Intelligent Transport Systems: What Contributes Best to the NZTS Objectives?

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An Important Note for the Reader

The research detailed in this report was commissioned by Land Transport New Zealand.

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Abbreviations and Acronyms

AID	Automated Incident Detector
ANPR	Automatic Number Plate Recognition
ATIS	Advanced Traveler Information Systems
AVL	Automated Vehicle Location
AWIS	Automated Work Zone Information System
CAD	Computer-Aided Dispatch
CCTV	Closed Circuit Television
doppler effect	The apparent change in frequency and wavelength of a wave that is perceived by an observer moving relative to the source of the waves.
DOT	Department of Transport
DSRC	Dedicated Short Range Communications
ETC	Electronic Toll Collection
GPRS	General Packet Radio Service
GPS	Global Positioning System
HGV	Heavy Goods Vehicle
HMI	Human-Machine Interface
ITS	Intelligent Transport Systems
km/h	kilometres per hour
KSI	Killed or Seriously Injured
LED	Light-Emitting Diode
LTMA	Land Transport Management Act
m/h	Miles per hour
MMS	Motorway Management Systems
MVMS	Mobile Variable Message Signs
NTAP	National Tolls Administration Project
ODOT	Oregon Department of Transport
PIA	Personal Injury Accidents
PTZ	Pan Tilt Zoom cameras
RWIS	Road and Weather Information System
RUC	Road User Charges
SCATS	Sydney Coordinated Adaptive Traffic System
SCOOT	Split Cycle Offset Optimizer Technique
SH	State Highway
TMC	Traffic Management Centre
UTC	Urban Traffic Control
VASCAR	Vehicle Average Speed Calculator and Recorder
v/hr	Vehicles per hour
VMS	Variable Message Signs
VDS	Video Detection System

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Introduction

The purpose of this study has been to document international experience of where the greatest benefits have been gained from the implementation of Intelligent Transport Systems (ITS), and to compare these benefits with the key outcomes sought in the New Zealand Transport Strategy (NZTS) and Land Transport Management Act (LTMA).

The resulting report provides guidance on the ways in which different ITS initiatives can contribute to these objectives, with a particular focus on the use of ITS for demand management and in optimising the use of existing land transport infrastructure.

A particular focus of the research has been to provide guidance on the tools (ITS initiatives) available to achieve the NZTS and LTMA outcomes, and which tools will contribute best to the different outcomes. In the context of Regional Land Transport Strategies, the new LTMA requires the development of demand management plans. This research has been developed in order to provide guidance on the kinds of demand management initiatives that ITS applications provide, and the levels of contribution that they might make.

Intelligent Transportation Systems in this context refer to the integrated application of advanced information, electronic, communications, and other technologies to the management and operation of surface transportation systems.

Principles and Objectives

The New Zealand Transport Strategy released in December 2002 sets out the Government's overall vision for Transport, quoted below.

"By 2010 New Zealand will have an affordable, integrated, safe and sustainable transport system"

This vision is underpinned by the following four principles and five objectives:

- Principles
  - Sustainability
  - Integration
  - Safety
  - Responsiveness

- Objectives
  - Economic Development
  - Safety and Personal Security

- Access and Mobility
- Public Health
- Environmental Sustainability

In support of the NZTS principles and objectives the Land Transport Management Act 2003 states that Transfund (Land Transport New Zealand) must be satisfied that any program it approves must contribute to the following:

a) Assist economic development.
b) Assist safety and personal security.
c) Improve access and mobility.
d) Protect and promote public health.
e) Ensure environmental sustainability.

A more detailed definition of these principles and objectives is set out below.

The purpose of this document is to assist in defining how ITS can be applied to help achieve the NZTS and LTMA objectives.

Drawn from the direction of the LTMA and consideration of New Zealand conditions and issues, the following nine target areas have been identified as of particular relevance to the application of ITS in New Zealand. This list will provide direction through the assessment of systems and subsequent rating of potential benefits against New Zealand conditions.

1. Congestion Relief
2. Demand Management
3. Incident Management
4. Compliance
5. Safety
6. Route Security
7. Quality and Efficiency
8. Travel Time Reliability
9. Environmental Mitigation

Methodology

A matrix is used to set out NZTS and LTMA objectives and scales for measuring the contribution of each application to the objectives (primarily focussing on demand management, optimising existing networks and sustaining benefits of infrastructure investments, but also considering the environmental, public health and access and mobility objectives).

Each application has been assessed, in terms of the types of benefits produced, in relation to the NZTS and LTMA objectives; primarily concentrating on demand management, optimising existing networks and sustaining benefits of infrastructure investments.

The assessment approach has been based on considering each benefit area in the context of the scale of overall benefits. In this regard there are many cases where, although some benefit may be achieved in a particular area, these are considered low in terms of scale when compared to those of other systems and/or benefit areas. For example; while speed cameras may deliver marginal benefits in terms of environmental effects, the safety related benefits are significantly higher.

Following this matrix assessment each application is assessed, setting out the types and scale of benefits produced by different ITS applications, potential problem areas and conditions in which they are best applied.

In each case a table is provided drawn from the matrix, identifying the main areas of benefit and providing a brief description/comments on how these are achieved. This is followed by examples of actual applications and reported benefits (New Zealand and/or international).

Conclusions and Recommendations

The conclusions identify that the systems or groups of systems that have the greatest potential to provide benefits in the context of the NZTS and LTMA objectives are those that have a strong focus on travel demand monitoring, management and control, as well as those aimed at early detection and management of specific problems in congested areas.

This reflects the fact that, in urban situations, the benefits of improved demand management and real time management of traffic conditions can have a significant impact on a range of other areas important in the context of the NZTS. The improved management of travel demand and traffic congestion in urban areas can lead to significant improvements in economic efficiency, safety, and environmental impacts.

The most effective are systems that influence travel demand through better information, and through direct means such as congestion pricing. These are supplemented by those that improve detection and monitoring, manage traffic congestion and further improve information reliability and delivery.

The best aligned systems are those that address the following four key elements of demand management:

- Improving ability to make informed choices (Advanced Traveller Information Systems).
- Influencing travel choice through direct means (Congestion Charging).
- Control and management of traffic flow (Adaptive Signal Control / Ramp Metering / Parking Systems).
- Early detection and management of incidents (Detection and Monitoring Systems).

The development and deployment of these types of facilities is growing rapidly in New Zealand. In order to ensure that the best results are achieved there is a need for good early planning together with a focus on the significant benefits of integration and interoperability, driven by a clear understanding of the risks and issues that will influence the success of these systems.

Key factors in the future success of these facilities will be:

- The future development of adaptive signal controls;
- The deployment of road-user/congestion charging, and
- The development of integrated traveller information systems.

Other systems rated highly that have particular relevance in the New Zealand context include

- Systems aimed at monitoring road weather conditions, prediction of adverse conditions, informing drivers and assisting in more effective response and treatment.
- Variable Message Signs and Information Dissemination on key rural highways.

These systems have particular relevance in New Zealand given the relatively high proportion of rural highways which are subject to adverse weather conditions and which provide important strategic connections. With the rapidly reducing costs of the technologies and communications options used in this area, the opportunities to improve the reliability and safety of these routes have increased. As the deployment of systems in this area increases there is an opportunity to benefit from the broadening of integration opportunities and increased interoperability

Although not in the top rated group several other systems have the potential to make a significant contribution, particularly when combined as part of an integrated urban system. These include:

- Real-Time Public Transport Passenger Information Systems as part of an integrated urban traffic control systems.
- Priority Signal Pre-emption and Advance Stop Line Intersections for bus services.
- Variable Message Signs used as part of a motorway management and arterial management systems.
- Environmental Monitoring and Forecasting elements of integrated urban traffic control systems.
- Tunnel systems for surveillance, fire, response and coordination.
- Speed and signal enforcement.

To assist in supporting the effective development of ITS solutions in these areas, it is recommended that further work be undertaken in the following areas:

1. A review of existing adaptive signal control facilities combined with planning for future development of these systems.

2. Research into the potential use of road-user/congestion charging in a New Zealand environment.
3. The future development of integrated traveller information systems.
4. The development of integrated weather condition monitoring, prediction, mitigation and warning systems.
5. The development of integrated real-time urban transport information systems.
6. Development of environmental monitoring and forecasting elements of integrated urban traffic control systems.
7. Review and future planning of tunnel systems for surveillance, fire, response and coordination.

Abstract

The purpose of this study has been to document international experience on the benefits gained from the implementation of ITS, and to compare these benefits with the key outcomes sought in the New Zealand Transport Strategy (NZTS) and Land Transport Management Act (LTMA).

The New Zealand Transport Strategy (NZTS) sets out the Government's overall vision for Transport and is underpinned by series of principles and objectives. The report provides guidance on the ways in which different ITS initiatives can contribute to these objectives.

Using a matrix structure, each application has been assessed, in terms of the types of benefits produced, considering each benefit area in the context of the scale of overall benefits. Following this matrix based assessment each application is summarised, setting out the types and scale of benefits produced by different ITS applications, potential problem areas and conditions in which they are best applied.

The conclusions identify the systems or groups of systems that have the greatest potential to provide benefits in the context of the NZTS and LTMA objectives. The highest rated applications include a strong focus on travel demand monitoring, management and control, as well as the early detection and management of specific problems, monitoring road weather conditions, prediction of adverse conditions, informing drivers and assisting in more effective response and treatment.

1. Introduction

1.1 Intelligent Transportation Systems defined

Intelligent Transportation Systems (ITS) describes the integrated application of advanced information, electronic, communications, and other technologies to the management and operation of surface transportation systems.

The International Standards Organisation (ISO) technical committee for Intelligent Transport Systems describes the field of ITS as:

> *"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".*

Building new transportation infrastructure is expensive and has significant environmental impact. In most urban areas where traffic capacity is limited, it is becoming increasingly difficult to build new roads or increase physical capacity to meet transportation demand. By applying the latest technological advancements to the transportation system, ITS can help meet increasing demand for transportation by improving the quality, safety, and effective capacity of existing infrastructure.

Correctly targeted, ITS facilities and services have the ability to:

- Improve travel safety, reliability, and convenience;
- Increase mobility;
- Mitigate traffic congestion, and reduce fuel consumption and emissions;
- More effectively manage the transportation infrastructure;
- Better control and operate private vehicles, public transport, and commercial vehicles;
- Improve the quality and availability of information for users and providers of the transportation system; and
- Improve the ability to readily use the same products and services in many different places and environments.

1.2 Research Background

The purpose of this research has been to document international experience of where the greatest benefits have been gained from the implementation of ITS, and to compare these benefits with the key outcomes sought in the New Zealand Transport Strategy (NZTS) and Land Transport Management Act (LTMA).

The resulting report provides guidance on the ways in which different ITS initiatives can contribute to these objectives, with a particular focus on the use of ITS for demand management and in optimising the use of existing land transport infrastructure.

The LTMA and Land Transport New Zealand's Allocation Process are strongly focussed on ensuring that:

- Every opportunity is taken to maximise the use of existing networks (e.g. through traffic management or ramp metering), before a decision is made to invest in new or enhanced transport infrastructure.
- Once a decision is made to invest in new or enhanced transport infrastructure, steps are taken to ensure that demand is managed to the extent possible, with the aim being to sustain the benefits associated with the new infrastructure.

ITS initiatives such as Motorway Management Systems (MMS), Advanced Traveller Information Systems (ATIS), Integrated Traffic Control Systems, and Electronic Charging can play a major role in sustaining the benefits of existing and new infrastructure. This document uses international and New Zealand examples of actual applications to determine the achievable from individual and combined ITS initiatives, setting out a comprehensive catalogue of the benefits/impacts that should be expected from each application.

A particular focus of the research has been to provide guidance on the tools (ITS initiatives) available to achieve the NZTS and LTMA outcomes, and which tools will contribute best to the different outcomes. In the context of Regional Land Transport Strategies, the new LTMA requires the development of demand management plans. This research has been developed in order to provide guidance on the kinds of demand management initiatives that ITS applications provide, and the levels of contribution that they might make.

In preparing this document an important objective has been to provide greater evidence and information on the benefits of ITS initiatives, in order to increase the likelihood that they will make a realistic contribution.

1.3 Steering Group

This work has been carried out under the direction of a five person steering group, set up through ITS New Zealand. This group consisted of:

- Murray Russell - Transit New Zealand
- Lyndon Hammond - Land Transport New Zealand
- Don Houghton - Auckland Regional Council
- Sandy Fong - Land Transport New Zealand
- Roger Dunn - University of Auckland

2. Principles and Objectives

The New Zealand Transport Strategy (NZTS) released in December 2002 sets out the Government's overall vision for Transport.

"By 2010 New Zealand will have an affordable, integrated, safe and sustainable transport system"

This vision is underpinned by four principles and five objectives relating to:

- Principles
  - Sustainability
  - Integration
  - Safety
  - Responsiveness

- Objectives
  - Economic Development
  - Safety and Personal Security
  - Access and Mobility
  - Public Health
  - Environmental Sustainability

In support of the NZTS principles and objectives the Land Transport Management Act 2003 (LTMA) states that Transfund must be satisfied that any program it approves must contribute to the following:

a) Assisting economic development
b) Assisting safety and personal security
c) Improving access and mobility
d) Protecting and promoting public health
e) Ensuring environmental sustainability

A more detailed definition of these principles and objectives is set out below.

The purpose of this document is to assist in defining how ITS can be applied to help achieve the NZTS and LTMA objectives.

2.1 LTMA Principles

2.1.1 Principle 1 : Sustainability

Sustainability in this context is defined as:

A focus on improving the transport system in ways that enhance economic, social and environmental well-being, and that promote resilience and flexibility. Also to take account of the needs of future generations, and be guided by medium and long-term costs and benefits

ITS can play a major role in promoting and ensuring the sustainability of transport infrastructure. Through a range of means ITS can facilitate the more efficient use of existing infrastructure, regulate and control demand, encourage and facilitate the use of alternative modes, and manage congestion and its effects.

Key demand management tools such as electronic tolling, traveller information and access control are all ITS based, and are at the core of the demand management solutions that support transport infrastructure sustainability. Further, through the more efficient management of traffic on existing roads, ITS facilities can delay or negate the need for new infrastructure adding to the sustainability of all transport infrastructure.

2.1.2 Principle 2 : Integration

Integration in this context is defined as:

A focus on an efficient and integrated mix of transport modes; cooperation and collaboration between stakeholders, and ensuring the efficient use of existing and new public investment.

ITS can play a major role in promoting and facilitating an integrated transport system, particularly in congested urban areas such as Auckland. Through a range of means ITS can facilitate more efficient interoperability between modes, coordination across and between modes, and encourage and facilitate the use of public transport and other alternatives.

ITS tools such as integrated ticketing, electronic charging systems, traveller information services, integrated traffic management and bus priority all support transport systems integration by facilitating a coordinated transport system with seamless mode interfaces, allowing for optimisation of the transport system across all modes.

The development of multi modal ITS systems architecture, consistent standards, operating procedures and protocols are fundamental elements of good ITS Strategy and have a major role to play in ensuring system interoperability.

2.1.3 Principle 3 : Safety

Safety in this context is defined as:

Promoting high standards of health, safety and personal security for all people, including users, workers, and operators. Also, ensuring a robust health and safety framework, complemented by an emphasis on individual and business responsibility.

ITS can play a major role in promoting safe behaviours through a mixture of education and enforcement techniques. In the form of hazard detection and warning systems, variable speed limits, speed enforcement, access control and tunnel safety systems, ITS already contribute to improving the safety of the state highway network in New Zealand. These types of systems will continue to expand in both coverage and capability. Following overseas trends, they will begin to integrate with more advanced vehicle-based devices such as collision avoidance, automated speed limiters, driver monitoring systems and other road/vehicle interaction systems.

2.1.4 Principle 4 : Responsiveness

Responsiveness in this context is defined as:

Recognising the diverse needs of urban and rural communities (those who use transport and those affected by it) and promoting partnership between the Crown and Maori; between central and local government; between government and citizens and communities, including business.

ITS in its various forms has the potential to provide a wide range of innovative solutions to specific regional issues and problems. To facilitate effective use of these tools good ITS strategy is needed to focus on the specific requirements and issues of individual regions, and provide a structure within which the diverse needs of urban and rural communities can be effectively targeted.

ITS strategy also: (a) provides a structure within which appropriate responses to those needs can be identified and pursued; (b) identifies issues that are similar across other regions; and (c) develops coordinated solutions that provide benefits from economies of scale. The development of open and flexible architectures and standards will also lead to improved freedom to respond to specific regional needs within a reliable and cost-effective support structure.

2.2 Objectives

2.2.1 Objective 1: Economic Development

This objective is targeted at:

Delivering a coherent and efficient transport system that contributes to quality of life and supports economic development goals, both nationally and within regions; leading to improved flows of people, goods and services within and between urban and rural areas, and between New Zealand and overseas.

In the long term economic development and transport growth will be directly related, in order to facilitate sustainable transport systems; achieved through the use of advanced technologies, transport systems, integrated land use planning, and energy efficiency.

This approach will minimise the extent of transport growth necessary to achieve economic development goals, and minimise transport-related energy consumption.

Social, economic and environmental costs and benefits of transport will be incorporated into transport decision-making, and the true cost of different transport modes will be fair and transparent to users.

The main issue that ITS can address in this area is congestion relief, meaning both regularly occurring peak period traffic congestion, and congestion resulting from unplanned incidents such as accidents and breakdowns. Congestion is increasing in most urban areas of New Zealand causing cumulative delays that result in significant economic, social and environmental impacts.

2.2.1.1 Demand management

A major application of ITS in managing traffic on urban networks is demand management. ITS can be used to manage traffic demand through a range of active and passive means including:

- Electronically Charging vehicles entering congested areas; and potentially varying rates dependent on purpose and time of day.
- Controlling access to the motorway network through on-ramp controls.
- Encouraging the use of alternative routes by diverting traffic away from congested areas and advising on alternative routes.
- Informing travellers at all stages of their journey, providing information to homes, workplaces and travellers already in their vehicles in order to improve their ability to make alternative transport choices.

This is a major focus for Land Transport, particularly in Auckland, and supported by the recent LTMA legislation, the National Tolls Administration Project (NTAP) is being developed to support future deployment of these types of systems.

2.2.1.2 Tidal flow and dynamic lane control

In conjunction with other equipment, ITS can be used to increase the capacity of urban motorways at peak times by changing the direction and designation of some lanes.

2.2.1.3 Incident management

ITS in the form of cameras, emergency telephones and other specialist detection equipment on urban motorways, can enable operators in the traffic management centre to quickly detect any incident, providing a swift and appropriate response, and so a more rapid return to full capacity conditions. ITS also assists in diverting traffic away from the site of an incident, warning other drivers, and suggesting alternative routes. At the same time, traffic signals are coordinated to increase the capacity of the alternative routes to deal with the extra vehicles.

2.2.2 Objective 2: Safety and Personal Security

This objective is targeted at:

Addressing safety and personal security concerns in order to improve quality of life and to promote modes such as walking, cycling and public transport. Also, strengthening current commitments to road safety education and enforcement for all road users.

2.2.2.1 Safety education and enforcement

Safe behaviours can be encouraged through a mixture of education and enforcement techniques.

- The techniques include variable speed limits or advisory speeds using smart electronic speed signs where congestion, incidents or adverse road conditions require reduced speed on a regular basis.
- Smart signs can also be targeted at specific types of vehicle, for example heavy trucks approaching a curve too quickly.
- Electronic signs installed for other purposes can be used to issue safety messages.

- ITS can be used in rural and alpine areas for hazard warning, in particular snow and ice, avalanche danger, rock falls, wind or flooding.
- ITS Tunnel Safety systems monitor internal conditions and trigger responses such as fire sprinkler systems or increased ventilation.
- Personal security on the state highway network is being increasingly enhanced as more cameras and emergency roadside phones are installed.

2.2.3 Objective 3: Access and Mobility

This objective is focused on:

Improving access and mobility for all New Zealanders; through education, investment and infrastructure to improve local networks, communication and travel within and between regions. Affordable and reliable transport services will make a key contribution to better access and mobility through the promotion of the optimal use of different modes of transport in different settings through a range of measures including pricing and funding priorities.

2.2.3.1 Route security

Traffic congestion, either in the form of recurring peak delays or unplanned incidents and emergency works, has a major impact on access and mobility for those using urban streets and highways for local or longer distance travel. Outside these areas, snow, ice, flooding, rock falls, slips and high winds are the main causes of route closures, and are particularly common in areas such as the North Island Desert Road and alpine passes.

2.2.3.2 Congestion

Traffic congestion, either in the form of recurring peak delays or unplanned incidents and emergency works, has a major impact on access and mobility. There is a range of ITS measures that can assist with improving both the level and impact of congestion in urban areas.

2.2.3.3 Advance warning

For other areas ITS, in the form of remote weather stations, thermal mapping and other forms of condition monitoring systems, can provide early warnings of adverse conditions through VMS and other media. Timely mitigation measures can be implemented such as laying grit on ice-affected areas, or early advice to travellers of a closure so that they can divert or retime their journey.

2.2.3.4 Traveller experience

The ITS facilities that provide information via cell phone, email and web on incidents and conditions can also be used to indicate alternative more scenic routes, local attractions, and rest stops. These will enhance the travellers' experience of the highway system and reduce driver fatigue.

2.2.4 Objective 4: Public Health

This objective is focused on:

Contributing to healthy communities and human interaction. Health outcomes will be improved through regulation, education, encouragement and investment. Walking and cycling for short trips will be promoted and reduced dependence on private vehicles for mobility is encouraged. Encouraging modal shifts that enhance air and water quality and *reduce exposure to transport noise or other aspects of transport systems that can impinge on community and personal health.*

By providing reliable information on road conditions and alternatives, ITS can assist in promoting the use of alternatives such as walking, cycling and public transport. Examples of applications in this area include Closed Circuit Television (CCTV) security monitoring of cycle and walkways, specifically designed traffic signals at cycleway crossings and VMS on congested routes used to display current travel times on public transport and cycleways. These are aimed at promoting the use of alternatives.

2.2.5 Objective 5: Environmental Sustainability

This objective is focused on:
Making transport more energy efficient and environmentally sustainable. Negative local and global environmental effects of transport will be reduced through education, regulation, technology and investment. Improving mobility for people, goods and services within New Zealand and between New Zealand and overseas through creative responses that meet people's needs with minimal adverse effects on the environment. Improving the efficiency of existing road and rail networks, promoting alternatives to roads, and reducing traffic growth will be key elements in minimising the adverse effects of land transport.

ITS can assist environmental sustainability objectives by encouraging the use of alternative, less impacting transport modes. As described above, ITS can also be used to better manage bus and high occupancy vehicle lanes, provide priority for buses at signal controlled intersections, track public transport vehicles and so improve the delivery of accurate schedule information to bus passengers.

A major focus for ITS is the management of congestion, and there are a range of applications that target this issue. The effective management of congestion has a positive effect in the environmental sustainability field from a number of areas.

- The more efficient management of traffic on existing roads can delay or negate the need for new infrastructure.
- Reduced congestion leads to reduced vehicle emissions, as vehicles run more efficiently.

2.3 Additional measures

In addition to the principles and objectives of the NZTS and LMTA, two further measures have been included in this assessment in order to provide a more complete picture of ITS applications, and assist users in identifying cost and technology risks.

2.3.1 Affordability and Cost Effectiveness

This measure is focussed on the general balance of benefits-to-costs likely to be achieved by each facility, the level of operating and maintenance costs, and the level of contribution from users.

An issue with many ITS applications is the adequate consideration of full life costs, and the understanding of the level of commitment required to operate and maintain facilities. The ratings under this category provide a basic assessment of these issues relative to each system.

2.3.2 Implementation Risk

This measure is focussed on the risks associated with ITS applications in areas such as technical capacity, interoperability, cost certainty, public acceptance and implementation constraints. The ratings under this category provide a basic assessment of these issues relative to each system.

3. ITS Applications and Conditions

3.1 New Zealand conditions

A key element in achieving maximum benefit from ITS solutions is the ability to effectively define the problem in terms of specific needs, and design an appropriate solution to meet those needs. The range of ITS applications is wide and the benefits of particular systems can vary significantly depending on the nature of the transport problem they address. For example, the level of traffic, frequency of incidents and availability of alternatives can have a major effect on the benefits that can be achieved from an urban Motorway Management System (MMS).

It is therefore important to develop some understanding of the particular transport challenges and environments that are relevant in New Zealand, before considering which ITS solutions may deliver benefit, and how best to categorise these.

Table 3.1.1 sets out a series of categories of roads and other transport situations, together with the main issues currently relevant to New Zealand, taking particular direction from the objectives set out by the NZTS and LTMA summarised above.

