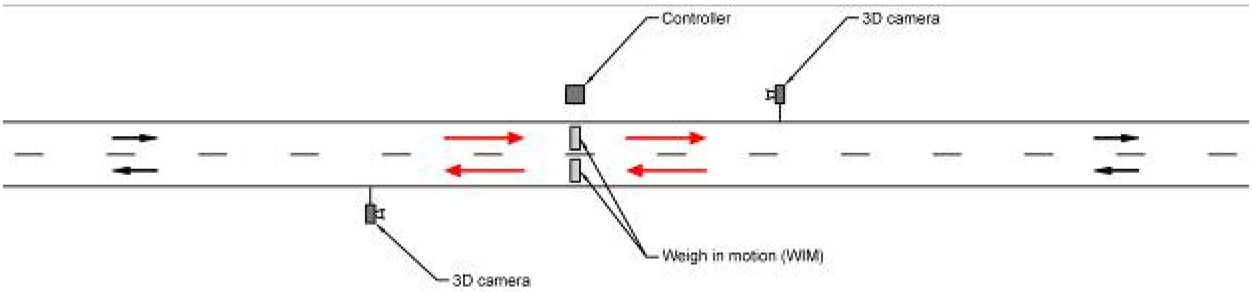
Appendix E: Potential site layouts

These drawings are not to scale and are not developed to final form. They are intended solely as the basis for discussion around the merits and drawbacks of each layout. It is accepted that the lane layout and entry/exit areas will vary in final designs to optimise the sometimes conflicting drivers of compliance, safety, efficiency and productivity.

E1 Virtual weigh station (SEM) site

This layout has a standalone virtual capability. Side-view cameras (not shown) will supplement the direct enforcement capability by confirming axle group configuration and providing additional confirmation of identity. Where a weigh station or weigh pits are nearby it is recommended to place one site either side.

This would enable an automated check to ensure that vehicles directed to stop or comply have in fact done so.

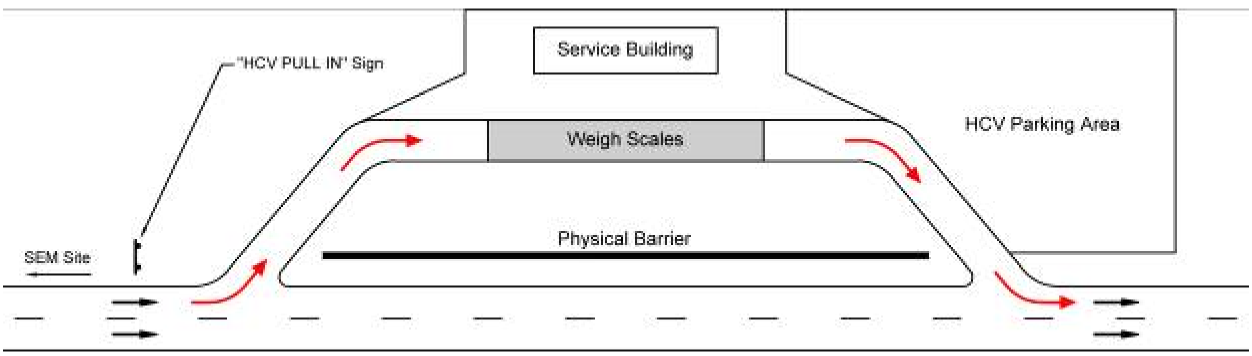


E2 Typical New Zealand highway weigh station

New Zealand weigh stations are each configured differently and this diagram is indicative of a highway station with a median barrier. A SEM site on approach is indicated for screening purposes when enforcement staff are present. Operationally most New Zealand weigh sites have bi-directional flow requiring HCVs to cross oncoming traffic and enter in the lane shown as the exit in this diagram.