Drawn from the direction of the LTMA and consideration of New Zealand conditions and issues, the following nine target areas have been identified as of particular relevance in the application of ITS in New Zealand. This list will provide direction through the assessment of systems and subsequent rating of potential benefits against New Zealand conditions.

1. Congestion Relief
2. Demand Management
3. Incident Management
4. Compliance
5. Safety
6. Route Security
7. Quality and Efficiency
8. Travel Time Reliability
9. Environmental Mitigation

Table 3.1.1 Issues relevant to transport situations.

Situation / Condition	Description	Example	Issues relevant in these situations								
			Congestion Relief	Demand Management	Incident Management	Regulatory Compliance	Safety	Route Security	Quality & Efficiency	Travel Time Reliability	Environment
Congested Motorway	Regular peak period delays. Small incidents lead to major delays.	SH1 Southern Motorway Auckland	✓	✓	✓	✓	✓	✓	✓	✓	✓
Congested Urban Arterials	Regular peak period delays even without incidents. Small incidents lead to major delays.	SH1 Wellington CBD to Basin Reserve	✓	✓	✓		✓		✓	✓	✓
Un-congested Motorway	Free flowing during peak period. Congestion occurs mainly as a result of incidents.	SH1 Johnsonville to Porirua Motorway			✓		✓	✓	✓	✓	✓
High-volume Rural Highway	>10,000 Vehicles per day	SH1 Levin to Otaki			✓		✓	✓	✓	✓	✓
Low-volume Rural Strategic Highway	<10,000 Vehicles per day	SH2 Masterton to Woodville			✓		✓	✓	✓	✓	✓
Low-volume non-strategic route	<2,000 Vehicles per day	SH53 Featherston to Martinborough			✓		✓		✓	✓	✓
Commuter Rail	Regular Services	Wellington Transmetro							✓	✓	
Dedicated Bus Lanes	Regular Services	Northern Busway (Auckland)	✓						✓	✓	
Alternatives	Provision for, and encouraging, walking, cycling.						✓		✓		✓

3.2 Potential ITS solutions

There are a wide range of ITS applications in use, targeted at improving the transport environment. The following table sets out a structured list of potential ITS facilities and services drawn from New Zealand and international experience that may assist in delivering benefit in the above areas in the New Zealand environment.

The following list of systems and facilities provides the basis for a matrix of ITS solutions, assessing the contribution of each facility against NZTS and LTMA objectives.

Table 3.2.1 ITS applications.

1	**MOTORWAY MANAGEMENT SYSTEMS**
1.1	Traffic Monitoring and Surveillance
1.2	Incident Detection Systems
1.3	Variable Message Signs
1.4	Mobile Variable Message Signs
1.5	Speed Enforcement
1.6	Ramp Metering
1.7	Vehicle Access (Ramp) Control Systems
1.8	Lane Control Systems
1.9	Variable Speed Limits
1.10	Special Event Transportation Management
1.11	Electronic Safety Screening
1.12	Electronic Weight Screening
2	**ARTERIAL MANAGEMENT SYSTEMS**
2.1	Traffic Monitoring and Surveillance
2.2	Adaptive Signal Control
2.3	Incident Detection Systems
2.4	Variable Message Signs
2.5	Parking Management
2.6	Traffic Signal Enforcement – Red Light Cameras
3	**INTEGRATED URBAN TRAFFIC CONTROL SYSTEMS**
3.1	Parking Management and Availability
3.2	Environmental Monitoring and Forecasting
3.3	Real-Time Public Transport Passenger Information Systems
3.4	Access Control Systems
3.5	Integrated Smart Cards / Multi-Use Payment Systems

Table 3.2.1 ITS applications (continued).

4 BUS MANAGEMENT SYSTEMS	
4.1	Priority Signal Pre-emption & Advance Stop Line Intersection
4.2	On-Vehicle & Facility Surveillance
4.3	Dynamic Routing/Scheduling
5 RURAL HIGHWAY SYSTEMS	
5.1	Speed Enforcement
5.2	Intersection Enforcement
5.3	Incident Detection
5.4	VMS & Information Dissemination
5.5	Electronic Safety Screening
5.6	Electronic Weight Screening
6 EMERGENCY MANAGEMENT SYSTEMS	
6.1	Mobilisation, Response & Recovery / Hazardous Materials Management / Emergency Medical Services
7 ADVANCED TRAVELLER INFORMATION SYSTEMS	
7.1	Detection, Information Collection & Processing
7.2	Ride Share Information
7.3	En-Route & Pre-Trip Information
7.4	In-Vehicle & Handheld Devices
8 INFORMATION MANAGEMENT	
8.1	Data Archiving / Interoperability / Analysis
9 CRASH PREVENTION & SAFETY	
9.1	Road Geometry Warning Systems: Ramp Rollover / Curve Speed / Downhill Speed
9.2	Highway Rail Crossing Systems
9.3	Intersection Collision Warning
10 ROADWAY OPERATIONS & MAINTENANCE	
10.1	Asset Management
10.2	Work Zone Management
11 ROAD WEATHER CONDITIIONS MANAGEMENT	
11.1	Road Weather Conditions Management

Table 3.2.1 ITS applications (continued).

12 ELECTRONIC ROAD USER CHARGING	
12.1	Wide Area RUC
12.2	Project Specific E-Toll Collection Systems
12.3	Electronic Road / Congestion Pricing
13 FLEET MANAGEMENT SYSTEMS	
13.1	Fleet Management Systems
14 TUNNEL MANAGEMENT SYSTEMS	
14.1	Tunnel Management Systems

4. Contribution Matrix

The following matrix sets out NZTS and LTMA objectives and scales for measuring the contribution of each application to the objectives (primarily focussing on demand management, optimising existing networks and sustaining benefits of infrastructure investments, but also considering the environmental, public health and access and mobility objectives).

Each application has been assessed, in terms of the types of benefits produced, in relation to the NZTS and LTMA objectives, primarily concentrating on demand management, optimising existing networks and sustaining benefits of infrastructure investments.

The assessment approach has been based on considering each benefit area in the context of the scale of overall benefits. In this regard there are many cases where, although some benefit may be achieved in a particular area, these are considered low in terms of scale when compared to those of other systems and/or benefit areas. For example, while speed cameras may deliver marginal benefits in terms of environmental effects, the safety related benefits are significantly higher.

The matrix considers each of the 14 ITS applications listed in Table 3.2.1 (together with each of the application's systems and facilities) and then rates them with respect to their contribution to the individual elements of each of the following objectives/issues:

A	Economic Development
B	Safety and Personal Security
C	Access and Mobility
D	Public Health
E	Sustainability
F	Energy Efficiency
G	Integration
H	Responsiveness
I	Affordability and Cost Effectiveness
J	Implementation Risk

The scale of each element's contribution is graded as follows:

Individual Elements	Overall Contribution to Objective/Issue
✓ = Positive Contribution	H = High
✗ = No Significant Contribution	M = Medium
➲ = Partial Contribution	L = Low

Contribution Matrix – Section 1.

Contributes To		How Contribution Assessed	MOTORWAY MANAGEMENT SYSTEMS										
			Traffic Surveillance	Incident Detection	Variable Message Signs	Speed Enforcement	Ramp Metering	Ramp Control: Priority	Lane Control	Variable Speed Limits	Special Event Transportation Management	Electronic Safety Screening	Electronic Weight Screening
A. Economic Development			*H*	*H*	*H*	*L*	*H*	*L*	*L*	*M*	*M*	*L*	*L*
A1	Traffic Congestion	*Reduced +* *Increased -*	✓	✓	✓	✗	✓	✗	✗	✓	✓	✗	✗
A2	Traffic/ Transport Demand	*Higher ability to manage +* *Lower ability to manage -*	➲	➲	✓	✗	✓	✗	✗	✓	✓	✗	✗
A3	Travel time on key routes	*Reduced +* *Increased -*	✓	✓	✓	✗	✓	➲	➲	➲	✓	✗	✗
A4	Transportation Costs (travel time, VOC)	*Reduced +* *Increased -*	✓	✓	✓	✗	✓	✗	✗	✓	✓	✗	✗
A5	Transport users face the true costs of use	*Higher true costs of use +* *Lower indirect costs of use -*	✗	✗	✗	✗	✗	➲	✗	✗	✗	➲	➲
A6	Travel time for car commuters to key employment centres	*Short travel time +* *Long travel time -*	✓	✓	✓	✗	✓	✗	✗	➲	✓	✗	✗
A7	Maintain strategic route security / availability / information	*Higher availability & information +* *Lower availability & information -*	✓	✓	✓	➲	✓	✗	✗	➲	✓	➲	➲
A8	Quality & efficiency of transport	*High level +* *Low level -*	✓	✓	✓	➲	✓	➲	✓	✓	✓	➲	✓
A9	Freight transport and mode transfer	*Improved efficiency +* *Reduced efficiency -*	✗	✗	✗	✗	✗	✗	✗	✗	➲	✗	✓
A10	Travel time reliability	*Higher level +* *Lower level -*	✓	✓	✓	✗	✓	➲	➲	✓	✓	✗	✗
B Safety and Personal Security			*M*	*M*	*M*	*H*	*M*	*M*	*M*	*M*	*M*	*H*	*L*
B1	Number of traffic crashes	*Reducing number +* *Increasing number -*	➲	➲	➲	✓	➲	✓	✓	✓	✓	✓	➲
B2	Level of fatalities	*Reducing number +* *Increasing number -*	➲	➲	✗	✓	✗	✗	➲	➲	✗	✓	✗
B3	Level & severity of personal injury	*Lower +* *Higher -*	➲	➲	➲	✓	✗	✗	✗	✗	✗	✓	✗

Contribution Matrix – Section 1 (continued).

Contributes To		How Contribution Assessed	MOTORWAY MANAGEMENT SYSTEMS										
			Traffic Surveillance	Incident Detection	Variable Message Signs	Speed Enforcement	Ramp Metering	Ramp Control: Priority	Lane Control	Variable Speed Limits	Special Event Transportation Management	Electronic Safety Screening	Electronic Weight Screening
B Safety and Personal Security (continued)			*M*	*M*	*M*	*H*	*M*	*M*	*M*	*M*	*M*	*H*	*L*
B4	Level of conflict between vehicles / cyclists / pedestrians and other road users	*Lower +* *Higher -*	✗	✗	✗	✗	✓	✓	✓	✓	✓	✗	✗
B5	Perceived personal safety/security for non car mode trips	*Higher +* *Lower -*	✗	✗	✗	✗	✗	✓	✗	✗	✗	✗	✗
B6	Compliance (with traffic / transport regulations)	*High level +* *Low level -*	➲	➲	✗	✓	✗	➲	✗	✗	✗	✓	✓
C Access & Mobility			*H*	*H*	*H*	*L*	*H*	*M*	*L*	*M*	*M*	*M*	*L*
C1	Traffic Congestion	*Reduced +* *Increased -*	✓	✓	✓	✗	✓	✗	✗	✓	✓	✗	✗
C2	Traffic/Transport Demand	*Higher ability to manage +* *Lower ability to manage -*	➲	➲	✓	✗	✓	✗	✗	✓	✓	✗	✗
C3	Sector to sector travel times by car	*Shorter travel time +* *Longer travel time -*	✓	✓	✓	✗	✓	➲	➲	➲	✓	✗	✗
C4	Frequency and reliability of key passenger transport services	*Higher +* *Lower -*	✓	✓	➲	✗	✓	✓	✗	➲	➲	✗	✗
C5	Convenience (perceived and actual) of public transport services	*Higher +* *Lower -*	➲	➲	➲	✗	✓	✓	✗	➲	➲	✗	✗
C6	Level (%) of commuting trips by passenger transport	*Higher +* *Lower -*	➲	➲	➲	✗	✓	✓	✗	➲	➲	✗	✗
C7	Level (%) of commuting trips by Cycle	*Higher +* *Lower -*	✗	✗	✗	✗	✗	✗	✗	✗	✗	✗	✗

Contribution Matrix – Section 1 (continued).

Contributes To		How Contribution Assessed	MOTORWAY MANAGEMENT SYSTEMS										
			Traffic Surveillance	Incident Detection	Variable Message Signs	Speed Enforcement	Ramp Metering	Ramp Control: Priority	Lane Control	Variable Speed Limits	Special Event Transportation Management	Electronic Safety Screening	Electronic Weight Screening
C Access & Mobility (continued)			*H*	*H*	*H*	*L*	*H*	*M*	*L*	*M*	*M*	*M*	*L*
C8	Level (%) of commuting trips by Pedestrians	*Higher + Lower -*	✗	✗	✗	✗	✗	✗	✗	✗	✗	✗	✗
C9	Compliance (with traffic / transport regulations)	*Higher + Lower -*	➲	✗	✗	✓	✗	➲	✗	✗	✗	✓	✓
C10	Strategic route security / availability / information	*Higher availability & information + Lower availability & information -*	✓	✓	✓	➲	✓	✗	✗	➲	✓	➲	➲
C11	Quality & efficiency of transport	*Higher level + Lower level -*	✓	✓	✓	➲	✓	➲	✓	✓	✓	➲	✓
C12	Travel time reliability	*Higher level + Lower level -*	✓	✓	✓	✗	✓	➲	➲	✓	✓	✗	✗
D Public Health			*M*	*M*	*L*	*L*	*L*	*L*	*L*	*L*	*L*	*M*	*L*
D1	Traffic congestion in urban areas (impacts on local air quality)	*Lower level +Higher level -*	✓	✓	✓	✗	✓	✗	✗	✓	✓	✗	✗
D2	Vehicle noise	*Lower level +higher level -*	➲	➲	✗	✗	➲	✗	✗	➲	✓	➲	✗
D3	Numbers of short trips made by walking or cycling	*Higher level +Lower level -*	✗	✗	✗	✗	✗	✗	✗	✗	✗	✗	✗
D4	Numbers of commuting trips made by walking or cycling	*Higher level +Lower level -*	✗	✗	✗	✗	✗	✗	✗	✗	✗	✗	✗
D5	Compliance (with emissions regulations)	*Higher level + Lower level -*	✓	➲	✗	✗	✗	✗	✗	✗	✗	✓	✗
D6	Level & severity of personal injury	*Lower +Higher -*	➲	➲	➲	✓	✗	✗	✗	✗	✗	✓	✗

Contribution Matrix – Section 1 (continued).

	Contributes To	How Contribution Assessed	MOTORWAY MANAGEMENT SYSTEMS										
			Traffic Surveillance	Incident Detection	Variable Message Signs	Speed Enforcement	Ramp Metering	Ramp Control: Priority	Lane Control	Variable Speed Limits	Special Event Transportation Management	Electronic Safety Screening	Electronic Weight Screening
E Sustainability			*H*	*H*	*H*	*L*	*H*	*H*	*L*	*M*	*M*	*L*	*M*
E1	Traffic/Transport Demand	*Higher ability to manage + Lower ability to manage - -*	➲	➲	✓	✗	✓	✗	✗	✓	✓	✗	✗
E2	Level(%) of trips that are not car based	*Higher level + Lower level -*	➲	➲	➲	✗	➲	✓	✗	➲	➲	✗	✗
E3	Non road freight volumes as a percentage of total	*Higher level + Lower level -*	✗	✗	✗	✗	✗	✗	✗	✗	✗	➲	✓
E4	Growth rate of total vehicle travel	*Lower level + Higher level -*	✗	✗	➲	✗	➲	✓	✗	✗	➲	✗	✗
E5	Emission levels (particulates, nitrogen oxides, carbon monoxides, CO_2)	*Lower level + Higher level -*	➲	➲	➲	✗	✓	✓	✗	➲	➲	✗	✗
E6	Extent to which users face full cost of their road use	*Full costs of use + Low indirect costs of use -*	✗	✗	✗	✗	✗	➲	✗	✗	✗	➲	➲
E7	Levels of service on key routes	*Higher LOS (Volume/capacity ratios). + Lower LOS -*	✓	✓	✓	✗	✓	➲	➲	➲	✓	✗	✗
E8	Extent to which the benefits will be sustainable over time	*Benefits that can be sustained + Benefits that are short term or eroded -*	✓	✓	✓	✗	✓	✓	✗	➲	✓	✓	✓
F Energy Efficiency			*H*	*H*	*H*	*L*	*H*	*H*	*M*	*M*	*M*	*M*	*M*
F1	Traffic Congestion	*Reduced + Increased -*	✓	✓	✓	✗	✓	✗	✗	✓	✓	✗	✗
F2	Traffic/Transport Demand	*Higher ability to manage + Lower ability to manage -*	➲	➲	✓	✗	✓	✗	✗	✓	✓	✗	✗
F3	Efficiency of routes taken	*A high proportion of efficient routes taken + Low proportion -*	➲	➲	✓	✗	✓	✗	✗	✓	✓	✗	✗

Contribution Matrix – Section 1 (continued).

Contributes To		How Contribution Assessed	MOTORWAY MANAGEMENT SYSTEMS										
			Traffic Surveillance	Incident Detection	Variable Message Signs	Speed Enforcement	Ramp Metering	Ramp Control: Priority	Lane Control	Variable Speed Limits	Special Event Transportation Management	Electronic Safety Screening	Electronic Weight Screening
F Energy Efficiency (continued)			*H*	*H*	*H*	*L*	*H*	*H*	*M*	*M*	*M*	*M*	*M*
F4	Fuel use	*Lower level +* *Higher level -*	➲	➲	➲	✗	✓	✓	✗	➲	➲	✗	✗
F5	level of travel in congested conditions	*Lower level +* *Higher level -*	✓	✓	✓	✗	✓	✗	✗	✓	✓	✗	✗
F6	Use of energy efficient modes	*Higher level +* *Lower level -*	➲	➲	➲	✗	✓	✓	✗	➲	➲	✗	✗
F7	Quality & efficiency of transport	*Higher level +* *Lower level -*	✓	✓	✓	➲	✓	➲	✓	✓	✓	➲	✓
G Integration			*L*	*L*	*M*	*L*	*L*	*H*	*L*	*L*	*H*	*L*	*M*
G1	Provision for all modes on key transport corridors	*Higher level +* *Lower level -*	✗	✗	✗	✗	➲	✓	✗	✗	➲	✗	✗
G2	Level of priority given to passenger transport	*Higher level +* *Lower level -*	✗	✗	✗	✗	✗	✓	✗	✗	➲	✗	✗
G3	Efficiency and convenience of mode transfer points	*Higher level of efficiency +* *Lower level -*	✗	✗	✓	✗	✗	➲	✗	✗	✓	✗	✓
G4	Level of integration between road and rail	*Higher level +* *Lower level -*	✗	✗	✓	✗	✗	✗	✗	✗	✗	✗	✓
G5	Improving rural community access & conditions	*Higher level +* *Lower level -*	✗	✗	✓	✓	➲	✓	✗	✗	✓	✗	✓
H Responsiveness			*H*	*H*	*H*	*L*	*H*	*H*	*M*	*M*	*H*	*L*	*L*
H1	Responding to diverse stake holder needs (particularly rural versus urban)	*High level +* *Low level -* *(e.g. open Architecture etc?)*	✗	✗	✓	✗	➲	✓	✗	✗	➲	✓	✓

Contribution Matrix – Section 1 (continued).

Contributes To		How Contribution Assessed	MOTORWAY MANAGEMENT SYSTEMS: Traffic Surveillance	Incident Detection	Variable Message Signs	Speed Enforcement	Ramp Metering	Ramp Control: Priority	Lane Control	Variable Speed Limits	Special Event Transportation Management	Electronic Safety Screening	Electronic Weight Screening
H Responsiveness			*H*	*H*	*H*	*L*	*H*	*H*	*M*	*M*	*H*	*L*	*L*
H2	Contributions to national objectives	*"Fit" with national objectives – as set out in EECS, NZTS, Road Safety 2010, Growing an Innovative New Zealand, Live + Work + Play (MFE).*	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
H3	Maintain strategic route security / availability / information	*Higher availability & information + Lower availability & information -*	✓	✓	✓	➲	✓	✗	✗	➲	✓	➲	➲
H4	Quality & efficiency of transport	*Higher level + Lower level -*	✓	✓	✓	➲	✓	➲	✓	✓	✓	➲	✓
H5	Travel time reliability	*Higher level + Lower level -*	✓	✓	✓	✗	✓	➲	✗	✓	✓	✗	✗
I Affordability and Cost Effectiveness			*M*	*H*	*M*	*H*	*M*	*M*	*M*	*M*	*M*	*M*	*M*
I1	Relative benefit to cost ratio	*High level + Low level -*	✓	✓	✓	✓	✓	➲	➲	➲	➲	➲	➲
I2	Level of operating cost	*Low level + High level -*	➲	✓	➲	✓	➲	➲	➲	➲	➲	✓	✓
I3	Contribution direct from users	*High level + Low level -*	✗	✗	✗	✗	✗	➲	✗	✗	✗	➲	➲
J Implementation Risk			*L*	*L*	*M*	*L*	*M*	*M*	*M*	*M*	*M*	*L*	*L*
J1	Technical complexity	*Low level + High level -*	✓	✓	➲	✓	➲	➲	➲	➲	➲	✓	✓
J2	Interoperability	*Minor issues + Major issues -*	✓	✓	➲	✓	➲	➲	➲	➲	➲	✓	✓
J3	Cost certainty	*High level + Low level -*	✓	✓	➲	✓	➲	➲	➲	➲	➲	✓	✓
J4	Public acceptance	*High level + Low level -*	➲	✓	✓	➲	➲	➲	➲	➲	➲	➲	✓
J5	Implementation constraints – resource consents, legal & others	*Low level + High level -*	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓

Contribution Matrix – Section 2.

Contributes To		How Contribution Assessed	ARTERIAL MANAGEMENT SYSTEMS						INTEGRATED URBAN TRAFFIC CONTROL SYSTEMS				
			Traffic Surveillance	Adaptive Signal Control	Incident Detection	Variable Message Signs	Parking Management	Traffic Signal Enforcement	Parking Management	Environmental Monitoring & Forecasting	Real-Time Public Transport Passenger Information Systems	Access Control Systems	Integrated Smart Cards / Multi-Use Payment Systems
A. Economic Development			*H*	*H*	*H*	*H*	*H*	*L*	*H*	*L*	*M*	*M*	*M*
A1	Traffic Congestion	*Reduced + Increased -*	✓	✓	✓	✓	✓	✗	✓	➲	➲	✓	✗
A2	Traffic/ Transport Demand	*Higher ability to manage + Lower ability to manage -*	➲	✓	➲	✓	✓	✗	✓	➲	➲	✓	➲
A3	Travel time on key routes	*Reduced + Increased -*	✓	✓	✓	✓	✓	✗	✓	✗	✗	✗	➲
A4	Transportation Costs (travel time, VOC)	*Reduced + Increased -*	✓	✓	✓	✓	✓	✗	✓	➲	✗	✗	✗
A5	Transport users face the true costs of use	*Higher true costs of use + Lower indirect costs of use -*	✗	✗	✗	✗	➲	✗	➲	➲	✗	➲	➲
A6	Travel time for car commuters to key employment centres	*Short travel time + Long travel time -*	✓	✓	✓	✓	✓	✗	✓	✗	✗	➲	✗
A7	Maintain strategic route security / availability / information	*Higher availability & information + Lower availability & information-*	✓	✓	✓	✓	✗	✗	✗	✗	✗	➲	✗
A8	Quality & efficiency of transport	*High level + Low level -*	✓	✓	✓	✓	✓	➲	✓	➲	✓	➲	✓
A9	Freight transport and mode transfer	*Improved efficiency + Reduced efficiency -*	✗	➲	✗	✗	✗	✗	✗	✗	✗	➲	➲
A10	Travel time reliability	*Higher level + Lower level -*	✓	✓	✓	✓	✓	✗	✓	✗	✓	✓	✗
B Safety and Personal Security			*M*	*M*	*M*	*L*	*L*	*H*	*L*	*L*	*L*	*M*	*L*
B1	Number of traffic crashes	*Reducing number + Increasing number -*	➲	➲	➲	➲	✗	✓	➲	✗	✗	✓	✗
B2	Level of fatalities	*Reducing number + Increasing number -*	➲	✗	➲	✗	✗	✓	✗	➲	✗	✗	✗
B3	Level & severity of personal injury	*Lower + Higher -*	➲	✗	➲	➲	✗	✓	✗	➲	✗	✗	✗

Contribution Matrix – Section 2 (continued).

Contributes To		How Contribution Assessed	ARTERIAL MANAGEMENT SYSTEMS						INTEGRATED URBAN TRAFFIC CONTROL SYSTEMS				
			Traffic Surveillance	Adaptive Signal Control	Incident Detection	Variable Message Signs	Parking Management	Traffic Signal Enforcement	Parking Management	Environmental Monitoring & Forecasting	Real-Time Public Transport Passenger Information Systems	Access Control Systems	Integrated Smart Cards / Multi-Use Payment Systems
B Safety and Personal Security (continued)			*M*	*M*	*M*	*L*	*L*	*H*	*L*	*L*	*L*	*M*	*L*
B4	Level of conflict between vehicles / cyclists / pedestrians and other road users	*Lower +* *Higher -*	✗	✓	✗	✗	✗	✓	➲	✗	✗	✓	✗
B5	Perceived personal safety/security for non car mode trips	*Higher +* *Lower -*	✗	✗	✗	✗	✗	➲	✗	✗	✓	✗	✗
B6	Compliance (with traffic / transport regulations)	*High level +* *Low level -*	➲	✗	✗	✗	✓	✓	✓	➲	✗	✓	➲
C Access & Mobility			*H*	*H*	*H*	*H*	*H*	*L*	*H*	*L*	*H*	*M*	*M*
C1	Traffic Congestion	*Reduced +* *Increased -*	✓	✓	✓	✓	✓	✗	✓	➲	➲	✓	➲
C2	Traffic/Transport Demand	*Higher ability to manage +* *Lower ability to manage -*	➲	✓	➲	✓	✓	✗	✓	➲	➲	✓	➲
C3	Sector to sector travel times by car	*Shorter travel time +* *Longer travel time -*	✓	✓	✓	➲	✓	✗	✓	✗	✗	➲	✗
C4	Frequency and reliability of key passenger transport services	*Higher +* *Lower -*	✓	✓	✓	✓	✓	➲	➲	✗	✓	✓	✓
C5	Convenience (perceived and actual) of public transport services	*Higher +* *Lower -*	✓	✓	✓	✓	✓	➲	➲	✗	✓	✓	✓
C6	Level (%) of commuting trips by passenger transport	*Higher +* *Lower -*	➲	✓	✓	✓	✓	➲	➲	✗	✓	✓	✓
C7	Level (%) of commuting trips by cycle	*Higher +* *Lower -*	✗	➲	✗	✗	✓	➲	➲	➲	✗	➲	➲

Contribution Matrix – Section 2 (continued).

Contributes To		How Contribution Assessed	ARTERIAL MANAGEMENT SYSTEMS						INTEGRATED URBAN TRAFFIC CONTROL SYSTEMS				
			Traffic Surveillance	Adaptive Signal Control	Incident Detection	Variable Message Signs	Parking Management	Traffic Signal Enforcement	Parking Management	Environmental Monitoring & Forecasting	Real-Time Public Transport Passenger Information Systems	Access Control Systems	Integrated Smart Cards / Multi-Use Payment Systems
C Access & Mobility (continued)			*H*	*H*	*H*	*H*	*H*	*L*	*H*	*L*	*H*	*M*	*M*
C8	Level (%) of commuting trips by Pedestrians	*Higher + Lower -*	✗	✓	✗	✗	✓	✓	✓	✓	➲	➲	✗
C9	Compliance (with traffic / transport regulations)	*Higher + Lower -*	➲	✗	✗	✗	✓	✓	✓	➲	✗	✓	✗
C10	Strategic route security / availability / information	*Higher availability & information + Lower availability & information -*	✓	✓	✓	✓	✗	✗	✗	✗	✗	➲	✗
C11	Quality & efficiency of transport	*Higher level + Lower level -*	✓	✓	➲	✓	✓	➲	✓	➲	✓	➲	✓
C12	Travel time reliability	*Higher level + Lower level -*	✓	✓	✓	✓	✓	✗	✓	✗	✓	✓	✗
D Public Health			*M*	*H*	*M*	*L*	*M*	*M*	*M*	*H*	*M*	*M*	*L*
D1	Traffic congestion in urban areas (impacts on local air quality)	*Lower level + Higher level -*	✓	✓	✓	✓	✓	✗	✓	➲	➲	✓	✗
D2	Vehicle noise	*Lower level + Higher level -*	➲	✓	➲	✗	➲	✗	➲	➲	✗	✓	✗
D3	Numbers of short trips made by walking or cycling	*Higher level + Lower level -*	✗	✓	✗	✗	✓	✓	✓	✓	➲	➲	➲
D4	Numbers of commuting trips made by walking or cycling	*Higher level + Lower level -*	✗	✓	✗	✗	✓	✓	✓	✓	➲	➲	➲
D5	Compliance (with emissions regulations)	*Higher level + Lower level -*	✓	✗	➲	✗	✗	✗	✗	✓	✗	✓	✗
D6	Level & severity of personal injury	*Lower + Higher -*	➲	✗	➲	➲	✗	✓	✗	➲	✗	✗	✗

Contribution Matrix – Section 2 (continued).

Contributes To		How Contribution Assessed	ARTERIAL MANAGEMENT SYSTEMS: Traffic Surveillance	Adaptive Signal Control	Incident Detection	Variable Message Signs	Parking Management	Traffic Signal Enforcement	INTEGRATED URBAN TRAFFIC CONTROL SYSTEMS: Parking Management	Environmental Monitoring & Forecasting	Real-Time Public Transport Passenger Information Systems	Access Control Systems	Integrated Smart Cards / Multi-Use Payment Systems
E Sustainability			*H*	*H*	*H*	*H*	*H*	*L*	*H*	*H*	*H*	*H*	*M*
E1	Traffic/Transport Demand	*Higher ability to manage + Lower ability to manage -*	➲	✓	➲	✓	✓	✗	✓	➲	➲	✓	➲
E2	Level(%) of trips that are not car based	*Higher level + Lower level -*	➲	✓	✓	✓	✓	➲	➲	✗	✓	✓	✓
E3	Non road freight volumes as a percentage of total	*Higher level + Lower level -*	✗	✗	✗	✗	✗	✗	✗	➲	✗	✓	✗
E4	Growth rate of total vehicle travel	*Lower level + Higher level -*	✗	✗	✗	➲	✓	✗	✓	➲	✓	✓	✓
E5	Emission levels (particulates, nitrogen oxides, carbon monoxides, CO_2)	*Lower level + Higher level -*	➲	✓	✓	✓	✓	➲	➲	✗	✓	✓	✓
E6	Extent to which users face full cost of their road use	*Full costs of use + Low indirect costs of use -*	✗	✗	✗	✗	➲	✗	➲	➲	✗	➲	➲
E7	Levels of service on key routes	*Higher LOS (Volume/capacity ratios). + Lower LOS -*	✓	✓	✓	✓	✓	✗	✓	✗	✗	✗	➲
E8	Extent to which the benefits will be sustainable over time	*Benefits that can be sustained + Benefits that are short term or eroded -*	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
F Energy Efficiency			*H*	*H*	*H*	*H*	*H*	*L*	*H*	*H*	*H*	*H*	*L*
F1	Traffic Congestion	*Reduced + Increased -*	✓	✓	✓	✓	✓	✗	✓	➲	➲	✓	✗
F2	Traffic/Transport Demand	*Higher ability to manage + Lower ability to manage -*	➲	✓	➲	✓	✓	✗	✓	➲	➲	✓	➲
F3	Efficiency of routes taken	*A high proportion of efficient routes taken + Low proportion -*	➲	✓	➲	✓	✓	✗	✓	➲	➲	✓	➲

Contribution Matrix – Section 2 (continued).

Contributes To		How Contribution Assessed	ARTERIAL MANAGEMENT SYSTEMS						INTEGRATED URBAN TRAFFIC CONTROL SYSTEMS				
			Traffic Surveillance	Adaptive Signal Control	Incident Detection	Variable Message Signs	Parking Management	Traffic Signal Enforcement	Parking Management	Environmental Monitoring & Forecasting	Real-Time Public Transport Passenger Information Systems	Access Control Systems	Integrated Smart Cards / Multi-Use Payment Systems
F Energy Efficiency (continued)			*H*	*H*	*H*	*H*	*H*	*L*	*H*	*H*	*H*	*H*	*L*
F4	Fuel use	*Lower level + Higher level -*	➲	✓	✓	✓	✓	➲	➲	✗	✓	✓	✓
F5	level of travel in congested conditions	*Lower level + Higher level -*	✓	✓	✓	✓	✓	✗	✓	➲	➲	✓	✗
F6	Use of energy efficient modes	*Higher level + Lower level -*	➲	✓	✓	✓	✓	➲	➲	✗	✓	✓	✓
F7	Quality & efficiency of transport	*Higher level + Lower level -*	✓	✓	✓	✓	✓	➲	✓	➲	✓	➲	✓
G Integration			*L*	*M*	*L*	*M*	*H*	*L*	*H*	*L*	*H*	*H*	*H*
G1	Provision for all modes on key transport corridors	*Higher level + Lower level -*	✗	✓	✗	✗	✓	✓	✓	✗	➲	✓	✓
G2	Level of priority given to passenger transport	*Higher level + Lower level -*	✗	✗	✗	✗	✓	➲	➲	✗	✓	✓	✗
G3	Efficiency and convenience of mode transfer points	*Higher level of efficiency + Lower level -*	✗	✓	✗	✓	✓	✗	✓	✗	✓	✓	✓
G4	Level of integration between road and rail	*Higher level + Lower level -*	✗	✗	✗	✓	✗	✗	✗	✗	✓	✗	✓
G5	Improving rural community access & conditions	*Higher level + Lower level -*	✗	✗	✗	✓	✗	✗	✗	✗	✓	✗	✓
H Responsiveness			*H*	*H*	*H*	*H*	*H*	*M*	*H*	*H*	*H*	*H*	*H*
H1	Responding to diverse stake holder needs (particularly rural versus urban)	*High level + Low level - (e.g. open Architecture etc?)*	✗	✓	✗	✓	✓	✓	✓	➲	✓	➲	✓

Contribution Matrix – Section 2 (continued).

Contributes To		How Contribution Assessed	ARTERIAL MANAGEMENT SYSTEMS						INTEGRATED URBAN TRAFFIC CONTROL SYSTEMS				
			Traffic Surveillance	Adaptive Signal Control	Incident Detection	Variable Message Signs	Parking Management	Traffic Signal Enforcement	Parking Management	Environmental Monitoring & Forecasting	Real-Time Public Transport Passenger Information Systems	Access Control Systems	Integrated Smart Cards / Multi-Use Payment Systems
H Responsiveness (continued)			*H*	*H*	*H*	*H*	*H*	*M*	*H*	*H*	*H*	*H*	*H*
H2	Contributions to national objectives	*"Fit" with national objectives – as set out in EECS, NZTS, Road Safety 2010, Growing an Innovative New Zealand, Live + Work + Play (MFE).*	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
H3	Maintain strategic route security / availability / information	*Higher availability & information + Lower availability & information -*	✓	✓	✓	✓	✗	✗	✗	✗	✗	➲	✗
H4	Quality & efficiency of transport	*Higher level + Lower level -*	✓	✓	✓	✓	✓	➲	✓	➲	✓	➲	✓
H5	Travel time reliability	*Higher level + Lower level -*	✓	✓	✓	✓	✓	✗	✓	✗	✓	✓	✗
I Affordability and Cost Effectiveness			*H*	*H*	*H*	*M*	*H*	*H*	*H*	*M*	*M*	*M*	*M*
I1	Relative benefit to cost ratio	*High level + Low level -*	✓	✓	➲	➲	✓	✓	✓	➲	✓	➲	➲
I2	Level of operating cost	*Low level + High level -*	➲	➲	✓	➲	➲	✓	✓	✓	➲	➲	✓
I3	Contribution direct from users	*High level + Low level -*	✗	✗	✗	✗	➲	✗	➲	➲	✗	➲	➲
J Implementation Risk			*L*	*M*	*L*	*M*	*M*	*L*	*M*	*L*	*M*	*M*	*M*
J1	Technical complexity	*Low level + High level -*	✓	➲	✓	➲	➲	✓	➲	✓	➲	➲	➲
J2	Interoperability	*Minor issues + Major issues -*	✓	➲	✓	➲	➲	✓	➲	✓	➲	➲	➲
J3	Cost certainty	*High level + Low level -*	✓	➲	✓	➲	➲	✓	➲	✓	➲	➲	➲
J4	Public acceptance	*High level + Low level -*	➲	✓	✓	✓	➲	➲	✓	✓	✓	➲	✓
J5	Implementation constraints – resource consents, legal & others	*Low level + High level -*	✓	✓	✓	✓	➲	✓	➲	✓	✓	➲	✓

Contribution Matrix – Section 3.

Contributes To		How Contribution Assessed	BUS MANAGEMENT SYSTEMS			RURAL HIGHWAY SYSTEMS					
			Priority Signal Pre-emption & Advance Stop Line Intersections	On-Vehicle Surveillance & Facility Surveillance	Dynamic Routing/Scheduling	Speed Enforcement	Intersection Enforcement	Incident Detection	Detection VMS & Information Dissemination	Electronic Safety Screening	Electronic Weight Screening
A. Economic Development			*M*	*L*	*M*	*L*	*L*	*H*	*H*	*L*	*L*
A1	Traffic Congestion	*Reduced + Increased -*	➲	✗	➲	✗	✗	✓	✓	✗	✗
A2	Traffic/ Transport Demand	*Higher ability to manage + Lower ability to manage -*	✓	✗	➲	✗	✗	✗	✓	✗	✗
A3	Travel time on key routes	*Reduced + Increased -*	✓	✗	➲	✗	✗	➲	➲	✗	✗
A4	Transportation Costs (travel time, VOC)	*Reduced + Increased -*	➲	✗	➲	✗	✗	➲	➲	✗	✗
A5	Transport users face the true costs of use	*Higher true costs of use + Lower indirect costs of use -*	✗	✗	✗	✗	✗	✗	➲	➲	➲
A6	Travel time for car commuters to key employment centres	*Short travel time + Long travel time -*	✗	✗	✗	✗	✗	✗	➲	✗	✗
A7	Maintain strategic route security / availability / information	*Higher availability & information + Lower availability & information -*	✗	✗	✗	✗	✗	✓	✓	✗	✗
A8	Quality & efficiency of transport	*High level + Low level -*	✓	✓	✓	➲	✗	✓	✓	➲	✓
A9	Freight transport and mode transfer	*Improved efficiency + Reduced efficiency -*	✗	✗	✗	✗	✗	✓	✗	✗	✓
A10	Travel time reliability	*Higher level + Lower level -*	✓	✗	✓	✗	✗	✓	✓	✗	✗
B Safety and Personal Security			*M*	*M*	*L*	*H*	*H*	*M*	*M*	*H*	*L*
B1	Number of traffic crashes	*Reducing number + Increasing number -*	✗	✗	✗	✓	✓	➲	➲	✓	➲
B2	Level of fatalities	*Reducing number + Increasing number -*	✗	✗	✗	✓	✓	➲	✗	✓	✗
B3	Level & severity of personal injury	*Lower + Higher -*	✗	✗	✗	✓	✓	➲	➲	✓	✗

Contribution Matrix – Section 3 (continued).

Contributes To		How Contribution Assessed	BUS MANAGEMENT SYSTEMS			RURAL HIGHWAY SYSTEMS					
			Priority Signal Pre-emption & Advance Stop Line Intersections	On-Vehicle Surveillance & Facility Surveillance	Dynamic Routing/Scheduling	Speed Enforcement	Intersection Enforcement	Incident Detection	Detection VMS & Information Dissemination	Electronic Safety Screening	Electronic Weight Screening
B Safety and Personal Security (continued)			*M*	*L*	*M*	*H*	*H*	*M*	*M*	*H*	*L*
B4	Level of conflict between vehicles / cyclists / pedestrians and other road users	*Lower +* *Higher -*	✓	✗	✓	✗	✓	✗	✗	✗	✗
B5	Perceived personal safety/security for non car mode trips	*Higher +* *Lower -*	✓	✓	✓	✗	✗	✗	✗	✗	✗
B6	Compliance (with traffic / transport regulations)	*High level +* *Low level -*	✗	➲	✗	✓	✓	➲	✗	✓	✓
C Access & Mobility			*M*	*L*	*M*	*L*	*L*	*H*	*H*	*L*	*L*
C1	Traffic Congestion	*Reduced +* *Increased -*	➲	✗	➲	✗	✗	✓	✓	✗	✗
C2	Traffic/Transport Demand	*Higher ability to manage +* *Lower ability to manage -*	➲	✗	➲	✗	✗	✗	✓	✗	✗
C3	Sector to sector travel times by car	*Shorter travel time +* *Longer travel time -*	✗	✗	✗	✗	✗	✗	➲	✗	✗
C4	Frequency and reliability of key passenger transport services	*Higher +* *Lower -*	✓	➲	✓	✗	✗	✓	➲	✗	✗
C5	Convenience (perceived and actual) of public transport services	*Higher +* *Lower -*	✓	✓	✓	✗	✗	✓	➲	✗	✗
C6	Level (%) of commuting trips by passenger transport	*Higher +* *Lower -*	✓	✓	✓	✗	✗	✓	➲	✗	✗
C7	Level (%) of commuting trips by cycle	*Higher +* *Lower -*	➲	✗	✗	✗	✗	✗	✗	✗	✗

Contribution Matrix – Section 3 (continued).

Contributes To		How Contribution Assessed	BUS MANAGEMENT SYSTEMS			RURAL HIGHWAY SYSTEMS					
			Priority Signal Pre-emption & Advance Stop Line Intersections	On-Vehicle Surveillance & Facility Surveillance	Dynamic Routing/Scheduling	Speed Enforcement	Intersection Enforcement	Incident Detection	Detection VMS & Information Dissemination	Electronic Safety Screening	Electronic Weight Screening
C Access & Mobility (continued)			*M*	*L*	*M*	*L*	*L*	*H*	*H*	*L*	*L*
C8	Level (%) of commuting trips by Pedestrians	*Higher +* *Lower -*	✘	✘	✘	✓	✘	✘	✘	✘	✘
C9	Compliance (with traffic / transport regulations)	*Higher +* *Lower -*	➲	➲	✘	✓	✓	➲	✘	✓	✓
C10	Strategic route security / availability / information	*Higher availability & information +* *Lower availability & information -*	✘	✘	✘	✘	✘	✓	✓	✘	✘
C11	Quality & efficiency of transport	*Higher level +* *Lower level -*	✓	✓	✓	➲	✘	✓	✓	➲	✓
C12	Travel time reliability	*Higher level +* *Lower level -*	✓	✘	✓	✘	✘	✓	✓	✘	✘
D Public Health			*L*	*L*	*L*	*M*	*L*	*L*	*L*	*M*	*L*
D1	Traffic congestion in urban areas (impacts on local air quality)	*Lower level +* *Higher level -*	➲	✘	➲	✘	✘	✓	✓	✘	✘
D2	Vehicle noise	*Lower level +* *Higher level -*	✓	✘	✘	✘	✘	✘	✘	➲	✘
D3	Numbers of short trips made by walking or cycling	*Higher level +* *Lower level -*	➲	✘	✘	✓	✘	✘	✘	✘	✘
D4	Numbers of commuting trips made by walking or cycling	*Higher level +* *Lower level -*	➲	✘	✘	✓	✘	✘	✘	✘	✘
D5	Compliance (with emissions regulations)	*Higher level +* *Lower level -*	✘	✘	✘	✘	✘	✘	✘	✓	✘
D6	Level & severity of personal injury	*Lower +* *Higher -*	✘	✘	✘	✓	✓	➲	➲	✓	✘

Contribution Matrix – Section 3 (continued).

Contributes To		How Contribution Assessed	BUS MANAGEMENT SYSTEMS			RURAL HIGHWAY SYSTEMS					
			Priority Signal Pre-emption & Advance Stop Line Intersections	On-Vehicle Surveillance & Facility Surveillance	Dynamic Routing/Scheduling	Speed Enforcement	Intersection Enforcement	Incident Detection	Detection VMS & Information Dissemination	Electronic Safety Screening	Electronic Weight Screening
E Sustainability			*H*	*M*	*H*	*L*	*L*	*M*	*H*	*M*	*M*
E1	Traffic/Transport Demand	*Higher ability to manage + Lower ability to manage -*	✓	✗	➲	✗	✗	✗	✓	✗	✗
E2	Level(%) of trips that are not car based	*Higher level + Lower level -*	✓	✓	✓	✗	✗	✓	➲	✗	✗
E3	Non road freight volumes as a percentage of total	*Higher level + Lower level -*	✗	✗	✗	✗	✗	✗	✗	➲	✓
E4	Growth rate of total vehicle travel	*Lower level + Higher level -*	✓	✓	✓	✗	✗	✗	➲	✗	✗
E5	Emission levels (particulates, nitrogen oxides, carbon monoxides, CO_2)	*Lower level + Higher level -*	✓	✓	✓	✗	✗	✓	➲	✗	✗
E6	Extent to which users face full cost of their road use	*Full costs of use + Low indirect costs of use -*	✗	✗	✗	✗	✗	✗	➲	➲	➲
E7	Levels of service on key routes	*Higher LOS (Volume/capacity ratios). + Lower LOS -*	✓	✗	➲	✗	✗	➲	➲	✗	✗
E8	Extent to which the benefits will be sustainable over time	*Benefits that can be sustained + Benefits that are short term or eroded -*	✓	✓	✓	✓	✗	✓	➲	✓	✓
F Energy Efficiency			*H*	*M*	*H*	*L*	*L*	*M*	*H*	*L*	*L*
F1	Traffic Congestion	*Reduced + Increased -*	➲	✗	➲	✗	✗	✓	✓	✗	✗
F2	Traffic/Transport Demand	*Higher ability to manage + Lower ability to manage -*	✓	✗	➲	✗	✗	✗	✓	✗	✗
F3	Efficiency of routes taken	*A high proportion of efficient routes taken + Low proportion -*	✓	✗	➲	✗	✗	✗	✓	✗	✗

Contribution Matrix – Section 3 (continued).

Contributes To		How Contribution Assessed	BUS MANAGEMENT SYSTEMS			RURAL HIGHWAY SYSTEMS					
			Priority Signal Pre-emption & Advance Stop Line Intersections	On-Vehicle Surveillance & Facility Surveillance	Dynamic Routing/Scheduling	Speed Enforcement	Intersection Enforcement	Incident Detection	Detection VMS & Information Dissemination	Electronic Safety Screening	Electronic Weight Screening
F Energy Efficiency (continued)			*H*	*M*	*H*	*L*	*L*	*M*	*H*	*L*	*L*
F4	Fuel use	*Lower level +* *Higher level -*	✓	✓	✓	✗	✗	✓	➲	✗	✗
F5	level of travel in congested conditions	*Lower level +* *Higher level -*	➲	✗	➲	✗	✗	✓	✓	✗	✗
F6	Use of energy efficient modes	*Higher level +* *Lower level -*	✓	✓	✓	✗	✗	✓	➲	✗	✗
F7	Quality & efficiency of transport	*Higher level +* *Lower level -*	✓	✓	✓	➲	✗	✓	✓	➲	✓
G Integration			*H*	*M*	*H*	*M*	*M*	*L*	*M*	*L*	*M*
G1	Provision for all modes on key transport corridors	*Higher level +* *Lower level -*	✓	✗	✗	✗	✗	✗	✗	✗	✗
G2	Level of priority given to passenger transport	*Higher level +* *Lower level -*	✓	✓	✓	✗	✗	✗	✗	✗	✗
G3	Efficiency and convenience of mode transfer points	*Higher level of efficiency +* *Lower level -*	✓	✓	✓	✗	✗	✗	✓	✗	✗
G4	Level of integration between road and rail	*Higher level +* *Lower level -*	✗	✗	✓	✗	✗	✗	✓	✗	✓
G5	Improving rural community access & conditions	*Higher level +* *Lower level -*	✗	✗	✓	✓	✓	✗	✓	✗	✓
H Responsiveness			*H*	*H*	*H*	*M*	*M*	*H*	*H*	*M*	*M*
H1	Responding to diverse stake holder needs (particularly rural versus urban)	*High level +* *Low level -* *(e.g. open Architecture etc?)*	✓	✗	✗	✗	✓	✓	✓	➲	✓

Contribution Matrix – Section 3 (continued).