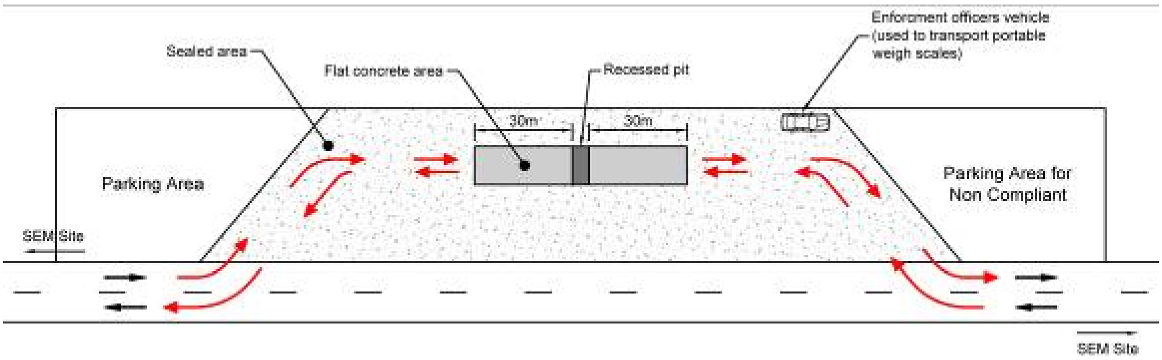
The identified enforcement staff constraint means that the opposing pairs of weigh stations (as installed at Plimmerton) may not provide strong value for money and are rarely both operational.

This raises the question of alternative concepts as indicated in sections E6 and E.7.



E3 Typical New Zealand weigh pit layout

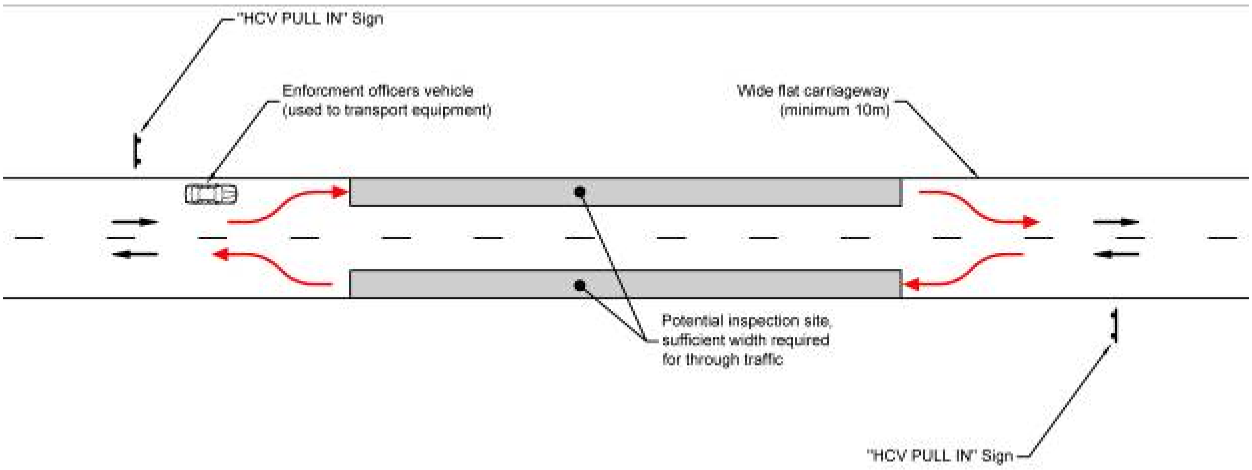
Weigh pits are common around New Zealand and addition of SEM sites would add value in terms of screening HCVs when staff are present and checking that automated compliance requirements are conducted when staff are not present.



E4 Mobile inspection site

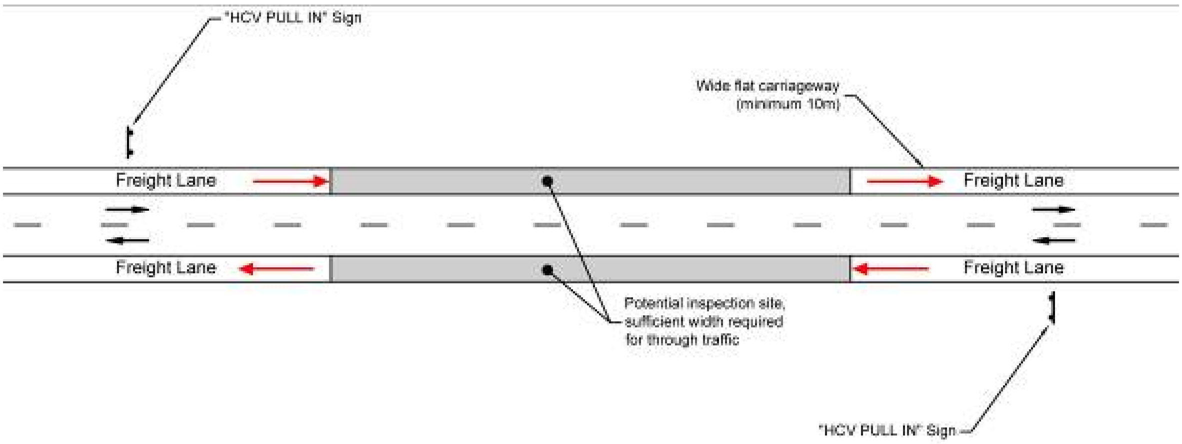
This site is representative of mobile enforcement. The 'All trucks stop' signs currently used are portable.