Contributes To		How Contribution Assessed	BUS MANAGEMENT SYSTEMS			RURAL HIGHWAY SYSTEMS					
			Priority Signal Pre-emption & Advance Stop Line Intersections	On-Vehicle Surveillance & Facility Surveillance	Dynamic Routing/Scheduling	Speed Enforcement	Intersection Enforcement	Incident Detection	Detection VMS & Information Dissemination	Electronic Safety Screening	Electronic Weight Screening
H Responsiveness (continued)			*H*	*H*	*H*	*M*	*M*	*H*	*H*	*M*	*M*
H2	Contributions to national objectives	*"Fit" with national objectives – as set out in EECS, NZTS, Road Safety 2010, Growing an Innovative New Zealand, Live + Work + Play (MFE).*	✓	✓	✓	✓	✓	✓	✓	✓	✓
H3	Maintain strategic route security / availability / information	*Higher availability & information + Lower availability & information -*	✗	✗	✗	✗	✗	✓	✓	✗	✗
H4	Quality & efficiency of transport	*Higher level + Lower level -*	✓	✓	✓	➲	✗	✓	✓	➲	✓
H5	Travel time reliability	*Higher level + Lower level -*	✓	✗	✓	✗	✗	✓	✓	✗	✗
I Affordability and Cost Effectiveness			*H*	*M*	*M*	*H*	*M*	*M*	*M*	*M*	*M*
I1	Relative benefit to cost ratio	*High level + Low level -*	✓	➲	✓	✓	➲	✓	➲	➲	➲
I2	Level of operating cost	*Low level + High level -*	✓	➲	➲	✓	✓	➲	➲	✓	✓
I3	Contribution direct from users	*High level + Low level -*	✗	✗	✗	✗	✗	✗	➲	➲	➲
J Implementation Risk			*M*	*L*	*M*	*L*	*M*	*L*	*L*	*L*	*L*
J1	Technical complexity	*Low level + High level -*	➲	✓	➲	✓	➲	✓	✓	✓	✓
J2	Interoperability	*Minor issues + Major issues -*	➲	✓	➲	✓	➲	✓	✓	✓	✓
J3	Cost certainty	*High level + Low level -*	➲	✓	➲	✓	➲	✓	✓	✓	✓
J4	Public acceptance	*High level + Low level -*	➲	➲	✓	➲	➲	✓	✓	➲	✓
J5	Implementation constraints – resource consents, legal & others	*Low level + High level -*	✓	➲	✓	✓	➲	✓	✓	➲	✓

Contribution Matrix – Section 4.

Contributes To		How Contribution Assessed	EMERGENCY MANAGEMENT SYSTEMS	ADVANCED TRAVELLER INFORMATION SYSTEMS				INFORMATION MANAGEMENT
			Response / Recovery / Hazardous Materials / Emergency Medical Services	Detection, Information Collection & Processing	Ride Share Information	Pre-trip and En-Route Information	In-Vehicle & Hand-Held Devices	Data Archiving / Interoperability / Analysis
A. Economic Development			*M*	*H*	*H*	*H*	*M*	*M*
A1	Traffic Congestion	*Reduced +* *Increased -*	✓	✓	✓	✓	✓	✗
A2	Traffic/ Transport Demand	*Higher ability to manage +* *Lower ability to manage -*	✗	➲	✓	✓	✓	✗
A3	Travel time on key routes	*Reduced +* *Increased -*	➲	➲	✗	✓	➲	➲
A4	Transportation Costs (travel time, VOC)	*Reduced +* *Increased -*	➲	➲	➲	✓	➲	➲
A5	Transport users face the true costs of use	*Higher true costs of use +* *Lower indirect costs of use -*	✗	✗	✗	➲	✗	➲
A6	Travel time for car commuters to key employment centres	*Short travel time +* *Long travel time -*	✗	➲	✓	✓	➲	➲
A7	Maintain strategic route security / availability / information	*Higher availability & information +* *Lower availability & information -*	✓	✓	✓	✓	✓	➲
A8	Quality & efficiency of transport	*High level +* *Low level -*	✓	✓	✓	✓	✓	➲
A9	Freight transport and mode transfer	*Improved efficiency +* *Reduced efficiency -*	✓	✓	✓	✓	✓	➲
A10	Travel time reliability	*Higher level +* *Lower level -*	➲	✓	✓	✓	✓	➲
B Safety and Personal Security			*H*	*M*	*L*	*L*	*L*	*L*
B1	Number of traffic crashes	*Reducing number +* *Increasing number -*	➲	➲	➲	➲	➲	➲
B2	Level of fatalities	*Reducing number +* *Increasing number -*	✓	➲	✗	✗	✗	✗
B3	Level & severity of personal injury	*Lower +* *Higher -*	✓	➲	➲	➲	✗	➲

Contribution Matrix – Section 4 (continued).

	Contributes To	How Contribution Assessed	EMERGENCY MANAGEMENT SYSTEMS: Response / Recovery / Hazardous Materials / Emergency Medical Services	ADVANCED TRAVELLER INFORMATION SYSTEMS: Detection, Information Collection & Processing	ADVANCED TRAVELLER INFORMATION SYSTEMS: Ride Share Information	ADVANCED TRAVELLER INFORMATION SYSTEMS: Pre-trip and En-Route Information	ADVANCED TRAVELLER INFORMATION SYSTEMS: In-Vehicle & Hand-Held Devices	INFORMATION MANAGEMENT: Data Archiving / Interoperability / Analysis
B	*Safety and Personal Security (continued)*		*H*	*M*	*L*	*L*	*L*	*L*
B4	Level of conflict between vehicles / cyclists / pedestrians and other road users	*Lower +* *Higher -*	✗	✗	✗	✗	➲	✗
B5	Perceived personal safety/security for non car mode trips	*Higher +* *Lower -*	✗	✗	✗	✗	✗	✗
B6	Compliance (with traffic / transport regulations)	*High level +* *Low level -*	➲	✗	➲	✗	➲	✗
C	*Access & Mobility*		*M*	*H*	*M*	*H*	*H*	*L*
C1	Traffic Congestion	*Reduced +* *Increased -*	✓	✓	✓	✓	✓	✗
C2	Traffic/Transport Demand	*Higher ability to manage +* *Lower ability to manage -*	✗	➲	✓	✓	✓	✗
C3	Sector to sector travel times by car	*Shorter travel time +* *Longer travel time -*	✗	✓	✗	✓	➲	➲
C4	Frequency and reliability of key passenger transport services	*Higher +* *Lower -*	✗	✓	➲	➲	➲	➲
C5	Convenience (perceived and actual) of public transport services	*Higher +* *Lower -*	✗	✓	➲	➲	➲	➲
C6	Level (%) of commuting trips by passenger transport	*Higher +* *Lower -*	✗	✓	➲	➲	➲	➲
C7	Level (%) of commuting trips by cycle	*Higher +* *Lower -*	✗	✗	➲	➲	➲	➲

Contribution Matrix – Section 4 (continued).

Contributes To		How Contribution Assessed	EMERGENCY MANAGEMENT SYSTEMS	ADVANCED TRAVELLER INFORMATION SYSTEMS				INFORMATION MANAGEMENT
			Response / Recovery / Hazardous Materials / Emergency Medical Services	Detection, Information Collection & Processing	Ride Share Information	Pre-trip and En-Route Information	In-Vehicle & Hand-Held Devices	Data Archiving / Interoperability / Analysis
C Access & Mobility (continued)			*M*	*H*	*M*	*H*	*H*	*L*
C8	Level (%) of commuting trips by Pedestrians	*Higher +* *Lower -*	✗	✗	➲	➲	➲	➲
C9	Compliance (with traffic / transport regulations)	*Higher +* *Lower -*	➲	✗	➲	✗	✗	➲
C10	Strategic route security / availability / information	*Higher availability & information +* *Lower availability & information -*	✓	✓	✓	✓	✓	➲
C11	Quality & efficiency of transport	*Higher level +* *Lower level -*	✓	✓	✓	✓	✓	➲
C12	Travel time reliability	*Higher level +* *Lower level -*	➲	✓	✓	✓	✓	➲
D Public Health			*M*	*M*	*L*	*M*	*M*	*L*
D1	Traffic congestion in urban areas (impacts on local air quality)	*Lower level +* *Higher level -*	➲	✓	✓	✓	➲	✗
D2	Vehicle noise	*Lower level +* *Higher level -*	✗	➲	✗	✗	✗	➲
D3	Numbers of short trips made by walking or cycling	*Higher level +* *Lower level -*	✗	✗	➲	➲	➲	➲
D4	Numbers of commuting trips made by walking or cycling	*Higher level +* *Lower level -*	✗	✗	➲	➲	➲	➲
D5	Compliance (with emissions regulations)	*Higher level +* *Lower level -*	✗	✗	✗	✗	✗	➲
D6	Level & severity of personal injury	*Lower +* *Higher -*	✓	➲	➲	➲	✗	➲

Contribution Matrix – Section 4 (continued).

Contributes To		How Contribution Assessed	EMERGENCY MANAGEMENT SYSTEMS	ADVANCED TRAVELLER INFORMATION SYSTEMS				INFORMATION MANAGEMENT
			Response / Recovery / Hazardous Materials / Emergency Medical Services	Detection, Information Collection & Processing	Ride Share Information	Pre-trip and En-Route Information	In-Vehicle & Hand-Held Devices	Data Archiving / Interoperability / Analysis
E Sustainability			*M*	*H*	*H*	*H*	*M*	*L*
E1	Traffic/Transport Demand	*Higher ability to manage +* *Lower ability to manage -*	✗	➲	✓	✓	✓	✗
E2	Level(%) of trips that are not car based	*Higher level +* *Lower level -*	✗	✓	➲	➲	➲	➲
E3	Non road freight volumes as a percentage of total	*Higher level +* *Lower level -*	✓	➲	➲	➲	✗	➲
E4	Growth rate of total vehicle travel	*Lower level +* *Higher level -*	✗	✓	➲	➲	➲	➲
E5	Emission levels (particulates, nitrogen oxides, carbon monoxides, CO_2)	*Lower level +* *Higher level -*	✗	✓	➲	✓	➲	➲
E6	Extent to which users face full cost of their road use	*Full costs of use +* *Low indirect costs of use -*	✗	✗	✗	➲	✗	➲
E7	Levels of service on key routes	*Higher LOS (Volume/capacity ratios). +* *Lower LOS -*	➲	➲	✗	✓	➲	➲
E8	Extent to which the benefits will be sustainable over time	*Benefits that can be sustained +* *Benefits that are short term or eroded -*	✓	✓	✓	✓	✓	✓
F Energy Efficiency			*M*	*H*	*H*	*H*	*H*	*L*
F1	Traffic Congestion	*Reduced +* *Increased -*	✓	✓	✓	✓	✓	✗
F2	Traffic/Transport Demand	*Higher ability to manage +* *Lower ability to manage -*	✗	➲	✓	✓	✓	✗
F3	Efficiency of routes taken	*A high proportion of efficient routes taken +* *Low proportion -*	✗	➲	✓	✓	✓	✗

Contribution Matrix – Section 4 (continued).

Contributes To		How Contribution Assessed	EMERGENCY MANAGEMENT SYSTEMS	ADVANCED TRAVELLER INFORMATION SYSTEMS				INFORMATION MANAGEMENT
			Response / Recovery / Hazardous Materials / Emergency Medical Services	Detection, Information Collection & Processing	Ride Share Information	Pre-trip and En-Route Information	In-Vehicle & Hand-Held Devices	Data Archiving / Interoperability / Analysis
F Energy Efficiency (continued)			*M*	*H*	*H*	*H*	*H*	*L*
F4	Fuel use	*Lower level +* *Higher level -*	✗	✓	➲	✓	➲	➲
F5	level of travel in congested conditions	*Lower level +* *Higher level -*	✓	✓	✓	✓	✓	✗
F6	Use of energy efficient modes	*Higher level +* *Lower level -*	✗	✓	➲	➲	➲	➲
F7	Quality & efficiency of transport	*Higher level +* *Lower level -*	✓	✓	✓	✓	✓	➲
G Integration			*L*	*L*	*H*	*M*	*M*	*L*
G1	Provision for all modes on key transport corridors	*Higher level +* *Lower level -*	✗	✗	✓	✗	✗	➲
G2	Level of priority given to passenger transport	*Higher level +* *Lower level -*	✗	✗	➲	➲	➲	➲
G3	Efficiency and convenience of mode transfer points	*Higher level of efficiency +* *Lower level -*	✗	✗	✓	➲	✗	➲
G4	Level of integration between road and rail	*Higher level +* *Lower level -*	✗	✗	✓	➲	➲	➲
G5	Improving rural community access & conditions	*Higher level +* *Lower level -*	✗	✗	✓	➲	✓	➲
H Responsiveness			*H*	*H*	*H*	*H*	*H*	*L*
H1	Responding to diverse stake holder needs (particularly rural versus urban)	*High level +* *Low level -* *(e.g. open Architecture etc?)*	✓	✗	✓	✓	✓	➲

Contribution Matrix – Section 4 (continued).

Contributes To		How Contribution Assessed	EMERGENCY T MANAGEMENT SYSTEMS	ADVANCED TRAVELLER INFORMATION SYSTEMS				INFORMATION MANAGEMENT
			Response / Recovery / Hazardous Materials / Emergency Medical Services	Detection, Information Collection & Processing	Ride Share Information	Pre-trip and En-Route Information	In-Vehicle & Hand-Held Devices	Data Archiving / Interoperability / Analysis
H Responsiveness (continued)			*H*	*H*	*H*	*H*	*H*	*L*
H2	Contributions to national objectives	*"Fit" with national objectives – as set out in EECS, NZTS, Road Safety 2010, Growing an Innovative New Zealand, Live + Work + Play (MFE).*	✓	✓	✓	✓	✓	✓
H3	Maintain strategic route security / availability / information	*Higher availability & information + Lower availability & information -*	✓	✓	✓	✓	✓	➲
H4	Quality & efficiency of transport	*Higher level + Lower level -*	✓	✓	✓	✓	✓	➲
H5	Travel time reliability	*Higher level + Lower level -*	➲	✓	✓	✓	✓	➲
I Affordability and Cost Effectiveness			*H*	*M*	*H*	*H*	*M*	*H*
I1	Relative benefit to cost ratio	*High level + Low level -*	✓	✓	✓	✓	➲	✓
I2	Level of operating cost	*Low level + High level -*	✓	➲	✓	✓	➲	✓
I3	Contribution direct from users	*High level + Low level -*	✗	✗	✗	➲	✗	➲
J Implementation Risk			*L*	*M*	*L*	*L*	*M*	*L*
J1	Technical complexity	*Low level + High level -*	✓	✓	✓	✓	➲	
J2	Interoperability	*Minor issues + Major issues -*	✓	✓	✓	✓	➲	✓
J3	Cost certainty	*High level + Low level -*	✓	✓	✓	✓	➲	✓
J4	Public acceptance	*High level + Low level -*	✓	✓	✓	✓	✓	➲
J5	Implementation constraints – resource consents, legal & others	*Low level + High level -*	✓	✓	✓	✓	➲	➲

Contribution Matrix – Section 5.

Contributes To		How Contribution Assessed	CRASH PREVENTION & SAFETY			ROADWAY OPERATIONS & MAINTENANCE		ROAD WEATHER MANAGEMENT
			Road Geometry Warning Systems: Ramp Rollover / Curve Speed / Downhill Speed	Highway Rail Crossing Systems	Intersection Collision Warning	Asset Management	Work Zone Management	Monitoring, Prediction, Informing, Response and Treatment
A. Economic Development			*L*	*L*	*L*	*L*	*M*	*H*
A1	Traffic Congestion	*Reduced +* *Increased -*	✗	✗	✗	✗	✓	✓
A2	Traffic/ Transport Demand	*Higher ability to manage +* *Lower ability to manage -*	✗	✗	✗	✗	✗	➲
A3	Travel time on key routes	*Reduced +* *Increased -*	✗	✗	✗	✗	➲	➲
A4	Transportation Costs (travel time, VOC)	*Reduced +* *Increased -*	✗	✗	✗	✗	➲	➲
A5	Transport users face the true costs of use	*Higher true costs of use +* *Lower indirect costs of use -*	✗	✗	✗	✗	✗	✗
A6	Travel time for car commuters to key employment centres	*Short travel time +* *Long travel time-*	✗	✗	✗	✗	➲	➲
A7	Maintain strategic route security / availability / information	*Higher availability & information +* *Lower availability & information -*	➲	➲	➲	✓	✓	✓
A8	Quality & efficiency of transport	*High level +* *Low level -*	➲	➲	➲	✓	✓	✓
A9	Freight transport and mode transfer	*Improved efficiency +* *Reduced efficiency -*	➲	✗	✗	✗	➲	✓
A10	Travel time reliability	*Higher level +* *Lower level -*	✗	✗	✗	✗	✓	✓
B Safety and Personal Security			*H*	*H*	*H*	*M*	*H*	*H*
B1	Number of traffic crashes	*Reducing number +* *Increasing number -*	✓	✓	✓	➲	➲	✓
B2	Level of fatalities	*Reducing number +* *Increasing number -*	✓	✓	✓	✗	✗	✓
B3	Level & severity of personal injury	*Lower +* *Higher -*	✓	✓	✓	➲	➲	✓

Contribution Matrix – Section 5 (continued).

Contributes To		How Contribution Assessed	CRASH PREVENTION & SAFETY			ROADWAY OPERATIONS & MAINTENANCE		ROAD WEATHER MANAGEMENT
			Road Geometry Warning Systems: Ramp Rollover / Curve Speed / Downhill Speed	Highway Rail Crossing Systems	Intersection Collision Warning	Asset Management	Work Zone Management	Monitoring, Prediction, Informing, Response and Treatment
B Safety and Personal Security (continued)			*H*	*H*	*H*	*M*	*H*	*H*
B4	Level of conflict between vehicles / cyclists / pedestrians and other road users	*Lower +* *Higher -*	✓	✓	✓	✗	✓	✗
B5	Perceived personal safety/security for non car mode trips	*Higher +* *Lower -*	✗	✗	✗	✗	✗	➲
B6	Compliance (with traffic / transport regulations)	*High level +* *Low level -*	➲	➲	➲	✗	✓	✗
C Access & Mobility			*L*	*L*	*L*	*L*	*M*	*H*
C1	Traffic Congestion	*Reduced +* *Increased -*	✗	✗	✗	✗	✓	✓
C2	Traffic/Transport Demand	*Higher ability to manage +* *Lower ability to manage -*	✗	✗	✗	✗	✗	➲
C3	Sector to sector travel times by car	*Shorter travel time +* *Longer travel time -*	✗	✗	✗	✗	➲	➲
C4	Frequency and reliability of key passenger transport services	*Higher +* *Lower -*	✗	✗	✗	✗	➲	➲
C5	Convenience (perceived and actual) of public transport services	*Higher +* *Lower -*	✗	✗	✗	✗	➲	➲
C6	Level (%) of commuting trips by passenger transport	*Higher +* *Lower -*	✗	✗	✗	✗	➲	➲
C7	Level (%) of commuting trips by cycle	*Higher +* *Lower -*	✗	✗	✗	✗	✗	➲

Contribution Matrix – Section 5 (continued).

Contributes To		How Contribution Assessed	CRASH PREVENTION & SAFETY			ROADWAY OPERATIONS & MAINTENANCE		ROAD WEATHER MANAGEMENT
			Road Geometry Warning Systems: Ramp Rollover / Curve Speed / Downhill Speed	Highway Rail Crossing Systems	Intersection Collision Warning	Asset Management	Work Zone Management	Monitoring, Prediction, Informing, Response and Treatment
C Access & Mobility (continued)			*L*	*L*	*L*	*L*	*M*	*H*
C8	Level (%) of commuting trips by pedestrians	*Higher + Lower -*	✘	✘	✘	✘	✘	➲
C9	Compliance (with traffic / transport regulations)	*Higher + Lower -*	➲	➲	➲	✘	✓	✘
C10	Strategic route security / availability / information	*Higher availability & information + Lower availability & information -*	➲	➲	➲	✓	✓	✓
C11	Quality & efficiency of transport	*Higher level + Lower level -*	➲	➲	➲	✓	✓	✓
C12	Travel time reliability	*Higher level + Lower level -*	✘	✘	✘	✘	✓	✓
D Public Health			*M*	*M*	*M*	*L*	*L*	*M*
D1	Traffic congestion in urban areas (impacts on local air quality)	*Lower level + Higher level -*	✘	✘	✘	✘	➲	✓
D2	Vehicle noise	*Lower level + Higher level -*	✘	✘	✘	➲	➲	✘
D3	Numbers of short trips made by walking or cycling	*Higher level + Lower level -*	✘	✘	✘	✘	✘	➲
D4	Numbers of commuting trips made by walking or cycling	*Higher level + Lower level -*	✘	✘	✘	✘	✘	➲
D5	Compliance (with emissions regulations)	*Higher level + Lower level -*	✘	✘	✘	✘	✘	➲
D6	Level & severity of personal injury	*Lower + Higher -*	✓	✓	✓	➲	➲	✓

Contribution Matrix – Section 5 (continued).

Contributes To		How Contribution Assessed	CRASH PREVENTION & SAFETY			ROADWAY OPERATIONS & MAINTENANCE		ROAD WEATHER MANAGEMENT
			Road Geometry Warning Systems: Ramp Rollover / Curve Speed / Downhill Speed	Highway Rail Crossing Systems	Intersection Collision Warning	Asset Management	Work Zone Management	Monitoring, Prediction, Informing, Response and Treatment
E Sustainability			*L*	*L*	*L*	*L*	*M*	*H*
E1	Traffic/Transport Demand	*Higher ability to manage + Lower ability to manage -*	✗	✗	✗	✗	✗	➲
E2	Level(%) of trips that are not car based	*Higher level + Lower level -*	✗	✗	✗	✗	➲	➲
E3	Non road freight volumes as a percentage of total	*Higher level + Lower level -*	✗	✗	✗	✗	✗	✗
E4	Growth rate of total vehicle travel	*Lower level + Higher level -*	✗	✗	✗	✗	✗	✗
E5	Emission levels (particulates, nitrogen oxides, carbon monoxides, CO_2)	*Lower level + Higher level -*	✗	✗	✗	✗	➲	➲
E6	Extent to which users face full cost of their road use	*Full costs of use + Low indirect costs of use -*	✗	✗	✗	✗	✗	✗
E7	Levels of service on key routes	*Higher LOS (Volume/capacity ratios). + Lower LOS -*	✗	✗	✗	✗	➲	➲
E8	Extent to which the benefits will be sustainable over time	*Benefits that can be sustained + Benefits that are short term or eroded -*	✓	✗	✗	✓	➲	✓
F Energy Efficiency			*L*	*L*	*L*	*L*	*M*	*H*
F1	Traffic Congestion	*Reduced + Increased -*	✗	✗	✗	✗	✓	✓
F2	Traffic/Transport Demand	*Higher ability to manage + Lower ability to manage -*	✗	✗	✗	✗	✗	➲
F3	Efficiency of routes taken	*A high proportion of efficient routes taken + Low proportion -*	✗	✗	✗	✗	✗	➲

Contribution Matrix – Section 5 (continued).

Contributes To		How Contribution Assessed	CRASH PREVENTION & SAFETY			ROADWAY OPERATIONS & MAINTENANCE		ROAD WEATHER MANAGEMENT
			Road Geometry Warning Systems: Ramp Rollover / Curve Speed / Downhill Speed	Highway Rail Crossing Systems	Intersection Collision Warning	Asset Management	Work Zone Management	Monitoring, Prediction, Informing, Response and Treatment
F Energy Efficiency (continued)			*L*	*L*	*L*	*L*	*M*	*H*
F4	Fuel use	*Lower level + Higher level -*	✘	✘	✘	✘	➲	➲
F5	level of travel in congested conditions	*Lower level + Higher level -*	✘	✘	✘	✘	✓	✓
F6	Use of energy efficient modes	*Higher level + Lower level -*	✘	✘	✘	✘	➲	➲
F7	Quality & efficiency of transport	*Higher level + Lower level -*	➲	➲	➲	✓	✓	✓
G Integration			*L*	*M*	*L*	*L*	*L*	*H*
G1	Provision for all modes on key transport corridors	*Higher level + Lower level -*	✘	✘	✘	✘	✘	✘
G2	Level of priority given to passenger transport	*Higher level + Lower level -*	✘	✘	✘	✘	➲	✘
G3	Efficiency and convenience of mode transfer points	*Higher level of efficiency + Lower level -*	✘	✘	✘	✘	✘	➲
G4	Level of integration between road and rail	*Higher level + Lower level -*	✘	✓	✘	✘	✘	➲
G5	Improving rural community access & conditions	*Higher level + Lower level -*	✘	✓	✘	✘	✘	✓
H Responsiveness			*M*	*M*	*M*	*H*	*H*	*H*
H1	Responding to diverse stake holder needs (particularly rural versus urban)	*High level + Low level - (e.g. open Architecture etc?)*	✓	✓	✓	✘	✓	✓

Contribution Matrix – Section 5 (continued).