Mobile enforcement can be conducted with or without the use of SEM in the area.



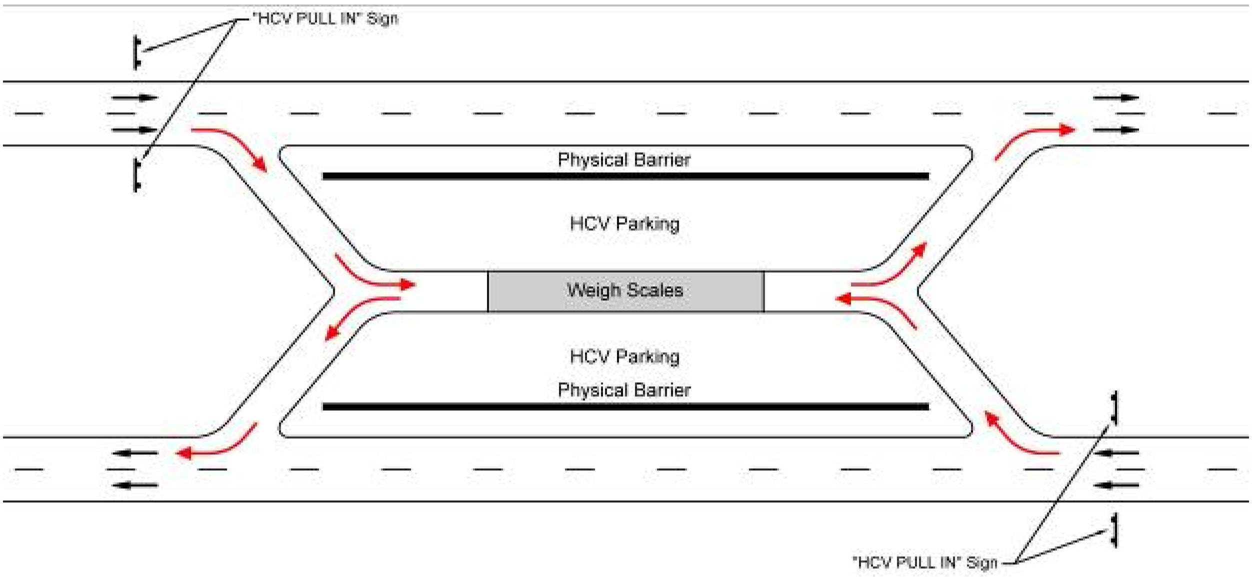
E5 Freight lane SEM concept

This concept includes the use of dedicated freight lanes in areas prone to congestion. Dedicated freight lanes deal with two issues: increasing freight productivity and providing an economic incentive to be electronically inspected.