	Contributes To	How Contribution Assessed	CRASH PREVENTION & SAFETY			ROADWAY OPERATIONS & MAINTENANCE		ROAD WEATHER MANAGEMENT
			Road Geometry Warning Systems: Ramp Rollover / Curve Speed / Downhill Speed	Highway Rail Crossing Systems	Intersection Collision Warning	Asset Management	Work Zone Management	Monitoring, Prediction, Informing, Response and Treatment
	H Responsiveness (continued)		*M*	*M*	*M*	*H*	*H*	*H*
H2	Contributions to national objectives	*"Fit" with national objectives – as set out in EECS, NZTS, Road Safety 2010, Growing an Innovative New Zealand, Live + Work + Play (MFE).*	✓	✓	✓	✓	✓	✓
H3	Maintain strategic route security / availability / information	*Higher availability & information + Lower availability & information -*	➲	➲	➲	✓	✓	✓
H4	Quality & efficiency of transport	*Higher level + Lower level -*	➲	➲	➲	✓	✓	✓
H5	Travel time reliability	*Higher level + Lower level -*	✗	✗	✗	✗	✓	✓
	I Affordability and Cost Effectiveness		*M*	*M*	*M*	*H*	*H*	*H*
I1	Relative benefit to cost ratio	*High level + Low level -*	➲	➲	➲	✓	✓	✓
I2	Level of operating cost	*Low level + High level -*	✓	✓	✓	✓	✓	✓
I3	Contribution direct from users	*High level + Low level -*	✗	✗	✗	✗	✗	✗
	J Implementation Risk		*L*	*L*	*M*	*L*	*L*	*L*
J1	Technical complexity	*Low level + High level -*	✓	✓	➲	✓	✓	✓
J2	Interoperability	*Minor issues + Major issues -*	✓	✓	➲	✓	✓	✓
J3	Cost certainty	*High level + Low level -*	✓	✓	➲	✓	✓	✓
J4	Public acceptance	*High level + Low level -*	✓	✓	➲	✓	✓	✓
J5	Implementation constraints – resource consents, legal & others	*Low level + High level -*	✓	➲	➲	✓	➲	✓

Contribution Matrix – Section 6.

Contributes To		How Contribution Assessed	ELECTRONIC ROAD USER CHARGING			FLEET MANAGEMENT SYSTEMS	TUNNEL MANAGEMENT SYSTEMS
			Wide Area RUC	Project Specific E-Toll Collection Systems	Electronic Road/Congestion Pricing	Fleet Management Systems	Surveillance, Fire Systems and Response Coordination
A. Economic Development			*H*	*H*	*H*	*M*	*M*
A1	Traffic Congestion	*Reduced + Increased -*	➲	✓	✓	✗	✗
A2	Traffic/ Transport Demand	*Higher ability to manage + Lower ability to manage -*	✓	✓	✓	✗	✗
A3	Travel time on key routes	*Reduced + Increased -*	➲	✓	➲	✗	✗
A4	Transportation Costs (travel time, VOC)	*Reduced + Increased -*	➲	✓	➲	➲	✗
A5	Transport users face the true costs of use	*Higher true costs of use + Lower indirect costs of use -*	✓	✓	✓	✗	✗
A6	Travel time for car commuters to key employment centres	*Short travel time + Long travel time -*	➲	✓	➲	✗	✗
A7	Maintain strategic route security / availability / information	*Higher availability & information + Lower availability & information -*	➲	➲	➲	✗	✓
A8	Quality & efficiency of transport	*High level + Low level -*	✓	✓	✓	✗	✗
A9	Freight transport and mode transfer	*Improved efficiency + Reduced efficiency -*	✓	✓	✓	✓	✗
A10	Travel time reliability	*Higher level + Lower level -*	➲	✓	➲	✗	✗
B Safety and Personal Security			*L*	*M*	*M*	*L*	*H*
B1	Number of traffic crashes	*Reducing number + Increasing number -*	✗	✓	✓	✓	✓
B2	Level of fatalities	*Reducing number + Increasing number -*	✗	✗	✗	✗	✓
B3	Level & severity of personal injury	*Lower + Higher -*	✗	➲	➲	✗	✓

Contribution Matrix – Section 6 (continued).

Contributes To		How Contribution Assessed	ELECTRONIC ROAD USER CHARGING			FLEET MANAGEMENT SYSTEMS	TUNNEL MANAGEMENT SYSTEMS
			Wide Area RUC	Project Specific E-Toll Collection Systems	Electronic Road/Congestion Pricing	Fleet Management Systems	Surveillance, Fire Systems and Response Coordination
B Safety and Personal Security (continued)			*L*	*M*	*M*	*L*	*H*
B4	Level of conflict between vehicles / cyclists / pedestrians and other road users	*Lower + Higher -*	➲	➲	➲	✗	✗
B5	Perceived personal safety/security for non car mode trips	*Higher + Lower -*	➲	✗	✓	✗	✓
B6	Compliance (with traffic / transport regulations)	*High level + Low level -*	✓	✓	✓	✓	✓
C Access & Mobility			*M*	*H*	*H*	*L*	*M*
C1	Traffic Congestion	*Reduced + Increased -*	➲	✓	✓	✗	✗
C2	Traffic/Transport Demand	*Higher ability to manage + Lower ability to manage -*	✓	✓	✓	✗	✗
C3	Sector to sector travel times by car	*Shorter travel time + Longer travel time -*	➲	✓	➲	✗	✗
C4	Frequency and reliability of key passenger transport services	*Higher + Lower -*	✗	✓	✓	➲	✗
C5	Convenience (perceived and actual) of public transport services	*Higher + Lower -*	✗	➲	✓	➲	✗
C6	Level (%) of commuting trips by passenger transport	*Higher + Lower -*	✗	➲	✓	➲	✗
C7	Level (%) of commuting trips by cycle	*Higher + Lower -*	✗	✗	✓	✗	✗

Contribution Matrix – Section 6 (continued).

Contributes To		How Contribution Assessed	ELECTRONIC ROAD USER CHARGING			FLEET MANAGEMENT SYSTEMS	TUNNEL MANAGEMENT SYSTEMS
			Wide Area RUC	Project Specific E-Toll Collection Systems	Electronic Road/Congestion Pricing	Fleet Management Systems	Surveillance, Fire Systems and Response Coordination
C Access & Mobility (continued)			*M*	*H*	*H*	*L*	*M*
C8	Level (%) of commuting trips by Pedestrians	*Higher + Lower -*	✗	✗	✓	✗	✗
C9	Compliance (with traffic / transport regulations)	*Higher + Lower -*	✓	✓	✓	✗	✓
C10	Strategic route security / availability / information	*Higher availability & information + Lower availability & information -*	➲	➲	➲	✗	✓
C11	Quality & efficiency of transport	*Higher level + Lower level -*	✓	✓	✓	✗	✗
C12	Travel time reliability	*Higher level + Lower level -*	➲	✓	➲	✗	✗
D Public Health			*L*	*L*	*H*	*L*	*M*
D1	Traffic congestion in urban areas (impacts on local air quality)	*Lower level + Higher level -*	➲	✓	✓	✗	✗
D2	Vehicle noise	*Lower level + Higher level -*	➲	✓	✓	➲	➲
D3	Numbers of short trips made by walking or cycling	*Higher level + Lower level -*	✗	✗	✓	✗	✗
D4	Numbers of commuting trips made by walking or cycling	*Higher level + Lower level -*	✗	✗	✓	✗	✗
D5	Compliance (with emissions regulations)	*Higher level + Lower level -*	✓	✓	✓	➲	➲
D6	Level & severity of personal injury	*Lower + Higher -*	✗	➲	➲	✗	✓

Contribution Matrix – Section 6 (continued).

	Contributes To	How Contribution Assessed	ELECTRONIC ROAD USER CHARGING			FLEET MANAGEMENT SYSTEMS	TUNNEL MANAGEMENT SYSTEMS
			Wide Area RUC	Project Specific E-Toll Collection Systems	Electronic Road/Congestion Pricing	Fleet Management Systems	Surveillance, Fire Systems and Response Coordination
	E Sustainability		*H*	*H*	*H*	*M*	*L*
E1	Traffic/Transport Demand	*Higher ability to manage +* *Lower ability to manage -*	✓	✓	✓	✗	✗
E2	Level(%) of trips that are not car based	*Higher level +* *Lower level -*	✗	➲	✓	➲	✗
E3	Non road freight volumes as a percentage of total	*Higher level +* *Lower level -*	✓	➲	➲	✗	✗
E4	Growth rate of total vehicle travel	*Lower level +* *Higher level -*	✓	✓	✓	✗	✗
E5	Emission levels (particulates, nitrogen oxides, carbon monoxides, CO_2)	*Lower level +* *Higher level -*	✗	➲	✓	➲	✗
E6	Extent to which users face full cost of their road use	*Full costs of use +* *Low indirect costs of use -*	✓	✓	✓	✗	✗
E7	Levels of service on key routes	*Higher LOS (Volume/ capacity ratios). +* *Lower LOS -*	➲	✓	➲	✗	✗
E8	Extent to which the benefits will be sustainable over time	*Benefits that can be sustained +* *Benefits that are short term or eroded -*	✓	✓	✓	✓	✓
	F Energy Efficiency		*H*	*H*	*H*	*H*	*L*
F1	Traffic Congestion	*Reduced +* *Increased -*	➲	✓	✓	✗	✗
F2	Traffic/Transport Demand	*Higher ability to manage +* *Lower ability to manage -*	✓	✓	✓	✗	✗
F3	Efficiency of routes taken	*A high proportion of efficient routes taken +* *Low proportion -*	✓	✓	✓	✗	✗

Contribution Matrix – Section 6 (continued).

Contributes To		How Contribution Assessed	ELECTRONIC ROAD USER CHARGING			FLEET MANAGEMENT SYSTEMS	TUNNEL MANAGEMENT SYSTEMS
			Wide Area RUC	Project Specific E-Toll Collection Systems	Electronic Road/Congestion Pricing	Fleet Management Systems	Surveillance, Fire Systems and Response Coordination
F Energy Efficiency (continued)			*H*	*H*	*H*	*H*	*L*
F4	Fuel use	*Lower level + Higher level -*	✗	➲	✓	➲	✗
F5	level of travel in congested conditions	*Lower level + Higher level -*	➲	✓	✓	✗	✗
F6	Use of energy efficient modes	*Higher level + Lower level -*	✗	➲	✓	➲	✗
F7	Quality & efficiency of transport	*Higher level + Lower level -*	✓	✓	✓	✗	✗
G Integration			*M*	*L*	*H*	*L*	*L*
G1	Provision for all modes on key transport corridors	*Higher level + Lower level -*	✓	✓	✓	✗	✗
G2	Level of priority given to passenger transport	*Higher level + Lower level -*	✓	✓	✓	✗	✗
G3	Efficiency and convenience of mode transfer points	*Higher level of efficiency + Lower level -*	✗	✗	✓	✗	✗
G4	Level of integration between road and rail	*Higher level + Lower level -*	➲	✗	✗	✗	✗
G5	Improving rural community access & conditions	*Higher level + Lower level -*	✓	✗	✗	✗	✗
H Responsiveness			*H*	*H*	*H*	*L*	*H*
H1	Responding to diverse stake holder needs (particularly rural versus urban)	*High level + Low level - (e.g. open Architecture etc?)*	✓	✓	✓	✗	✗

Contribution Matrix – Section 6 (continued).

Contributes To		How Contribution Assessed	ELECTRONIC ROAD USER CHARGING			FLEET MANAGEMENT SYSTEMS	TUNNEL MANAGEMENT SYSTEMS
			Wide Area RUC	Project Specific E-Toll Collection Systems	Electronic Road/Congestion Pricing	Fleet Management Systems	Surveillance, Fire Systems and Response Coordination
H Responsiveness (continued)			*H*	*H*	*H*	*L*	*H*
H2	Contributions to national objectives	*"Fit" with national objectives – as set out in EECS, NZTS, Road Safety 2010, Growing an Innovative New Zealand, Live + Work + Play (MFE).*	✓	✓	✓	✓	✓
H3	Maintain strategic route security / availability / information	*Higher availability & information + Lower availability & information -*	➲	➲	➲	✗	✓
H4	Quality & efficiency of transport	*Higher level + Lower level -*	✓	✓	✓	✗	✗
H5	Travel time reliability	*Higher level + Lower level -*	➲	✓	➲	✗	✗
I Affordability and Cost Effectiveness			*M*	*M*	*M*	*H*	*H*
I1	Relative benefit to cost ratio	*High level + Low level -*	➲	➲	➲	✓	✓
I2	Level of operating cost	*Low level + High level -*	➲	➲	➲	✓	➲
I3	Contribution direct from users	*High level + Low level -*	✓	✓	✓	✗	✗
J Implementation Risk			*M*	*M*	*M*	*L*	*L*
J1	Technical complexity	*Low level + High level -*	➲	➲	➲	✓	✓
J2	Interoperability	*Minor issues + Major issues -*	➲	➲	➲	✓	✓
J3	Cost certainty	*High level + Low level -*	➲	➲	➲	✓	✓
J4	Public acceptance	*High level + Low level -*	➲	➲	➲	✓	➲
J5	Implementation constraints – resource consents, legal & others	*Low level + High level -*	➲	➲	➲	✓	➲

5. Implementation Examples and Benefits

The following application assessments describe each facility assessed, setting out the types and scale of benefits produced by different ITS applications, potential problem areas and conditions in which they are best applied.

In effect, each column in the matrix is given individual consideration. A table is derived from the matrix, identifying the main areas of benefit and providing a brief description/comment on how these are achieved. This is followed by examples of actual applications and reported benefits (New Zealand and/or international).

5.1 Motorway Management Systems

Motorway management systems use detection and video monitoring equipment to support the management of traffic and incidents. Variable message signs and other traveller information facilities provide advance warning of conditions and assist in keeping motorway traffic flowing more safely. Traffic control measures on motorway entrance ramps, such as ramp meters, can be used to optimise motorway travel speeds and ramp wait times. Lane management applications can address the effective capacity of motorways and promote the use of high-occupancy commute modes. Special event transportation management systems can help control the impact of congestion at stadiums or convention centres. Advanced communications have improved the dissemination of information to the travelling public. Motorists are now able to receive relevant information on location specific traffic conditions in a number of ways, including dynamic message signs, in-vehicle signing, or specialised information transmitted only to a specific set of vehicles.

There are twelve ITS motorway management systems covered in this section:

5.1.1 Traffic Monitoring and Surveillance

5.1.2 Incident Detection Systems

5.1.3 Variable Message Signs

5.1.4 Mobile Variable Message Signs

5.1.5 Speed Enforcement

5.1.6 Ramp Metering

5.1.7 Vehicle Access (Ramp) Control Systems

5.1.8 Lane Control Systems

5.1.9 Variable Speed Limits

5.1.10 Special Event Transportation Management

5.1.11 Electronic Safety Screening

5.1.12 Electronic Weight Screening

5.1.1 Traffic Monitoring and Surveillance

5.1.1.1 Description

Traffic monitoring and surveillance systems provide information to transport planners and controllers for use in traffic management systems, incident detection and travel survey analysis. They generally comprise:

- CCTV surveillance cameras;
- Automated monitoring and detection systems; and
- A central control facility with data processing software and visual monitoring equipment.

Surveillance and monitoring facilities also often form part of other traffic and transport management systems, such as:

- Ramp metering controls, used to regulate the flow of vehicles onto motorways.
- Motorway lane control systems.
- Enforcement systems for tolling, speed, height etc.
- Safety systems in tunnels.

5.1.1.2 Benefits

The main benefits of traffic surveillance and monitoring systems are that they enable traffic planners and managers to observe traffic movements in real-time and respond to any problems that may arise. In particular, surveillance and monitoring systems can help in the following areas:

- Reducing incident response times leading to more rapid return to maximum capacity.
- Assisting in managing traffic congestion.
- Providing a reliable source of information to other systems (such as ATI).
- Assisting in monitoring regulation compliance (e.g. Toll facilities / Ramp metering).
- Indirectly improving safety through reduced congestion related or secondary accidents.

5.1.1.3 Potential Problems

The main problems associated with traffic surveillance and monitoring systems are:

- Public concern regarding privacy and civil liberties.
- Recognition of the cost of maintenance and commitment to ongoing operations.

5.1.1.4 Applications

In a Motorway environment this type of technology is used most widely where traffic volumes are high and the effect of minor incidents is significant. This translates to mainly urban motorway situations with high peak traffic flows, or particularly vulnerable sections. Although, with the rapidly reducing costs of camera and communications technology, this is changing and the cost/benefit equation for surveillance of less congested sections of motorway is improving.

An important component of surveillance systems is the monitoring resource. Where a TMC or other dedicated facility exists this is generally not a significant issue. However, as the deployment of surveillance increases it is important to ensure that these facilities are resourced to deal with the increasing level of demand.

The use of traffic surveillance for purposes other than incident detection and congestion management is also increasing, including toll systems and other regulation enforcement. However, the primary benefits of traffic surveillance in a motorway environment remain the management of incidents and congestion and therefore the main criteria for deployment should be relatively high traffic volumes and vulnerability of flow to minor incidents.

5.1.1.5 Relevance to NZTS/LTMA Objectives

Table 5.1.1.1 Contribution of Traffic Monitoring and Surveillance to NZTS/LTMA objectives (derived from Contribution Matrix Section 1).

NZTS / LTMA Objective	*Level of contribution*	*Comment*
A. Economic Development	*High*	
Traffic Congestion	✓	Assist in early detection & management of incidents; so reducing congestion and incident related delays. Supporting economic development goals, such as improving the efficient flows of people, goods and services; and extracting maximum capacity from existing infrastructure. In the area of traffic/transport demand management, these facilities contribute mainly as a component of other systems.
Traffic/Transport Demand	➲	
Travel time on key routes	✓	
Transportation Costs	✓	
Travel time for car commuters to key employment centres	✓	
Maintain strategic route security / availability / information	✓	
Quality & efficiency of transport	✓	
Travel time reliability	✓	
B Safety and Personal Security	*Medium*	
Number of traffic crashes	➲	Assist in reducing congestion related secondary crashes, improving response time to critical injuries, so improving personal safety, and assisting in road safety enforcement as a component of other systems.
Level of fatalities	➲	
Level & severity of personal injury	➲	
Compliance (with traffic / transport regulations)	➲	
C Access & Mobility	*High*	
Traffic Congestion	✓	Assist in early detection & management of incidents on critical and strategic routes; so reducing congestion and incident related delays. Improve access and mobility through the more efficient use of local networks and supporting traffic/transport demand management as a component of other systems.
Traffic/Transport Demand	➲	
Sector to sector travel times by car	✓	
Frequency and reliability of key passenger transport services	✓	
Convenience (perceived and actual) of public transport services	➲	
Level (%) of commuting trips by passenger transport	➲	
Compliance (with traffic / transport regulations)	➲	
Strategic route security / availability / information	✓	
Quality & efficiency of transport	✓	
Travel time reliability	✓	

Table 5.1.1.1 (continued)

NZTS / LTMA Objective	***Level of contribution***	***Comment***
D Public Health	*Medium*	
Traffic congestion in urban areas (impacts on local air quality)	✓	Contribute to public health objectives such as enhancing air quality and reduce exposure to transport noise by: Assisting in early detection of incidents and managing traffic, so reducing congestion and related emissions and noise. Improving enforcement of emissions regulations, reducing congestion related crashes and response time to critical injuries.
Vehicle noise	➲	
Compliance (with emissions regulations)	✓	
Level & severity of personal injury	➲	
E Sustainability	*High*	
Traffic/Transport Demand	➲	Contribute to sustainability objectives such as improving the efficiency of existing networks, and improving mobility for people, goods and services with minimal adverse effects by: Assisting in early detection of incidents and managing traffic; so reducing congestion and related delays, emissions and noise. Supporting traffic/transport demand management as a component of other systems.
Level(%) of trips that are not car based	➲	
Emission levels (particulates, nitrogen oxides, carbon monoxides, CO_2)	➲	
Levels of service on key routes	✓	
Extent to which the benefits will be sustainable over time	✓	
F Energy Efficiency	*High*	
Traffic Congestion	✓	Contribute to energy efficiency objectives such as improving the efficiency of existing networks. Assist in early detection of incidents and managing traffic, so reducing congestion and related delays. Supporting traffic/transport demand management as a component of other systems.
Traffic/Transport Demand	➲	
Efficiency of routes taken	➲	
Fuel use	➲	
level of travel in congested conditions	✓	
Use of energy efficient modes	➲	
Quality & efficiency of transport	✓	
G Integration	*Low*	
None	✗	Although often a component of other integrated systems, does not deliver specifically to any integration objectives.
H Responsiveness	*High*	
Contributions to national objectives	✓	Assist in early detection & management of incidents, so reducing congestion and incident related delays. Support responsiveness goals, such as improving travel time reliability, maintaining strategic route availability and the general quality and efficiency of transport.
Maintain strategic route security / availability / information	✓	
Quality & efficiency of transport	✓	
Travel time reliability	✓	

Table 5.1.1.1 (continued)

NZTS / LTMA Objective	Level of contribution	Comment
I Affordability and Cost Effectiveness	*Medium*	
Relative benefit to cost ratio	✓	When implemented in appropriate situations cost effectiveness is good. However the cost of ongoing operations and maintenance needs to be fully considered.
Level of operating cost	➲	
J Implementation Risk	*Low*	
Technical complexity	✓	Generally, the base technologies in this area are well developed and the complexity level low. This leads to a high level of cost reliability and low risk. The main sources of risk are recognizing the level of operating commitment and cost, and public acceptance of surveillance.
Interoperability	✓	
Cost certainty	✓	
Public acceptance	➲	
Implementation constraints – resource consents, legal & others	✓	
✓ = Positive Contribution; ✗ = No Significant Contribution; ➲ = Partial Contribution		

5.1.1.6 Summary and Conclusions

Traffic surveillance and monitoring systems mainly provide an aid to transport planners and traffic managers in the control of traffic flow.

In a motorway environment the most common uses of this technology are the detection and management of incidents, managing the effects of congestion and to support enforcement of specific regulations such as toll systems or ramp controls. They are also being used increasingly as a reliable source of information to road users through ATIS.
The main benefits of these systems are related to the early detection and management of incidents, so reducing congestion and incident related delays.

The use of these systems in New Zealand is growing, particularly in Auckland and Wellington, and studies have indicated benefits are being achieved in these areas.
In terms of the objectives set out by the NZTS and LTMA, these systems deliver benefits in the following areas:

- Economic Development
- Safety and Personal Security
- Access and Mobility
- Public Health
- Sustainability

They also have the potential to provide a positive contribution towards the following New Zealand specific target areas:

- Congestion Relief
- Demand Management
- Incident Management
- Safety
- Route Security
- Travel Time Reliability

Implemented in the appropriate areas, and with a suitable level of operations resource, the technologies used are well developed and low risk.

5.1.1.7 Example Applications

Table 5.1.1.2 Example applications of Traffic Monitoring and Surveillance systems.

Location	Description	Observed Benefits & Costs
Auckland Motorway (NZ)	Used since 1999 to monitor traffic and manage incidents on the core motorway network and, since 2003, for ramp metering monitoring and public traffic information services.	An analysis of 62 events captured on video in 2001 showed that where a response was required from the TMC, the situation was detected and the response initiated within 10 minutes for more than 90% of events. Most being attended to within 5 minutes.
Georgia, USA NAVIGATOR	Georgia's NAVIGATOR Intelligent Transportation System is a motorway management system, consisting of 66 surveillance cameras and 318 video detection system (VDS) cameras. Research carried out in 1999 focused exclusively on reduced delay due to accidents on the motorway.	The benefits identified during this evaluation were attributed entirely to the surveillance and incident detection facilities. The study documented a 38% reduction in response time, leading to an average 23-minute reduction in incident duration, resulting in cost savings of US$44.6 million/year due to reduced delay time.
San Antonio, Texas, USA	Study carried out in 2000 focused on the evaluation of nine ITS implementation projects in the city of San Antonio, Texas, during a period of significant growth in both population and travel demand. The nine projects studied were aimed at assisting the existing transportation infrastructure in accommodating this growth. San Antonio already had a relatively extensive implementation of ITS prior to this study and, consequently, the incremental benefits experienced in San Antonio through expansion and additions to the existing system were expected to be smaller than the benefits that could be achieved in areas with little prior implementation of ITS.	Through a modelling exercise, the study investigated the impacts of each implementation individually, as well as the combined impact. Results indicated that the most effective stand-alone implementation was incident detection and management, recording improvements in all impact measures assessed. Incident detection and management resulted in a 5.7% decrease in delay, a 2.8% decrease in crashes, and a 1.2% decrease in fuel consumption annually. Using the fully integrated systems of incident management and VMS along a particular corridor the reduction in delay during a major incident was 16.2 %; with and incident management system operating alone the reduction was 4.6 %.

5.1.2 Incident Detection Systems

5.1.2.1 Description

Incident detection systems assist traffic management centre controllers to pick up incidents more rapidly, enabling wider coverage to be achieved without compromising response time.

They generally consist of:

- Video image processors used in conjunction with CCTV cameras.
- Induction loops set at regular intervals and monitored using complex algorithms.
- Virtual loops using video image processing to simulate on road loops.
- Infrared detectors.
- Ultrasonic detectors.