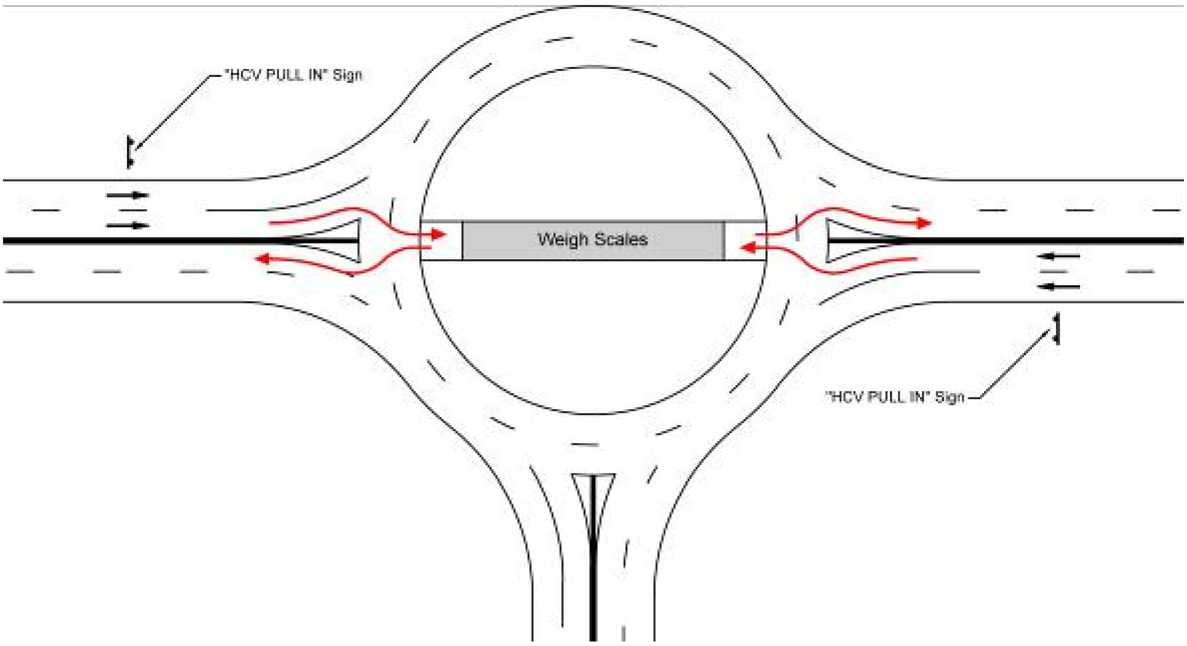
E6 Alternative highway layout concept

New Zealand enforcement officers currently direct HCVs to cross opposing highway speed traffic at several weigh stations. This alternative concept for a central weigh site reduces the current risk levels and could be tailored further to improve safety. It mirrors existing situations such as Mana Esplanade (near Wellington) where HCVs are already required to use the right lane of SH1.



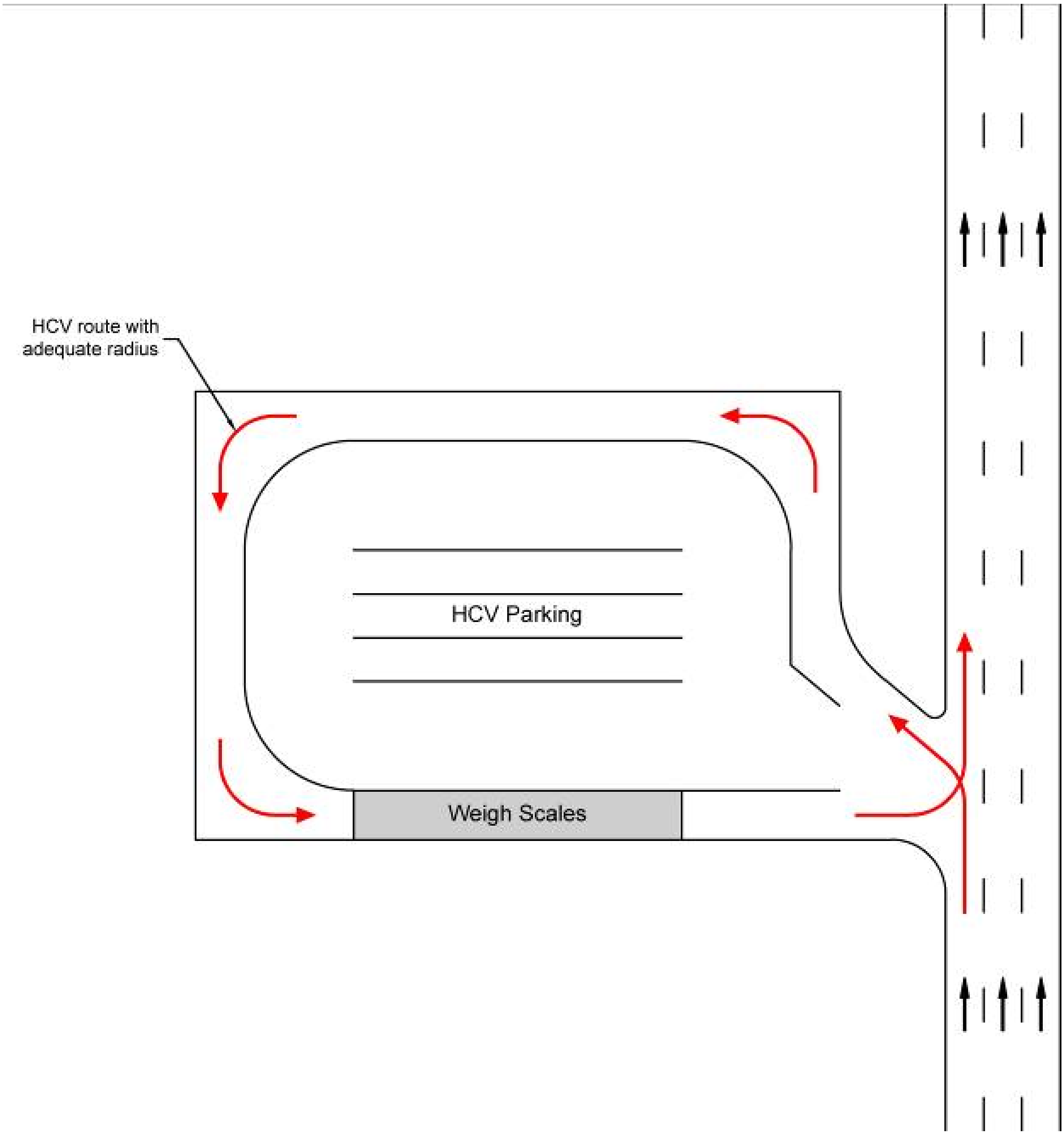
E7 Roundabout concept

This alternative concept for a centralised weigh station in a roundabout at major intersections reduces the current risk levels that exist at some intersections by introducing a large roundabout at lower speed and channelling HCVs into a central HCV inspection facility.



E8 Urban weigh site

This style of site is intended primarily for use in urban areas and in some respects is similar to the existing Stanley St weigh station in Central Auckland. It is considered important that local authorities in larger urban areas are included as part of an overall SEM concept and all available resources are shared to maximise overall HCV compliance.



Appendix F: Glossary

ABS	Anti-skid electronic braking system
ANPR	(Automatic number plate recognition) also known as: automatic licence plate recognition (ALPR), automatic vehicle identification (AVI), car plate recognition (CPR), licence plate recognition (LPR) and lecture automatique de plaques d'immatriculation (LAPI)
APT	Air pressure transducers
ASSET	European Commission Advanced Safety and Driver Support for Essential Road Transport project
CAN	Controller area network
CMOS	Complementary metal-oxide semiconductor the type of image detection sensor used in many devices including smart phones.
CoF	Certificate of fitness
CVISN	Commercial vehicles information systems and network (USA)
CVIU	NZ Police Commercial Vehicle Investigation Unit
DQC	Data quality control
DSRC	Dedicated short-range communications. Allows communication between vehicles and on-road Infrastructure
ESC	Electronic stability control (ESC), also referred to as electronic stability program (ESP) or dynamic stability control (DSC), is a computerised technology that improves the stability of a HCV combination by detecting and reducing loss of traction (*skidding*). When ESC detects loss of steering control, it automatically applies the brakes to help 'steer' the combination where the driver intends to go. Braking is applied to individual wheels generally starting at the rear of a heavy trailer.
EDR	Electronic distance recorder as defined by the Road User Charges Act 1977
Electronic service provider	As defined by the Road User Charges Act 1977, specifically referring to a provider of services supporting an electronic distance recorder.
ES	Envelope shape
FLIR	Forward looking infrared, heat detection camera supporting thermal imaging systems.
FMCSA	Federal Motor Carrier Safety Administration (USA)
GNSS	Global navigation satellite system. Collective term for all satellite supported global navigation systems. These provide timed radio signals to permit devices on earth to cross reference and determine longitude, latitude and elevation. Current commercially available devices, generally used in vehicles are accurate to within 5–7m. More expensive survey grade equipment can be accurate to within 30cm. GNSS includes NAVSTAR – GPS (US), Glonass (Russia), Galileo (Europe), Beidou (China) and IRNSS (India). The only fully operational system is GPS.
GPS	Global positioning system. US system using satellites to provide reference points to determine position. Part of the wider GNSS.
GPS	Government policy statement on land transport funding. A statement of the New Zealand government funding priorities last updated in 2011 (GPS 2012).
GVM	Gross vehicle mass
HLE	High-level estimate
HPMV	High productivity motor vehicle – freight vehicles that have been permitted by the NZTA and/or other road controlling authorities to operate over-mass and/or over dimension vehicles when carrying divisible loads.