In recent years advances in Video Image Processing technology has led to an increased use of video based systems, and an expansion from dedicated fixed camera based systems to VIP applications on existing Pan Tilt Zoom cameras. The application of radar, infrared and ultrasonic detection devices has also increased as these technologies have become more reliable and cost effective.

5.1.2.2 Benefits

The main benefits of Automated Incident Detection (AID) systems are that they allow traffic managers to monitor traffic movements across a wider area more effectively and efficiently in real-time and to respond to any problems that may arise more quickly. As with broader surveillance and monitoring systems they can help in the following areas:

- Reducing incident response times leading to more rapid return to maximum capacity.
- Assisting in managing traffic congestion.
- Providing an improved source of information to other systems (such as ATIS).
- Improving traffic efficiency through more effective management of incidents.
- Indirectly improving safety through reduced secondary accidents.

Some of the benefits of specific technologies include;

- Infrared - day/night operation, installation and repair do not require traffic disruption, better detection rates in fog than standard image based systems.
- Ultrasonic - can measure volume, speed, occupancy, presence, and queue length.
- Video image processing - provides a live image of traffic and therefore more information to the operator, can monitor multiple lanes, installation and repair do not require traffic disruption.

5.1.2.3 Potential Problems

The main problems associated with automated incident detection are:

- Public concern regarding privacy and civil liberties when video is used.
- False alarm rates or missed incidents if the system is not adjusted correctly.
- Managing multiple incident alarms when congestion develops from the first incident.
- Sensitivity of loop based systems and application to appropriate conditions.
- Achieving full coverage using video can be expensive.

Some of the problems with specific technologies include;

- Infrared - sensors have unstable detection zones, and one per lane generally required.
- Ultrasonic - subject to distortion from environmental factors.
- Video image processing - different algorithms usually required for day and night use, susceptible to atmospheric effects and adverse weather.

5.1.2.4 Applications

As with other surveillance technologies, in a motorway environment this type of technology is used most widely where traffic volumes are high and the effect of minor incidents is significant. This translates to mainly urban motorway situations with high peak traffic flows, or particularly vulnerable sections.

An important component of any surveillance systems is the monitoring resource. Where a TMC or other dedicated facilities exist, AID can be an effective tool to help increase coverage and improve response time without major expansion of the operating resource.

A major factor in the successful deployment of AID is designing a system appropriate to the specific needs of the area. This can mean for example combining loop or virtual loop applications on longer open sections with targeted video systems in the most vulnerable sections.

The primary benefits of any traffic surveillance technology in a motorway environment remains the management of incidents and congestion and therefore the main criteria for deployment should be relatively high traffic volumes and vulnerability of flow to minor incidents.

5.1.2.5 Relevance to NZTS/LTMA Objectives

Table 5.1.2.1 Contribution of Incident Detection Systems to NZTS/LTMA objectives (derived from Contribution Matrix Section 1).

NZTS / LTMA Objective	Level of contribution	Comment
A. Economic Development	High	
Traffic Congestion	✓	Assist in early detection of incidents, so reducing congestion and incident related delays. Supporting economic development goals, such as improving the efficient flows of people, goods and services, and assisting in extracting maximum capacity from existing infrastructure. In the area of traffic/transport demand management, these facilities contribute mainly as a component of other systems.
Traffic/Transport Demand	➲	
Travel time on key routes	✓	
Transportation Costs (travel time, VOC)	✓	
Travel time for car commuters to key employment centres	✓	
Maintain strategic route security / availability / information	✓	
Quality & efficiency of transport	✓	
Travel time reliability	✓	
B Safety and Personal Security	Medium	
Number of traffic crashes	➲	Assist in reducing congestion related secondary crashes, improving response time to critical injuries, so improving personal safety.
Level of fatalities	➲	
Level & severity of personal injury	➲	
Compliance (with traffic / transport regulations)	➲	

Table 5.1.2.1 (continued)

NZTS / LTMA Objective	Level of contribution	Comment
C Access & Mobility	*High*	
Traffic Congestion	✓	Assist in early detection of incidents on critical and strategic routes, so reducing congestion and incident related delays. Improve access and mobility through the more efficient use of local networks and supporting traffic/transport demand management as a component of other systems.
Traffic/Transport Demand	➲	
Sector to sector travel times by car	✓	
Frequency and reliability of key passenger transport services	✓	
Convenience (perceived and actual) of public transport services	➲	
Level (%) of commuting trips by passenger transport	➲	
Strategic route security / availability / information	✓	
Quality & efficiency of transport	✓	
Travel time reliability	✓	
D Public Health	*Medium*	
Traffic congestion in urban areas (impacts on local air quality)	✓	Contribute to public health objectives such as enhancing air quality and reduce exposure to transport noise by assisting in early detection of incidents, so reducing congestion and related emissions and noise. Reduce congestion related crashes and response time to critical injuries.
Vehicle noise	➲	
Compliance (with emissions regulations)	➲	
Level & severity of personal injury	➲	
E Sustainability	*High*	
Traffic/Transport Demand	➲	Contribute to sustainability objectives such as Improving the efficiency of existing networks, and improving mobility for people, goods and services with minimal adverse effects by: Assisting in early detection of incidents; so reducing congestion and related delays, emissions and noise. Supporting traffic/transport demand management as a component of other systems.
Level(%) of trips that are not car based	➲	
Emission levels (particulates, nitrogen oxides, carbon monoxides, CO_2)	➲	
Levels of service on key routes	✓	
Extent to which the benefits will be sustainable over time	✓	
F Energy Efficiency	*High*	
Traffic Congestion	✓	Contribute to energy efficiency objectives such as improving the efficiency of existing networks. Assist in early detection of incidents; so reducing congestion and related delays. Support traffic/transport demand management as a component of other systems.
Traffic/Transport Demand	➲	
Efficiency of routes taken	➲	
Fuel use	➲	
level of travel in congested conditions	✓	
Use of energy efficient modes	➲	
Quality & efficiency of transport	✓	
G Integration	*Low*	
None	×	Although often a component of other integrated systems, does not deliver specifically to any integration objectives.

Table 5.1.2.1 (continued)

NZTS / LTMA Objective	***Level of contribution***	***Comment***
H Responsiveness	*High*	
Contributions to national objectives	✓	Assist in early detection of incidents, so reducing congestion and incident related delays. Support responsiveness goals, such as improving travel time reliability, maintaining strategic route availability and the general quality and efficiency of transport.
Maintain strategic route security / availability / information	✓	
Quality & efficiency of transport	✓	
Travel time reliability	✓	
I Affordability and Cost Effectiveness	*High*	
Relative benefit to cost ratio	✓	When implemented in appropriate situations cost effectiveness is good. However the cost of ongoing operations and maintenance needs to be fully considered.
Level of operating cost	✓	
J Implementation Risk	*Low*	
Technical complexity	✓	Generally, the base technologies in this area are well developed. Complexity levels are highest in the areas of AID algorithms and video image processing. Cost reliability is generally good and low risk. The main sources of risk are inappropriate applications or combinations and recognizing the level of operating commitment and cost.
Interoperability	✓	
Cost certainty	✓	
Public acceptance	✓	
✓ = Positive Contribution; ✗ = No Significant Contribution; ➲ = Partial Contribution		

5.1.2.6 Summary and Conclusions

AID systems mainly provide an aid to traffic operators in the early detection of problems to improve response time. In a motorway environment the most common uses of this technology are in areas of high traffic flow where minor incidents lead to significant traffic congestion and delay. They are also being used increasingly to improve the reliability of information to road users through ATIS.

The main benefits of these systems are related to the early detection of incidents; so reducing congestion and incident related delays. There are a number of these systems in New Zealand, on the Auckland and Wellington motorways, using video and loop technologies.

In terms of the objectives set out by the NZTS and LTMA, these systems deliver benefits in several areas, including:

- Economic Development
- Safety and Personal Security
- Access and Mobility
- Public Health
- Sustainability

They also have the potential to provide a positive contribution towards the following New Zealand specific target areas:

- Congestion Relief

- Demand Management
- Incident Management
- Safety
- Route Security
- Travel Time Reliability

Implemented in the appropriate areas, and with a suitable level of operations resource, the technologies used are well developed and low risk.

5.1.2.7 *Example Applications*

Table 5.1.2.2 Example applications of Incident Detection Systems

Location	Description	Observed Benefits & Costs
USA - comparison of accident detection time to fatalities	A study in the early 1990s carried out by the USDOT research authority examined the benefits for accident victims when the accident notification time is reduced, specifically, the relationship between accident fatalities and accident notification time. Considering the benefits of AID in this area, access to emergency medical services (EMS) was shown to positively affect accident fatality rates.	The time period before the arrival of EMS is often critical in determining fatalities. During this period, accident victims receive little or no first aid and unattended injuries may lead to death. In the United States, accident notification time constitutes about forty-five percent of the time period before arrival of EMS. Based on national statistics, the average accident notification time was 5.2 minutes (the accident notification time being the difference between the time the accident occurs and the time that an EMS was notified). Reducing this notification time from 5.2 minutes to 3 minutes using AID was estimated to lead to an 11% reduction in fatalities. If the accident notification time were reduced to 2 minutes, a 15% reduction in fatalities would be achieved.
Ngauranga Gorge Incident Detection System Wellington, NZ	Installed in 1999/2000 the Ngauranga Gorge AID system uses Video Image Processes to detect incidents through a vulnerable and strategic section of motorway.	Although no specific studies have been done to asses the effectiveness of this system, studies of the overall benefits of the traffic management system have indicated that the rapid detection achieved through the AID contributes to a significant improvement in response time.
Gowanus Expressway/ Prospect Expressway rehabilitation project. Brooklyn, NY, USA	The Gowanus Expressway/Prospect Expressway rehabilitation project in Brooklyn has an advanced incident detection system consisting of video AID system and 20 closed-circuit television (CCTV) cameras with pan/tilt/zoom capabilities. Other technologies include highway advisory radio (HAR), VMS, and a construction information hotline. Processors analyze the data from the CCTVs and determine speed, occupancy, and volume of the vehicles.	Before the Automated incident detection system was introduced it took an average of 1.5 hours to clear any type of incident. Since implementation of the system, the time it takes to aid a motorist whose vehicle has broken down has been reduced to 19 minutes. If an accident occurs, the average time from inception to clearing is now 31 minutes.

5.1.3 Variable Message Signs

5.1.3.1 Description

Variable Message Signs (VMS) provide information to road users on incidents, traffic and road conditions. In a motorway environment they are generally large gantry mounted devices using Light-Emitting Diode (LED) technology; operated from a traffic control centre. VMS are also used to provide information on alternative routes, planned works and special events, safety messages and in some instances advertising messages.

VMS are often used as a component of other systems such as:

- Ramp metering controls.
- Motorway lane control systems.
- Warning systems for speed, height restrictions etc.
- Automated warning of specific hazards such as ice / fog / hidden queues.

5.1.3.2 Benefits

The main benefit of VMS in a motorway environment is providing drivers with real-time information on congestion and incidents. Thus allowing improved selection of alternative routes and reducing the risk of secondary accidents when incidents occur. In particular, VMS can help in the following areas:

- Improving traffic efficiency by reducing demand in congested areas.
- Assisting in diverting traffic away from incidents or heavily congested areas.
- Providing up to date information to drivers on hazards and road conditions.
- Improving safety through reduced congestion related or secondary accidents.

5.1.3.3 Potential Problems

The main problems associated with VMS:

- Ensuring they are placed in locations where they deliver optimum value (e.g. where drivers have the best opportunity to benefit from the information provided).
- To be effective there must be a reliable source of information)e.g. Surveillance and TMC).
- Ensuring that any. sign systems installed are interoperable with existing facilities (e.g. TMC communications).
- Recognition of the cost of maintenance and commitment to ongoing operations
- The cost of units suitable for motorway application is relatively high; and there is some evidence that, where a range of alternative information sources are available, the tangible benefits are limited.

5.1.3.4 Applications

In a motorway environment this type of technology is used most widely where traffic volumes are high and the effect of incidents leads to there being benefit in having advance warning. As the cost of these facilities is relatively high, they are best deployed where alternative routes are available and accessible, or where there is an identified safety benefit from the advance warning of incidents and congestion. This translates to mainly urban motorway situations with high traffic flows, or particularly vulnerable sections.

The use of automated VMS is also growing in the area of hazard warning.

5.1.3.5 Relevance to NZTS/LTMA Objectives

Table 5.1.3.1 Contribution of Variable Message Signs to NZTS/LTMA objectives (derived from Contribution Matrix Section 1).

NZTS / LTMA Objective	Level of contribution	Comment
A Economic Development	*High*	
Traffic Congestion	✓	Assist in providing warning of incidents and congestion, reducing congestion and improving traffic flow. Support economic development goals, such as improving the efficient flows of people, goods and services; and extracting maximum capacity from existing infrastructure. In the area of traffic/transport demand management, these facilities contribute by reducing traffic demand in congested areas.
Traffic/Transport Demand	✓	
Travel time on key routes	✓	
Transportation Costs (travel time, VOC)	✓	
Travel time for car commuters to key employment centres	✓	
Maintain strategic route security / availability / information	✓	
Quality & efficiency of transport	✓	
Travel time reliability	✓	
B Safety and Personal Security	*Medium*	
Number of traffic crashes	➲	Contribute indirectly by reducing secondary crashes due to advance warning of congestion and incidents
Level & severity of personal injury	➲	
C Access & Mobility	*High*	
Traffic Congestion	✓	Assist in providing warning of incidents and congestion, reducing congestion and improving traffic flow on critical and strategic routes. Improving access and mobility through the more efficient use of local networks. In the area of traffic/transport demand management, these facilities contribute by reducing traffic demand in congested areas.
Traffic/Transport Demand	✓	
Sector to sector travel times by car	✓	
Frequency and reliability of key passenger transport services	➲	
Convenience (perceived and actual) of public transport services	➲	
Level (%) of commuting trips by passenger transport	➲	
Strategic route security / availability / information	✓	
Quality & efficiency of transport	✓	
Travel time reliability	✓	
D Public Health	*Low*	
Traffic congestion in urban areas (impacts on local air quality)	✓	Provide advance warning of incidents and congestion, allowing selection of alternatives routes/modes and reducing further build up. Contributes indirectly by reducing secondary crashes due to advance warning of congestion and incidents.
Level & severity of personal injury	➲	

Table 5.1.3.1 (continued)

NZTS / LTMA Objective	***Level of contribution***	***Comment***
E Sustainability	*High*	
Traffic/Transport Demand	✓	Contribute to sustainability objectives such as Improving the efficiency of existing networks, and improving mobility for people, goods and services with minimal adverse effects. Provide advance warning of incidents and congestion, allowing selection of alternatives routes/modes and reducing further build up; so reducing congestion and related delays, emissions and noise. In the area of traffic/transport demand management, these facilities contribute by reducing traffic demand in congested areas.
Level(%) of trips that are not car based	➲	
Growth rate of total vehicle travel	➲	
Emission levels (particulates, nitrogen oxides, carbon monoxides, CO_2)	➲	
Levels of service on key routes	✓	
Extent to which the benefits will be sustainable over time	✓	
F Energy Efficiency	*High*	
Traffic Congestion	✓	Contribute to energy efficiency objectives; improving the efficiency of existing networks, and improving mobility for people, goods and services. Provide advance warning of incidents and congestion, allowing selection of alternatives routes/modes and reducing further build up; so reducing congestion. In the area of traffic/transport demand management, these facilities contribute by reducing traffic demand in congested areas.
Traffic/Transport Demand	✓	
Efficiency of routes taken	✓	
Fuel use	➲	
level of travel in congested conditions	✓	
Use of energy efficient modes	➲	
Quality & efficiency of transport	✓	
G Integration	*Medium*	
Efficiency and convenience of mode transfer points	✓	Assist in providing timely information to users on broader transport alternatives such as rail and bus. Contributes to improving integration between modes.
Level of integration between road and rail	✓	
Improving rural community access & conditions	✓	
H Responsiveness	*High*	
Responding to diverse stake holder needs (particularly rural versus urban)	✓	Assist in providing warning of incidents and congestion; reducing congestion and improving traffic flow. Support responsiveness maintaining strategic route availability, travel time reliability and quality and efficiency of transport.
Contributions to national objectives	✓	
Maintain strategic route security / availability / information	✓	
Quality & efficiency of transport	✓	
Travel time reliability	✓	
I Affordability and Cost Effectiveness	*Medium*	
Relative benefit to cost ratio	✓	When implemented in appropriate situations cost effectiveness is good. However initial cost is high and the cost of ongoing operations and maintenance needs to be fully considered.
Level of operating cost	➲	

Table 5.1.3.1 (continued)

NZTS / LTMA Objective	Level of contribution	Comment
J Implementation Risk	*Low*	
Technical complexity	✓	Generally, the base technologies in this area are well developed and the complexity level low. This leads to a high level of cost reliability and low risk. The main sources of risk are inappropriate applications, interoperability with broader TMC systems, and recognizing the level of operating commitment and cost.
Interoperability	✓	
Cost certainty	✓	
Public acceptance	➲	
Implementation constraints – resource consents, legal & others	✓	
✓ = Positive Contribution; ✗= No Significant Contribution; ➲ = Partial Contribution		

5.1.3.6 Summary and Conclusions

Variable Message Signs (VMS) provide information to road users on incidents, traffic and road conditions, alternative routes and occasionally advance warning of planned road works. In a motorway environment they are generally large gantry mounted devices using LED technology.

The main benefits of VMS in a motorway environment are achieved by providing drivers information on road conditions, congestion and incidents, facilitating improved selection of alternative routes and reducing the risk of secondary accidents. In terms of the objectives set out by the NZTS and LTMA, these systems deliver benefits in several areas, including:

- Economic Development
- Safety and Personal Security
- Access and Mobility
- Sustainability

They also have the potential to provide a positive contribution towards the following New Zealand specific target areas:

- Congestion Relief
- Demand Management
- Incident Management
- Safety
- Route Security
- Quality and Efficiency
- Travel Time Reliability

Implemented in the appropriate areas, and with a suitable level of operations resource, the technologies used are well developed and low risk.

5.1.3.7 Example Applications

Table 5.1.3.2 Example applications of Variable Message Signs.

<table>
<tr><th>Location</th><th>Description</th><th>Observed Benefits & Costs</th></tr>
<tr><td>Auckland Motorway, NZ</td><td>Used since 1999 to warn of incidents and congestion on the core urban motorway network.</td><td>The Auckland ATMS Stage II Project on the Northern Motorway has reduced non-recurrent congestion and delays due to incidents and accidents.
Savings in accidents and accident security have also been identified as a result of the en-route driver information provided by VMS. Some of this reduction directly related to warnings of previous accidents or incidents.
Estimated values of the benefits achieved
<table>
<tr><th>Type of Benefit</th><th>Demonstration Project Benefits ($ million)</th></tr>
<tr><td>Reduction in non-recurrent congestion</td><td>3.2</td></tr>
<tr><td>Accident reduction benefits</td><td>5.2</td></tr>
<tr><td>Reduced delays due to accidents</td><td>3.9</td></tr>
<tr><td>Reduction in recurrent congestion</td><td>1.6</td></tr>
</table></td></tr>
<tr><td>Wisconsin, USA</td><td>In December 2001, the University of Wisconsin surveyed drivers to assess the impacts of traveller information made available on a motorway Variable Message Sign (VMS) system.</td><td>Approximately 68% of respondents reported adjusting their travel routes based on the traffic information provided by the VMS system during the winter months (December – March). About 12% of respondents adjusted their travel routes more than 5 times per month using this information.
Approximately 72% of respondents reported adjusting their travel routes based on the traffic information provided by the VMS system during non-winter months (April – November). About 18% of respondents adjusted their travel routes more than 5 times per month using this information.</td></tr>
<tr><td>Detroit, USA</td><td>A study of the combined ITS facilities on the Detroit motorways provided evidence that ITS proved most beneficial under conditions of significant supply variations, such as incidents, and to a lesser extent during demand variations.</td><td>As part of this study variable message signs were shown to benefit commuters in terms of awareness of traffic activities. Providing psychological/convenience benefits in terms of providing drivers with information about what is causing delays and congestion.
In terms of delay reductions, however, commuters acting upon VMS messages of delay found little benefit, and at times also increased delay by diverting.
VMS proved no benefit to facility operation in terms of flow or speed.</td></tr>
</table>

5.1.4 Mobile Variable Message Signs

5.1.4.1 Description

Mobile Variable Message Signs (MVMS) are mobile signs used to display messages at temporary locations. The signs are usually trailer mounted, with their own battery power supply; however other power supplies are used, including diesel generator, mains, solar and wind.

There are a range of technologies used for the actual display, including magnetic disks, rotating prisms and LED's. With their low power consumption and high performance and reliability, LED's are the most widely used. These are now available in a number of colours, but to meet traffic sign regulations white, yellow/amber and red are generally used.

These LED signs can be categorised into two types, full matrix and fixed. The matrix signs comprise of a bed of LED's, which enable the operator to produce any number of message and in some cases, pictorial messages.

Fixed LED signs usually have the ability to show only two messages, with each message triggered by some defined criteria. These signs are substantially cheaper than the full matrix type but have limited capability. These signs are generally used in conjunction with some form of detection e.g., speed detection.

There are various systems available for programming messages. Early systems required an engineer to physically plug into each sign to alter a message, but it is now more common for wireless communications to be used, with ability to control groups of signs simultaneously. This move to wireless communications allows the signs to be managed centrally in conjunction with any static VMS to provide a coordinated traffic management system and avoids any conflict or misinformation.

5.1.4.2 Benefits

The trailer-mounted design of mobile VMS allows for easy and speedy deployment. Their stand alone design allows them to be deployed in any number of locations to deal with short term incidents or seasonal issues. Mobile VMS provide the same strategic benefits as static VMS, however their mobility provides the additional benefits below;

- No construction required i.e. posts, power supply, communications.
- Reusable.
- Can be located in areas with no power supply.
- No need to be connected to a fixed communications line.
- Quickly and easily deployed.
- Easily programmed.

5.1.4.3 Potential Problems

The main problems associated with mobile VMS:

- Ensuring they are placed in locations where they deliver optimum strategic value.
- The sign is only as good as the information it is displaying. Accurate reliable information is paramount.

- Ensuring that any sign systems installed are interoperable with existing facilities (e.g. TMC communications).
- Battery needs recharging/generator needs refueling periodically.
- Signs are not as large as static VMS therefore messages may not be clear to high speed vehicles.

5.1.4.4 Applications

Mobile VMS can be used for a number of applications;

General traffic management

Unplanned events such as accidents always require a rapid response, the flexibility of mobile VMS makes them invaluable tools in these situations.
Planned events such as road works and diversions are suited to mobile VMS deployment. The use of automated VMS is also growing in the area of hazard warning, with these mobile units now using wireless communications they can be managed from the same central system as static VMS, receiving data from Automatic Incident Detection Systems.

Event management

Large events often require their own traffic management plans. Mobile VMS can be quickly deployed without the need for any disruptive civil works. The plans can easily be created to suit the specific requirements of the event.

Safety messages and public information messages.

Mobile VMS are a useful tool in the provision of other types of information. The VMS can be implemented to provide road safety messages either for a particular campaign or in locations known to have a specific safety problem at a particular time of year. With the addition of speed detection equipment, these signs can become an effective safety tool. Mobile VMS have also been used to advertise alternative means of transport. With the signs located in areas of congestion the messages can inform drivers of park and ride schemes or comparative journey times for public transport.

5.1.4.5 Relevance to NZTS/LTMA Objectives

Table 5.1.4.1 Contribution of Mobile Variable Message Signs to NZTS/LTMA objectives (derived from Contribution Matrix Section 1).

NZTS / LTMA Objective	***Level of contribution***	***Comment***
A Economic Development	*High*	
Traffic Congestion	✓	Assist in providing warning of incidents and congestion, reducing congestion and improving traffic flow. Support economic development goals, such as improving the efficient flows of people, goods and services; and extracting maximum capacity from existing infrastructure. In the area of traffic/transport demand management, these facilities contribute by reducing traffic demand in congested areas. Through informative messages the signs can help improve modal shift.
Traffic/Transport Demand	✓	
Travel time on key routes	✓	
Transportation Costs (travel time, VOC)	✓	
Travel time for car commuters to key employment centres	✓	
Maintain strategic route security / availability / information	✓	
Quality & efficiency of transport	✓	
Travel time reliability	✓	

Table 5.1.4.1 (continued)

NZTS / LTMA Objective	***Level of contribution***	***Comment***
B Safety and Personal Security	*Medium*	
Number of traffic crashes	➲	Contribute indirectly by reducing secondary crashes due to advance warning of congestion and incidents.
Level & severity of personal injury	➲	
C Access & Mobility	*High*	
Traffic Congestion	✓	Assist in providing warning of incidents and congestion, reducing congestion and improving traffic flow on critical and strategic routes. Improve access and mobility through the more efficient use of local networks. In the area of traffic/transport demand management, these facilities contribute by reducing traffic demand in congested areas. The signs can also provide information regarding public transport in areas of congestion encouraging modal shift.
Traffic/Transport Demand	✓	
Sector to sector travel times by car	✓	
Frequency and reliability of key passenger transport services	➲	
Convenience (perceived and actual) of public transport services	➲	
Level (%) of commuting trips by passenger transport	➲	
Strategic route security / availability / information	✓	
Quality & efficiency of transport	✓	
Travel time reliability	✓	
D Public Health	*Low*	
Traffic congestion in urban areas (impacts on local air quality)	✓	Provide advance warning of incidents and congestion, allowing selection of alternatives routes/modes and reducing further build up. Contribute indirectly by reducing secondary crashes due to advance warning of congestion and incidents. Through congestion reduction air pollution is also reduced.
Level & severity of personal injury	➲	
E Sustainability	*High*	
Traffic/Transport Demand	✓	Contribute to sustainability objectives such as Improving the efficiency of existing networks, and improving mobility for people, goods and services with minimal adverse effects. Provide advance warning of incidents and congestion, allowing selection of alternative routes/modes and reducing further build up; so reducing congestion and related delays, emissions and noise. In the area of traffic/transport demand management, these facilities contribute by reducing traffic demand in congested areas.
Level(%) of trips that are not car based	➲	
Growth rate of total vehicle travel	➲	
Emission levels (particulates, nitrogen oxides, carbon monoxides, CO_2)	➲	
Levels of service on key routes	✓	
Extent to which the benefits will be sustainable over time	✓	

Table 5.1.4.1 (continued)

NZTS / LTMA Objective	***Level of contribution***	***Comment***
F Energy Efficiency	*High*	
Traffic Congestion	✓	Contribute to energy efficiency objectives; improving the efficiency of existing networks, and improving mobility for people, goods and services. Provide advance warning of incidents and congestion, allowing selection of alternatives routes/modes and reducing further build up, so reducing congestion. In the area of traffic/transport demand management, these facilities contribute by reducing traffic demand in congested areas.
Traffic/Transport Demand	✓	
Efficiency of routes taken	✓	
Fuel use	➲	
level of travel in congested conditions	✓	
Use of energy efficient modes	➲	
Quality & efficiency of transport	✓	
G Integration	*Medium*	
Efficiency and convenience of mode transfer points	✓	Assist in providing timely information to users on broader transport alternatives such as rail and bus. Contribute to improving integration between modes.
Level of integration between road and rail	✓	
Improving rural community access & conditions	✓	
H Responsiveness	*High*	
Responding to diverse stake holder needs (particularly rural versus urban)	✓	Assist in providing warning of incidents and congestion, reducing congestion and improving traffic flow. Support responsiveness maintaining strategic route availability, travel time reliability and quality and efficiency of transport.
Contributions to national objectives	✓	
Maintain strategic route security / availability / information	✓	
Quality & efficiency of transport	✓	
Travel time reliability	✓	
I Affordability and Cost Effectiveness	*High*	
Relative benefit to cost ratio	✓	Compared to static VMS the cost is relatively low. When implemented in appropriate situations cost effectiveness is good. Renewable energy sources can be used keeping operating costs low.
Level of operating cost	✓	
J Implementation Risk	*Low*	
Technical complexity	✓	Generally, the base technologies in this area are well developed and the complexity level low. This leads to a high level of cost reliability and low risk. The main sources of risk are inappropriate applications, interoperability with broader TMC systems, and recognizing the level of operating commitment and cost.
Interoperability	✓	
Cost certainty	✓	
Public acceptance	➲	
✓ = Positive Contribution; ✗= No Significant Contribution; ➲ = Partial Contribution		

5.1.4.6 Summary and Conclusions

Mobile VMS are a cost effective, versatile traffic management tool. Through the provision of reliable information, mobile VMS can help manage incidents, reducing congestion and incident related delays.

In terms of the objectives set out by the NZTS and LTMA, these systems deliver benefits in several areas, including:

- Economic Development

- Safety and Personal Security
- Access and Mobility
- Environmental Sustainability

They also have the potential to provide a positive contribution towards the following New Zealand specific target areas:

- Congestion Relief
- Demand Management
- Incident Management
- Compliance
- Safety
- Route Security
- Quality & Efficiency
- Travel Time Reliability
- Environmental Mitigation

Implemented in the appropriate areas that allow end users to make a strategic decision, and with a suitable level of operations resource, the technologies used are well developed and low risk.

Mobile VMS are currently used in New Zealand, mainly in the major urban centres.

5.1.4.7 Example Applications

Table 5.1.4.2 Example applications of Mobile Variable Message Signs.

Location	Description	Observed Benefits & Costs
United Kingdom	Highways Agency Safer Temporary Traffic Management Operations Initiative	As a part of the evaluation of both speed detection and variable messaging systems (VMS), the Trials Team undertook the testing of a 'portable' VMS system which was in use on a set of motorway works. The trial of the system aimed to determine whether such systems can slow traffic in advance of temporary works. Examination of the data for the sign deployed between the 1 mile and 800 yard signs suggests that there may be some useful effect. In terms of safety for the traffic management teams, the signs could simply be turned off remotely when the traffic management was not required, which cut down the number of worker/vehicle conflicts, significantly improving safety.
Virginia, USA	Effectiveness of Mobile Variable Message Signs in Controlling Speeds in Work Zones.	In combination with radar speed detection equipment, to relay speed back to passing vehicles, it was found that MVMS are an effective means of reducing vehicle speeds and speed variance.

5.1.5 Speed Enforcement

5.1.5.1 Description

Automated speed enforcement systems monitor the speed of passing vehicles using induction loops, radar or video virtual loops to determine speed; and use either video or film technology to record any speed violations. In most cases they are operated by the Police.

5.1.5.2 Benefits

The main benefit derived from speed enforcement systems is improved safety through compliance with static and variable speed limits. Additionally, in some areas this technology is used in conjunction with variable speed limits to help optimise capacity and improve general traffic flow.

5.1.5.3 Potential Problems

The main problems associated with speed enforcement systems are:

- The level of coverage is generally limited to spot locations.
- Increasing coverage across a wider area is expensive.
- Operational procedures can be complicated and costly.
- Public opposition, particularly where no specific safety problem is recognised.
- When used in conjunction with variable speed limits results are mixed.

5.1.5.4 Applications

In a motorway or arterial environment this type of technology is used most widely where there is a specific speed related accident problem, such as the approaches to intersections, areas of unusual geometry or grades. The specific locations of these devices can be critical, and consideration needs to be given to the potential safety problems they can cause (such as causing sharp breaking at hazardous locations).

Other considerations include:

- Technology restrictions of legislations (eg acceptability of digital images).
- Compatibility with privacy legislation and police/court processes.
- Access to cameras for servicing and calibration.
- Interoperability with variable speed systems.

5.1.5.5 Relevance to NZTS/LTMA Objectives

Table 5.1.5.1 Contribution of Speed Enforcement to NZTS/LTMA objectives (derived from Contribution Matrix Section 1).

NZTS / LTMA Objective	*Level of contribution*	*Comment*
A Economic Development	*Low*	
Maintain strategic route security / availability / information	➲	Can help improve safety and reduce crash related delays, and crash rates on vulnerable sections of strategic routes.
Quality & efficiency of transport	➲	

Table 5.1.5.1 (continued)

NZTS / LTMA Objective	Level of contribution	Comment
B Safety and Personal Security	High	
Number of traffic crashes	✓	Improve compliance with fixed and variable speed limits. Reduce speed related crashes through targeted enforcement.
Level of fatalities	✓	
Level & severity of personal injury	✓	
Compliance (with traffic / transport regulations)	✓	
C Access & Mobility	Low	
Compliance (with traffic / transport regulations)	✓	Improve compliance with fixed and variable speed limits. Can help improve safety and reduce crash related delays. Can help reduce crash rates on vulnerable sections of strategic routes.
Strategic route security / availability / information	➲	
Quality & efficiency of transport	➲	
D Public Health	Low	
Level & severity of personal injury	➲	Reduce speed related crashes through targeted enforcement.
E Sustainability	Low	
None	✖	Although can be a component of other systems, does not deliver specifically to any sustainability objectives.
F Energy Efficiency	Low	
Quality & efficiency of transport	➲	Can help improve safety and reduce crash related delays.
G Integration	Low	
Improving rural community access & conditions	✓	Assist in reducing speed through small communities.
H Responsiveness	Low	
Contributions to national objectives	✓	Can help improve safety and reduce crash related delays. Can help reduce crash rates on vulnerable sections of strategic routes.
Maintain strategic route security / availability / information	➲	
Quality & efficiency of transport	➲	
I Affordability and Cost Effectiveness	High	
Relative benefit to cost ratio	✓	When implemented in appropriate situations cost effectiveness is good. However cost of ongoing operations and maintenance needs to be fully considered.
Level of operating cost	✓	
J Implementation Risk	Low	
Technical complexity	✓	Generally, the base technologies in this area are well developed and the complexity level low. This leads to a high level of cost reliability and low risk. The main sources of risk are inappropriate applications, compatibility with legal process and interoperability with other systems.
Interoperability	✓	
Cost certainty	✓	
Public acceptance	➲	
Implementation constraints – resource consents, legal & others	✓	

✓ = Positive Contribution; ✖ = No Significant Contribution; ➲ = Partial Contribution

5.1.5.6 Summary and Conclusions

Speed Enforcement Technologies are used to improve compliance with fixed and variable speed limits. They contribute to reducing speed related crashes through targeted enforcement, and in doing so can help reduce crash related delays. They can contribute to reducing crash rates on vulnerable sections of strategic routes, and assists in reducing speed through small communities. The use of speed cameras in New Zealand is widespread.

When implemented in appropriate situations cost effectiveness is good. However the cost of ongoing operations and maintenance needs to be fully considered. Generally, the base technologies in this area are well developed and the complexity level low. This leads to a high level of cost reliability and low risk. The main sources of risk are inappropriate applications, compatibility with legal process and interoperability with other systems.
In terms of the objectives set out by the NZTS and LTMA, these systems deliver benefits in Safety and Personal Security

They also have the potential to provide a positive contribution towards the following New Zealand specific target areas:

- Compliance
- Safety
- Route Security

5.1.5.7 Example Applications

Table 5.1.5.2 Example applications of Speed Enforcement systems.

Location	**Description**						
UK National	An independent two year pilot study was carried out in the UK between 2000 and 2002 to evaluate the safety impacts and customer satisfaction associated with increased deployment of automated speed cameras and red-light cameras. The study covered 599 sites in 8 regions. The speed camera technologies used included fixed mount cameras at identified accident sites and portable (mobile) speed camera systems on longer sections of roadway where accident frequency was less clustered. The benefits recorded in seven of the regions examined are set out below.						
	Type	**# of Sites**	**Conditions**	**Crash Impacts at camera sites after 2 years**	**Crash Impacts**	**% Change in Vehicles exceeding speed limit**	**% Change exceeding >15 m/h**
Cleveland	Mobile	33	Area had little experience prior to pilot. All but one site were 30 m/h zones.	KSI casualties decreased 53% and PIAs fell 45%.	No statistically significant change	-46% (mobile)	-65% (mobile)
Lincolnshire	Mobile Fixed	2 42	Area had little experience prior to pilot. About half of sites were 60-70 m/h zones.	KSI casualties fell by 62% and PIAs by 39%	KSIs decreased by 12%.	-73% (fixed)	-94% (fixed)
Northants	Mobile Fixed	45 5	Area had little experience prior to pilot. Ten sites were 60-70 m/h zones.	KSI casualties fell by 39%.	KSI casualties fell by 9%	-81% (fixed)	-98% (fixed)

Table 5.5.2 (continued)

Location	Description						
	Type	**# of Sites**	**Conditions**	**Crash Impacts at camera sites after 2 years**	**Crash Impacts**	**% Change in Vehicles exceeding speed limit**	**% Change exceeding >15 m/h**
Strathclyde	Fixed	28	Nearly all sites were in 30 m/h zones. Area had extensive experience prior to pilot.	KSI casualties at camera sites were down by 67%. PIAs were down by 64% at camera sites.	KSI casualties were down by 14% in the city as a whole.	-61% (fixed)	-61% (fixed)
Essex	Mobile	46	Area had a long history of camera enforcement with casualty reduction. All mobile enforcement took place in urban areas.	No statistically significant change.		-24% (mobile)	-44% (mobile)
Thames Valley	Fixed Mobile	226 50	Area had a long history of camera enforcement. Most in 30 m/h zones.	PIAs increased by 14%.		-65% (fixed)	-98% (fixed)

Location	Description	Observed Benefits & Costs
New Zealand, Identified Black Spots	Speed cameras are sited on stretches of road that have a high number of speed-related crashes. In 2003 there were 13 static cameras operating from more than 50 sites in New Zealand and 31 mobile cameras operating from Police vehicles at more than 1,100 sites. Police choose sites after consultation with the Land Transport Safety Authority, Automobile Association and road controlling authorities. All speed camera sites are signposted.	A study of crash data in the 20 months following the introduction of speed cameras in New Zealand in 1993 found: • A 23% reduction in fatal and serious crashes at urban speed camera sites. • An 11% reduction in fatal and serious crashes at rural speed camera sites.

5.1.6 Ramp Metering

5.1.6.1 Description

Ramp metering is the use of traffic signals at motorway on-ramps to control the rate of entry of vehicles from the surrounding road network. Its main objective is to reduce congestion on the motorway by regulating the flow of vehicles from the on-ramp, thereby reducing the number of merging vehicles affecting the mainline flow. By fragmenting the flow of vehicles entering the mainline flow, the 'turbulence' that often results can be significantly reduced.

The ramp metering systems currently available are generally provided on the basis of:

- Fixed time operation.
- Real-time data.
- Predicted traffic demand.

The type of system used will often depend on the level of congestion experienced, the size of the area to be treated and the existing geometrical constraints of the motorway on-ramps under consideration.

Fixed time systems operate on the basis that the number of vehicles allowed to enter the motorway does not change with existing levels of congestion. It is generally the simplest to introduce, but can be the most uneconomic if congestion is alleviated more quickly than is expected as waiting times for vehicles on the on-ramp can not be altered.

Real-time data systems use information obtained by detectors both on the motorway and the on-ramps to determine the existing level of congestion and, subsequently, the number of vehicles allowed to enter the motorway at any time. These types of systems are considered to be more flexible than the fixed time systems. The main drawback of this type of system is that it is seen as reactive, adjusting metering rates after congestion has already occurred.

Predicted traffic demand systems use information gathered from detectors remotely located across the road network to monitor prevailing conditions, allowing a prediction to be made of the traffic flow conditions in the near future. The rate of entry from the on-ramp can then be adjusted accordingly.

5.1.6.2 Benefits

The main benefits of introducing ramp metering systems onto motorways where congestion occurs are:

- Increased capacity of the motorway, particularly during the peak periods.
- Reduced number of accidents associated with stop-start traffic flows.
- Lower journey times.
- Improved journey time reliability.
- Lower emissions from vehicles on the motorway.

5.1.6.3 Potential Problems

The main problems of introducing ramp metering in areas of motorway congestion are:

- Any existing congestion on the surrounding road network may be exacerbated as drivers divert to other routes as queues on the on-ramps increase.
- The emissions from vehicles waiting on the on-ramp may negate the reduction in emissions from vehicles in the mainline flow.
- Installation and maintenance costs.
- Installation mainly benefits vehicles on longer journeys.
- Poor public perception, as road users do not often appreciate the benefits to the road network as a whole.

5.1.6.4 Applications

Ramp metering is generally applicable in situations where congestion occurs on motorways as a result of:

- Platoons of vehicles entering the motorway from the on-ramp, causing disruption to the mainline flow of vehicles.
- Vehicle flow entering the motorway exceeding the corresponding exiting flow.
- Localised bottlenecks causing mainline congestion.

In order for ramp metering to be effective the following conditions must be satisfied:

- The availability of vehicle storage on the on-ramp and surrounding road network must exceed the queuing that may result following the introduction of the ramp metering controls; and
- Adequate acceleration distance downstream of the ramp meter cordon line must be provided to facilitate safe merging of vehicles into the main stream of traffic.

5.1.6.5 Relevance to NZTS/LTMA Objectives

Table 5.1.6.1 Contribution of Ramp Metering to NZTS/LTMA objectives (derived from Contribution Matrix Section 1).

NZTS / LTMA Objective	***Level of contribution***	***Comment***
A. Economic Development	*High*	
Traffic Congestion	✓	Improve on-ramp merging and controlling access to congested sections, so reducing congestion and related costs
Traffic/Transport Demand	✓	
Travel time on key routes	✓	
Transportation Costs (travel time, VOC)	✓	
Travel time for car commuters to key employment centres	✓	
Maintain strategic route security / availability / information	✓	
Quality & efficiency of transport	✓	
Travel time reliability	✓	
B Safety and Personal Security	*Medium*	
Number of traffic crashes	➲	Reduce conflict by improving on-ramp merging and controlling access to congested sections; and reducing secondary crashes due to congestion.
Level of conflict between vehicles / cyclists / pedestrians and other road users	✓	

Table 5.1.6.1 (continued)

NZTS / LTMA Objective	Level of contribution	Comment
C Access & Mobility	*High*	
Traffic Congestion	✓	Improve on-ramp merging and controlling access to congested sections. Reduce congestion and improve overall network efficiency.
Traffic/Transport Demand	✓	
Sector to sector travel times by car	✓	
Frequency and reliability of key passenger transport services	✓	
Convenience (perceived and actual) of public transport services	✓	
Level (%) of commuting trips by passenger transport	✓	
Strategic route security / availability / information	✓	
Quality & efficiency of transport	✓	
Travel time reliability	✓	
D Public Health	*Low*	
Traffic congestion in urban areas (impacts on local air quality)	✓	Reduce congestion by improving on-ramp merging and controlling access to congested sections. Contribute to smoother traffic flow as part of a wider demand management strategy.
Vehicle noise	➲	
E Sustainability	*High*	
Traffic/Transport Demand	✓	Reduce congestion by improving on- ramp merging and controlling access to congested sections.
Level(%) of trips that are not car based	➲	
Growth rate of total vehicle travel	➲	
Emission levels (particulates, nitrogen oxides, carbon monoxides, CO_2)	✓	
Levels of service on key routes	✓	
Extent to which the benefits will be sustainable over time	✓	
F Energy Efficiency	*High*	
Traffic Congestion	✓	Reduce congestion by improving on-ramp merging and controlling access to congested sections.
Traffic/Transport Demand	✓	
Efficiency of routes taken	✓	
Fuel use	✓	
level of travel in congested conditions	✓	
Use of energy efficient modes	✓	
Quality & efficiency of transport	✓	
G Integration	*Low*	
Provision for all modes on key transport corridors	➲	Assist in making provision for all modes. Improve efficiency of travel between centres.
Improving rural community access & conditions	➲	

Table 5.1.6.1 (continued)

NZTS / LTMA Objective	Level of contribution	Comment
H Responsiveness	*High*	
Responding to diverse stake holder needs (particularly rural versus urban)	➲	Assist in making provision for all modes. Reduce congestion by improving on-ramp merging and controlling access to congested sections.
Contributions to national objectives	✓	
Maintain strategic route security / availability / information	✓	
Quality & efficiency of transport	✓	
Travel time reliability	✓	
I Affordability and Cost Effectiveness	*Medium*	
Relative benefit to cost ratio	✓	When implemented in appropriate situations cost effectiveness is good. However the cost of ongoing operations and maintenance needs to be fully considered.
Level of operating cost	➲	
J Implementation Risk	*Medium*	
Technical complexity	➲	Generally, the base technologies in this area are well developed. Complexity levels are highest in the areas of AID algorithms and video image processing. Cost reliability is generally good and low risk. The main sources of risk are inappropriate applications or combinations and recognizing the level of operating commitment and cost.
Interoperability	➲	
✓ = Positive Contribution; ✗ = No Significant Contribution; ➲ = Partial Contribution		

5.1.6.6 Summary and Conclusions

In general, ramp metering is considered to be a very successful method of motorway demand management in areas where congestion occurs due to high flows of traffic from the on-ramp.

The benefits include significant improvements in the capacity of the motorway, reduced accident rates associated with stop-start traffic flow, reduced average journey times and increase journey time reliability. Some benefits with regard to a reduction in emissions by vehicles on the motorway can be expected, although this may be offset by increased emissions from vehicles queuing on the on-ramps. The main disbenefits relate to the increase in delays to vehicles on the surrounding road network, and the subsequent increase in congestion away from the motorway as drivers choose alternative routes. Ramp metering is being used to a limited extent in New Zealand at a number of sites on the Auckland motorway.

In terms of the objectives set out by the NZTS and LTMA, these systems deliver benefits in several areas, including:

- Economic Development
- Safety and Personal Security
- Access And Mobility
- Sustainability

They also have the potential to provide a positive contribution towards the following New Zealand specific target areas:

- Congestion Relief
- Demand Management
- Incident Management
- Safety
- Route Security
- Quality and Efficiency
- Travel Time Reliability

5.1.6.7 Example Applications

Table 5.1.6.2 Example applications of Ramp Metering.

Location	Description	Observed Benefits & Costs
Minneapolis / St Paul, Minnesota, USA	Introduction of 39 ramp meters with HOV bypass facilities along the I-35.	32% Increase in peak vehicle throughput. Average peak period vehicle speeds increased from 34 to 46 m/h. Number of peak period accidents declined 27%, and the peak period accident rate declined by 38%.
M6 Motorway, West Midlands, United Kingdom	Introduction of isolated ramp meter and VMS connected to central computer for monitoring purposes. The ramp metering system was eventually expanded to other sites in the locality.	Bottleneck capacity increased by 172vph reducing the peak period by 20 minutes. Daily saving of 107 vehicle hours. Less than 5% of drivers diverted to other routes. Ramp delays added 1.5 minutes to average travel time. No adverse public reaction.
Zoetemeer, Netherlands	Introduction of nine ramp metres on the A12 between Utrecht and The Hague.	Increase in average speeds in peak periods from 46kmp to 53kmp. Reduction in travel times of 13%. Increased bottleneck capacity by 3%. Increase in ramp travel times of 20 sec.

5.1.7 Vehicle Access (Ramp) Control Systems

5.1.7.1 Description

Vehicle access control systems (VACS) provide a means of regulating the entry of vehicles into restricted areas by introducing methods of control on designated access roads. These systems can include physical measures such as:

- Automated rising bollards.
- Road blockade barriers.

Video-based systems can also be used, which utilise automatic registration plate recognition technology to capture the vehicles that enter a restricted zone.

VACS systems can be introduced to:

- Support bus priority measures.
- Enforce HOV traffic regulations.
- Allow exclusive access for emergency service vehicles.
- Support tolling systems.

In general, the access control systems used to prevent or regulate vehicles in restricted areas are operated using a smart-card or electronic tags supplied to an approved vehicle. The card or tag is read as the vehicle approaches the device and the system removes the barrier and allows the vehicle to pass.

In areas where higher flow rates are required, optical character recognition cameras can be used to read the registration plate of approaching vehicles to determine whether the vehicles are entitled to proceed into the restricted area.

5.1.7.2 Benefits

The main benefits of introducing VACS are:

- Improved vehicle adherence to traffic regulations.
- Increased security in restricted areas.
- Improved ability to manage road capacity and demand.
- Improved potential for demand management.

5.1.7.3 Potential Problems

The main problems of introducing VACS are:

- Potential for failure through accidental or deliberate damage.
- Installation, operations and maintenance costs.
- Many requite tags or Smart cards which lead to significant cost and operational resource commitment.

5.1.7.4 Applications

VACS are used most commonly where the prohibition of general traffic from a designated area is required, but where other vehicles are permitted to enter at certain times (eg bus lanes, HOV lanes etc).

These systems are best deployed where there are reasonable levels of protection of the restricted area beyond the immediate area of the ramp control.

5.1.7.5 Relevance to NZTS/LTMA Objectives

Table 5.1.7.1 Contribution of Vehicle Access Control Systems to NZTS/LTMA objectives (derived from Contribution Matrix Section 1).