IAP	Intelligent Access Programme. Australian scheme to permit overweight and over-dimension vehicles to operate subject to remote GPS monitoring and exception reporting.
ITS	Intelligent transport systems: The application of information technology, communications technology and sensor technology, including the internet (both wired and wireless), to the general challenges and opportunities of surface transportation.
MoT	Ministry of Transport. The Ministry of Transport is the government's principal transport adviser, and the bulk of its work is in providing policy advice and support to Ministers, including drafting and advice on legislative change including Land Transport Rules.
NIWA	National Institute of Water and Atmospheric Research, a crown-owned research and consultancy company
NLTF	National Road Transport fund. Revenue for the NLTF comes from a number of sources including fuel excise duty, RUC, motor vehicle registration and licensing fees, Crown appropriations to the NLTF.
NLTP	NZTA develops a National Land Transport Programme (NLTP) every three years to give effect to the GPS. The NLTP sets out the activities that address the transport priorities of the GPS using the funding provided in the GPS for different activities. To be included in the NLTP, activities have to be: included in a regional land transport programme (including those concerning state highways) and proposed for funding from the National Land Transport Fund, or an activity that will be delivered nationally.
NZTA (NZ Transport Agency)	The agency formed from 1 July 2008 merging Land Transport NZ and Transit NZ.The NZTA has four statutory functions: planning the land transport networks, investing in land transport (funding the maintenance and improvement of state highways and co-investing in the maintenance and improvement of local roads and public transport infrastructure and services), managing the state highway network, and providing access to and use of the land transport system (including regulatory services for commercial vehicles, vehicle registration and driver licensing).
OBD	Onboard diagnostics
OBM	Onboard mass measurement
OBU	Onboard unit, a device carried in a truck generally including a GPS receiver and a communications unit.
OCR	Optical character recognition
OIML	International Organization of Legal Metrology. OIML is a worldwide intergovernmental organisation whose primary aim is to harmonize the regulations and metrological controls applied by the national metrological services
OIML R134	International standard for weighing vehicles in motion
ORS (operator rating system)	Currently in trial phase to publicly rate all licensed commercial transport operators in New Zealand potentially in 2013. The system is based on roadside inspections, certificate of fitness (safety inspection) pass rates and offences.
Police Infringement Bureau	Police Infringement Bureau The centralised Police office that processes all speed camera offence notices and all infringement notices (option to pay fine imposed by offence type and not requiring a court hearing)
RFIDs	Radio frequency identification is a system that uses transponders to identify specialised electronic chips and read information stored on them. Linked with GPS tracking and mobile data technologies these systems permit real-time tracking of goods and other items, generally for logistics purposes in the transport industry. RFIDs are becoming common in other applications such as tracking high value clothing, timing sports events and baggage handling.
RoNS	Roads of national significance. The government has identified seven essential state highways that are linked to New Zealand's economic prosperity. Called the roads of national significance, or RoNS for short, the GPS has signalled that the progress of these

	seven roads is a high investment priority over the next 10 years. The seven RoNS which the NZTA has responsibility to deliver are: Puhoi to Wellsford – SH1, Completing the Western Ring Route - SH16 and SH20, Victoria Park Tunnel, Auckland – SH1, Waikato Expressway – SH1, Tauranga Eastern Link – SH2, Wellington Northern Corridor – SH1, Christchurch Motorways
RPM	Revolutions per minute
RUC	Road user charges: The system in place in New Zealand for over 30 years to collect taxation from vehicles with a gross vehicle mass over 3500kg and vehicles powered by fuels that are not taxed at source. Petrol and LPG are taxed at source. Since 2010 there is an option for electronic monitoring and collection.
SEM	Strategic electronic monitoring – as described in this research paper.
SRT	Static rollover thresholds
Stored value card	Carries embedded value purchased from the card issuer
TNL	Temperature non-linearity
TSL	Transport service licence
USD	United States dollar
VACIS	Vehicle and Freight Inspection System (VACIS®) based on Gamma Ray technology
VMS	Variable message signs. Electronic signs where the message can be changed remotely to advise motorists of changes in travel conditions. May also include variable speed signs.
VIN	Vehicle identification number
VOSA	Vehicle and Operator Services Agency – a division of the UK Highways agency providing a range of licensing, testing and enforcement services with the aim of improving roadworthiness standards of vehicles, ensuring the compliance of operators and drivers within road traffic legislation.
VWS	Virtual weigh stations
WSDoT	Washington State Department of Transportation
WIM	Weigh in motion. A system that can measure the weight of moving vehicles.
Wireless local area network	Provides access to a computer network through a wireless router (range maximum around 300m 802.11n). May be secured to mitigate the risk of unauthorised access
WoF	Warrant of fitness