NZTS / LTMA Objective	*Level of contribution*	*Comment*
A. Economic Development	*Low*	
Travel time on key routes	➲	Reduce congestion by improving on ramp access and merging for bus services. Provide opportunity to control access and give priority to "true cost" users. Improve efficiency and travel time reliability for bus services by reducing congestion effects and providing priority access. Improve travel time reliability for bus services by reducing congestion effects and providing priority access.
Transport users face the true costs of use	➲	
Quality & efficiency of transport	➲	
Travel time reliability	➲	
B Safety and Personal Security	*Medium*	
Number of traffic crashes	✓	Reduce conflict by improving on-ramp merging and controlling access to congested sections; and reducing secondary crashes due to congestion.
Level of conflict between vehicles / cyclists / pedestrians and other road users	✓	
Perceived personal safety/security for non car mode trips	✓	
Compliance (with traffic / transport regulations)	➲	
C Access & Mobility	*Medium*	
Sector to sector travel times by car	➲	Reduce congestion by improving on-ramp access and merging for bus services. Improve compliance by providing managed priority. Improve efficiency and travel time reliability for bus services by reducing congestion effects and providing priority access.
Frequency and reliability of key passenger transport services	✓	
Convenience (perceived and actual) of public transport services	✓	
Level (%) of commuting trips by passenger transport	✓	
Compliance (with traffic / transport regulations)	➲	
Quality & efficiency of transport	➲	
Travel time reliability	➲	
D Public Health	*Low*	
None	✗	No direct contribution to Public Health objectives.
E Sustainability	*High*	
Level(%) of trips that are not car based	✓	Provide public transport priority, reduce conflict and improving on ramp merging. Provide opportunity for control access and to give priority to 'true cost' users. Reduce congestion by improving on ramp access and merging for bus services.
Growth rate of total vehicle travel	✓	
Emission levels (particulates, nitrogen oxides, carbon monoxides, CO_2)	✓	
Extent to which users face full cost of their road use	➲	
Levels of service on key routes	➲	
Extent to which the benefits will be sustainable over time	✓	

Table 5.1.7.1 (continued)

NZTS / LTMA Objective	Level of contribution	Comment
F Energy Efficiency	*High*	
Fuel use	✓	Provide public transport priority, reducing conflict and improving on ramp merging. Improve travel time reliability for bus services by reducing congestion effects and providing priority access.
Use of energy efficient modes	✓	
Quality & efficiency of transport	➲	
G Integration	*High*	
Provision for all modes on key transport corridors	✓	Assist in making provision for all modes. Provide public transport priority, reduce conflict and improving on ramp merging. Can be used at main interchanges to improve efficiency. Assist in making provision for all modes.
Level of priority given to passenger transport	✓	
Efficiency and convenience of mode transfer points	➲	
Improving rural community access & conditions	✓	
H Responsiveness	*High*	
Responding to diverse stake holder needs (particularly rural versus urban)	✓	Provide public transport priority, reducing conflict and improving on ramp merging. Improve efficiency and travel time reliability for bus services by reducing congestion effects and providing priority access.
Contributions to national objectives	✓	
Quality & efficiency of transport	➲	
Travel time reliability	➲	
I Affordability and Cost Effectiveness	*Medium*	
Relative benefit to cost ratio	➲	When implemented in appropriate situations cost effectiveness is good. However the cost of ongoing operations (particularly where vehicle based technology is used) and maintenance needs to be fully considered.
Level of operating cost	➲	
Contribution direct from users	➲	
J Implementation Risk	*Medium*	
Technical complexity	➲	Generally, the base technologies in this area are well developed. Complexity levels are highest in the areas of smart cards and video image processing. Cost reliability is generally good and low risk. The main sources of risk are inappropriate applications or combinations and recognizing the level of operating commitment and cost.
Interoperability	➲	
Cost certainty	➲	
Public acceptance	➲	
Implementation constraints – resource consents, legal & others	✓	
✓ = Positive Contribution; ✗ = No Significant Contribution; ➲ = Partial Contribution		

5.1.7.6 Summary and Conclusions

Vehicle access control systems enable road authorities to provide physical barriers, or effective enforcement tools; on access roads that reinforce traffic regulations and improve security by restricting traffic flow into designated areas.

In general, this technology is considered to be a successful method of access control provided the appropriate solutions are applied. These systems can assist in reducing congestion by improving on ramp access and merging for bus services, providing opportunity to control access and giving priority to 'true cost' users. They also assist in improving efficiency and travel time reliability for bus services by reducing congestion effects and providing priority access.

Safety benefits include reducing conflict by improving on ramp merging and controlling access to congested sections; and reducing secondary crashes due to congestion.
When implemented in appropriate situations cost effectiveness is good. However the cost of ongoing operations (particularly where vehicle based technology is used) and maintenance needs to be fully considered.

No such systems are currently operating in New Zealand.

In terms of the objectives set out by the NZTS and LTMA, these systems deliver benefits in several areas, including:

- Safety and Personal Security
- Access and Mobility
- Sustainability

They also have the potential to provide a positive contribution towards the following New Zealand specific target areas:

- Congestion Relief
- Demand Management
- Compliance
- Safety
- Route Security
- Quality and Efficiency
- Travel Time Reliability

5.1.7.7 Example Applications

Table 5.1.7.2 Example applications of Vehicle Access Control Systems.

Location	Description	Observed Benefits & Costs
Core Traffic Scheme – Cambridge, UK	Introduced in 1997 as part of a bus priority scheme, general traffic was prevented from travelling through a restricted cordon into Cambridge city centre. Rising bollards were installed at key locations and buses, taxis, local residents and businesses were provided with electronic keys to allow access to the restricted areas. Before and after surveys were carried out and a consultation period undertaken after the scheme had been operational for 6 months.	Targeted routes showed significant decreases, up to 85%, in traffic flow. Main evaluation of scheme concluded that there were significant decreases on targeted routes with rising bollards without a reciprocal increase in traffic flow on other routes. Peak journey times on inner ring road were significantly reduced, while off-peak journey times increased slightly. Air quality surveys indicated that nitrogen oxide levels at 16 out of 18 sites reduced or stayed the same following the introduction of the scheme. Implementation cost of scheme was £150,000, with annual maintenance costs of £5,000. Operation performance of the bollards was initially poor, with a number of vehicles trying to enter the restricted zone immediately behind a bus or taxi, causing damage to the bollards. However, the introduction of flashing warning lights on the approach to the bollards significantly reduced the number of vehicles trying to enter the zone illegally.
Congestion Charging Scheme – Durham, UK	Introduced in October 2002, the project restricted vehicle access to a small part of historical Durham city centre between 10am and 4pm. Drivers are charged £2 at an exit point controlled by a rising bollard in the middle of the exit road. The machine does not issue change; the correct amount must be paid. Residents, postal deliveries, emergency service vehicles and public service vehicles are exempt from the charge. Money raised by the charge subsidises a bus service between Durham Rail Station, park & ride sites & CC zone.	Prior to implementation of the scheme the number of vehicles entering the congestion-charging zone was 800-900 per day. This number has been reduced by 85-90% in the first 6 months of operation.

5.1.8 Lane Control Systems

5.1.8.1 Description

Lane control systems are generally mounted above motorway lanes and relay warning messages and travel information to drivers to inform them of the prevailing traffic conditions/lane availability ahead.

These systems can be used as follows:

- To inform drivers of an incident downstream to enable them to make informed decisions about the route they intend to take and the most appropriate lane in which to proceed, or to inform them of the likelihood of queues ahead.
- To reverse the direction of a lane to provide increased capacity at times of heavy traffic flow, as part of a tidal flow system.
- To inform drivers of lane closures or congestion ahead.
- To inform drivers of specific lane allocations such as peak period bus lanes.

The systems generally consist of:

- Variable message signs mounted on gantries above the carriageway.
- Traffic monitoring devices including surveillance cameras and loop detectors to monitor traffic flow and the build up of queues following incidents or during periods of inclement weather.

In general, the messages that are displayed are green, red or amber arrows to indicate the status of lanes ahead. These are often combined with a capability to display mandatory or advisory speed limits, and short messages.

5.1.8.2 Benefits

The main benefits of introducing lane control systems are:

- Providing an essential component of tidal flow or variable lane allocation systems.
- Reduction in the number and severity of primary and secondary accidents.
- Improved traffic flow stability.
- Reduction in traffic weaving.
- Improved safety and efficiency of maintenance and incident management operations.
- Improved emergency vehicle movement.

5.1.8.3 Potential Problems

The main problems of lane control systems are the relatively high cost and need for broad coverage in order to achieve effective results. To be effective there is a need to sign each lane, and this leads to a need for regularly spaced gantries and high numbers of sign units.

5.1.8.4 Applications

Lane control systems are generally applicable on multi lane motorways and other main arterial routes. They are applicable in situations where tidal flow is used, where there is a frequent need to warn of lane closures or queues, changes in lane allocation or use category.

5.1.8.5 Relevance to NZTS / LTMA Objectives

Table 5.1.8.1 Contribution of Lane Control Systems to NZTS/LTMA objectives (derived from Contribution Matrix Section 1).

NZTS / LTMA Objective	***Level of contribution***	***Comment***
A. Economic Development	*Low*	
Travel time on key routes	➲	Can help improve safety and reduce crash related delays; improving travel time reliability by assisting in incident management.
Quality & efficiency of transport	✓	
Travel time reliability	➲	
B Safety and Personal Security	*Medium*	
Number of traffic crashes	✓	Reduce conflict by improving lane allocation and use; and reduce secondary and congestion related accidents.
Level of fatalities	➲	
Level of conflict between vehicles / cyclists / pedestrians and other road users	✓	
C Access & Mobility	*Low*	
Sector to sector travel times by car	➲	Can help improve safety and reduce crash related delays, improving travel time reliability by assisting in incident management.
Quality & efficiency of transport	✓	
Travel time reliability	➲	
D Public Health	*Low*	
None	×	No direct contribution to Public Health objectives.
E Sustainability	*Low*	
Levels of service on key routes	➲	Can help improve safety and reduce crash related delays.
F Energy Efficiency	*Medium*	
Quality & efficiency of transport	✓	Can help improve safety and reduce crash related delays, improving travel time reliability by assisting in incident management.
G Integration	*Low*	
None	×	No direct contribution to Public Health objectives.
H Responsiveness	*Medium*	
Contributions to national objectives	✓	Can help improve safety and reduce crash related delays.
Quality & efficiency of transport	✓	
I Affordability and Cost Effectiveness	*Medium*	
Relative benefit to cost ratio	➲	Even when implemented in appropriate situations the cost effectiveness of these systems requires consideration. These systems have a relatively high cost and need for broad coverage in order to achieve effective results. To be effective there is a need to sign each lane, and this leads to a need for regularly spaced gantries and high numbers of sign units. The cost of operation also needs to be considered.
Level of operating cost	➲	

Table 5.1.8.1 (continued)

NZTS / LTMA Objective	***Level of contribution***	***Comment***
J Implementation Risk	*Medium*	
Technical complexity	➲	Generally, the base technologies in this area are well developed. Complexity levels are highest in the areas of interoperability with control systems. Cost reliability is generally good. The main sources of risk are inappropriate applications or combinations and recognizing the level of cost and operating commitment.
Interoperability	➲	
Cost certainty	➲	
Public acceptance	➲	
Implementation constraints – resource consents, legal & others	✓	
✓ = Positive Contribution; ✗= No Significant Contribution; ➲ = Partial Contribution		

5.1.8.6 Summary and Conclusions

Lane control systems can be installed on motorways in situations where the dissemination of information to motorists is important to help them to make informed choices about which lane is most appropriate given the prevailing traffic conditions.

The systems can be used to relay information about incidents downstream from the driver's current position, or to increase capacity of the road network at various times of the day as part of tidal flow or lane allocation systems. Outside of these broader systems, the main benefits are from accident savings and the management of traffic flows during incidents and congestion. A key issue is cost effectiveness, with these systems having a relatively high cost and the need for broad coverage in order to achieve effective results. Lane control signals are in use on the Auckland motorway and Harbour Bridge, particularly in the areas affected by the tidal flow system.

In terms of the objectives set out by the NZTS and LTMA, these systems deliver benefits in several areas, including:

- Safety and Personal Security
- Access and Mobility

They also have the potential to provide a positive contribution towards the following New Zealand specific target areas:

- Congestion Relief
- Demand Management
- Incident Management
- Safety
- Route Security

5.1.8.7 Example Applications

Table 5.1.8.2 Example applications of Lane Control Systems.

Location	Description	Observed Benefits & Costs
Kalla Bridges – Kuopio, Finland	Comprises 70 VMS and a pair of boom gates and traffic lights. The road is a high-level 2 carriageway (2+2 lanes) with maximum speed of 80 km/h on the bridges. The bridge is frequently closed to allow maritime traffic through, and also for maintenance.	Signs informing drivers of closed lanes were well observed. Traffic speed passing road works zones has been halved, significantly increasing road safety for maintenance engineers. Before introduction of system it took up to 4 hour to close the bridge, after it takes less than 10 minutes. Queues of traffic have been observed to be longer.
Harbour Bridge, Auckland, NZ	Operating for several years as part of a tidal flow facility and more recently extended to cover wider section of motorway.	Now operating with a moveable lane barrier, the tidal flow has provided significant benefits across the bridge. The broader use of LCS on the motorway has provided benefits in controlling lane use during works and incidents.
Examples of use purely for lane control; not as part of a tidal flow or lane allocation system are limited, and reflect the view that the high cost of these systems supported purely be the benefits of general traffic and incident management, in isolation.		

5.1.9 Variable Speed Limits

5.1.9.1 Description

Variable speed limits improve traffic flow conditions on roads by amending the speed limit over designated sections to suit prevailing traffic or weather conditions. The variable speed limit signs are generally linked to a central processing system that can be either manually or automatically updated using sensors located along the route.

The sensors located along the route can comprise:

- Surveillance cameras to monitor existing traffic conditions and alert the road authority to incidents or inclement weather, and subsequent congestion.
- Inductive and virtual loops to detect the speed, number and classification of vehicles.
- Rainfall sensors to detect the amount of precipitation and the likelihood of standing water on the carriageway.
- Condensation detectors to determine current levels of fog and mist.
- Wind gauges to measure average wind speeds and gusts.
- Temperature gauges to warn drivers of abnormal conditions in tunnels or on isolated sections of highway where ice may be encountered.

The systems can then operate under predetermined parameters, which restrict speeds under predefined conditions, or on a manual basis, controlled by operators at a central processing centre.

5.1.9.2 Benefits

The main benefits of introducing variable speed limits are:

- Increase in the capacity of the road by optimising flow rate, and subsequent reduction in congestion due to free-flowing traffic conditions.
- Improved network management under special conditions.
- Reduction in the number of speed violations.
- Reduction in the number and severity of accidents.
- Reduction in the number of vehicles weaving between lanes.
- Improved journey time reliability.

5.1.9.3 Potential Problems

The main problems of variable speed limits are:

- They can lead to confusion for drivers if it is not clear whether the speed limits are mandatory or advisory.
- Installation and maintenance costs.

5.1.9.4 Applications

Variable speed limits are generally applicable in situations where congestion occurs on roads as a result of:

- Frequently occurring inclement weather, such as fog or ice.
- In areas of specific hazards such as steep grades or reduced forward visibility.
- Traffic management issues, such as bottlenecks or access arrangements.
- Accident or incident blackspot locations where congestion is commonly experienced.

5.1.9.5 Relevance to NZTS / LTMA Objectives

Table 5.1.9.1 Contribution of Variable Speed Limits to NZTS/LTMA objectives (derived from Contribution Matrix Section 1).

NZTS / LTMA Objective	***Level of contribution***	***Comment***
A. Economic Development	*Medium*	
Traffic Congestion	✓	Reduce congestion by regulating speed to optimum levels, and controlling rate of traffic flow into down stream systems. Can help improve safety and reduce crash related delays. When used in conjunction with tidal flow or lane allocation systems the benefits can be significant. But these benefits are considered separately for the purposes of this study.
Traffic/Transport Demand	✓	
Travel time on key routes	➲	
Transportation Costs (travel time, VOC)	✓	
Travel time for car commuters to key employment centres	➲	
Maintain strategic route security / availability / information	➲	
Quality & efficiency of transport	✓	
Travel time reliability	✓	
B Safety and Personal Security	*Medium*	
Number of traffic crashes	✓	Reduce conflict by regulating speed to optimum levels; and controlling speeds approaching hazards.
Level of fatalities	➲	
Level of conflict between vehicles / cyclists / pedestrians and other road users	✓	
C Access & Mobility	*Medium*	
Traffic Congestion	✓	Reduce congestion by regulating speed to optimum levels, and controlling rate of traffic flow into down stream systems. Can help improve safety and reduce crash related delays; and contributes to smoother traffic flow as part of a wider demand management strategy.
Traffic/Transport Demand	✓	
Sector to sector travel times by car	➲	
Frequency and reliability of key passenger transport services	➲	
Convenience (perceived and actual) of public transport services	➲	
Level (%) of commuting trips by passenger transport	➲	
Strategic route security / availability / information	➲	
Quality & efficiency of transport	✓	
Travel time reliability	✓	

Table 5.1.9.1 (continued)

NZTS / LTMA Objective	***Level of contribution***	***Comment***
D Public Health	*Low*	
Traffic congestion in urban areas (impacts on local air quality)	✓	Reduce congestion by regulating speed to optimum levels and controlling rate of traffic flow into down stream systems. Contribute to smoother traffic flow as part of a wider demand management strategy.
Vehicle noise	➲	
E Sustainability	*Medium*	
Traffic/Transport Demand	✓	Can help improve safety and reduce crash related delays, and control the rate of traffic flow into down stream systems leading to smoother traffic flow and reduced emission levels.
Level(%) of trips that are not car based	➲	
Emission levels (particulates, nitrogen oxides, carbon monoxides, CO_2)	➲	
Levels of service on key routes	➲	
Extent to which the benefits will be sustainable over time	➲	
F Energy Efficiency	*Medium*	
Traffic Congestion	✓	Reduce congestion by regulating speed to optimum levels, and controlling the rate of traffic flow into down stream systems. Can help improve safety and reduce crash related delays; and contributes to smoother traffic flow as part of a wider demand management strategy.
Traffic/Transport Demand	✓	
Efficiency of routes taken	✓	
Fuel use	➲	
level of travel in congested conditions	✓	
Use of energy efficient modes	➲	
Quality & efficiency of transport	✓	
G Integration	*Low*	
None	✗	No direct contribution to Public Health objectives.
H Responsiveness	*Medium*	
Contributions to national objectives	✓	Reduce conflict and improving the smooth flow of traffic. Improving efficiency and travel time reliability, and reducing congestion effects.
Maintain strategic route security / availability / information	➲	
Quality & efficiency of transport	✓	
Travel time reliability	✓	

Table 5.1.9.1 (continued)

NZTS / LTMA Objective	Level of contribution	Comment
I Affordability and Cost Effectiveness	*Medium*	
Relative benefit to cost ratio	➲	Even when implemented in appropriate situations the cost effectiveness of these systems requires consideration. These systems have a relatively high cost and need for broad coverage in order to achieve effective results. To be effective signs for each lane are often necessary, and this leads to a need for regularly spaced gantries and high numbers of sign units. The cost of operation also needs to be considered.
Level of operating cost	➲	
J Implementation Risk	*Medium*	
Technical complexity	➲	Generally, the base technologies in this area are well developed. Complexity levels are highest in the areas of interoperability with control systems. Cost reliability is generally good. The main sources of risk are inappropriate applications or combinations and recognizing the level of cost and operating commitment.
Interoperability	➲	
Cost certainty	➲	
Public acceptance	➲	
Implementation constraints – resource consents, legal & others	✓	
✓ = Positive Contribution; ✗ = No Significant Contribution; ➲ = Partial Contribution		

5.1.9.6 Summary and Conclusions

Variable speed limits can be introduced in conjunction with other road network management systems to improve traffic flow generally, and particularly in poor weather conditions, and reduce the number of associated accidents. However, their introduction can lead to driver confusion if it is not apparent whether the speed limits are advisory or mandatory.

Variable speed signs have been in use in New Zealand for a number of years and in three main forms. In Auckland variable advisory speed signs are in place on sections of the motorway including the harbour bridge. These are used mainly to reduce the speed of traffic during incidents and lane closures.

In Wellington mandatory variable speed signs are in place on a specific section of motorway. These are used to reduce traffic speed during peak periods, incidents and planned highway works.

In the Christchurch area variable mandatory speed signs have been provided in areas close to some schools. These are used to reduce the speed of traffic at peak school times.

In terms of the objectives set out by the NZTS and LTMA, these systems deliver benefits in several areas, including:

- Economic Development
- Safety and Personal Security
- Access and Mobility

- Sustainability

They also have the potential to provide a positive contribution towards the following New Zealand specific target areas:

- Congestion Relief
- Demand Management
- Incident Management
- Safety
- Route Security
- Quality and Efficiency
- Travel Time Reliability

5.1.9.7 Example Applications

Table 5.1.9.2 Example applications of Variable Speed Limits.

Location	Description	Observed Benefits & Costs
E22 European Main Road, Southern Sweden	Variable speed limits in place for a number of years on a section of this road that historically has a high number of accidents.	Speed reductions of approximately 10% have had an impact of reducing accidents by +25%. Cost/benefit ratio of 8:1. Investment cost of AUD$20,000 per km. Speed limits are currently advisory, but planned to be made compulsory.
Salt Lake Valley, Utah, USA	Introduction of VMS signing and visibility sensors recommending speed limits under foggy conditions.	Prior to activation the average vehicle speed was 54 m/h with a standard deviation of 9.5 m/h. After the system began operation, average speeds increased to 62 m/h, with a standard deviation of 7.4 m/h. This represents a 15% increase in speeds and a 22% decrease in standard deviation of those speeds.
A5 Autobahn, Bad Homburg, Frankfurt, Germany	Introduction of loop detectors, video cameras and variable message signs to measure traffic volumes, speeds and detect incidents, and to relay to drivers appropriate speeds for the prevailing conditions.	All accident rates have fallen by an average of 20%. Serious accident rate has fallen by 29%. Estimated annual savings US$4 million for all injury accidents.
Ngauranga Gorge Variable Motorway Speed Signs (VMSS), Wellington, NXZ	Installed in 1999/2000 the Ngauranga Gorge (VMSS) are used mainly to reduce speeds during incidents and reduce congestion.	Studies into the effectiveness of these signs have indicated improvements in safety (reduced accident rates) at congested times.

5.1.10 Special Event Transportation Management

5.1.10.1 Description

Special event transportation management describes the use of a coordinated set of ITS facilities to manage the transportation impacts of a special event. For example the Olympic Games, major street races and other special events that affect either the demand or availability of key transport assets.

5.1.10.2 Benefits

The main benefits from the use of coordinated ITS facilities to manage these events are in minimising disruption to traffic and other transportation services by maximising the efficient use of available services under extreme conditions.
Solutions may include modifications to traffic signal controls, increased priority and capacity for public transport, targeted parking and access control.

5.1.10.3 Potential Problems

Problems associated with special event management plans can include:

- Coordination of systems across institutional boundaries.
- Coordination of public and private sector services.
- Communication of changes to event and local users.
- Capacity and flexibility of existing systems to cope with changes.
- Operations resource and training.

5.1.10.4 Applications

This type of coordinated approach is generally used for larger events from weekend closures of city centres; to large area wide events such as the Olympic Games. The level of planning and advance preparation required is relative to the size and impact of the event. For example, for the Salt Lake Winter Olympics in 2002 planning and development of ITS facilities began five years ahead of the event.

5.1.10.5 Relevance to NZTS / LTMA Objectives

Table 5.1.10.1 Contribution of Special Event Transportation Management systems to NZTS/LTMA objectives (derived from Contribution Matrix Section 1).

NZTS / LTMA Objective	***Level of contribution***	***Comment***
A. Economic Development	*Medium*	
Traffic Congestion	✓	Reduce congestion impacts by managing traffic and transport networks to optimum level. Can include provision for maintaining freight corridors during special events.
Traffic/Transport Demand	✓	
Travel time on key routes	✓	
Transportation Costs (travel time, VOC)	✓	
Travel time for car commuters to key employment centres	✓	
Maintain strategic route security / availability / information	✓	
Quality & efficiency of transport	✓	
Freight transport and mode transfer	➲	
Travel time reliability	✓	

Table 5.1.10.1 (continued)

NZTS / LTMA Objective	Level of contribution	Comment
B Safety and Personal Security	*Medium*	
Number of traffic crashes	✓	Reduce conflict by managing traffic network to optimum level. Also include integration with security systems to protect special events.
Level of conflict between vehicles / cyclists / pedestrians and other road users	✓	
C Access & Mobility	*Medium*	
Traffic Congestion	✓	Improve access and mobility by reducing congestion impacts through managing traffic demand and network operation to optimum level.
Traffic/Transport Demand	✓	
Sector to sector travel times by car	✓	
Frequency and reliability of key passenger transport services	➲	
Convenience (perceived and actual) of public transport services	➲	
Level (%) of commuting trips by passenger transport	➲	
Strategic route security / availability / information	✓	
Quality & efficiency of transport	✓	
Travel time reliability	✓	
D Public Health	*Low*	
Traffic congestion in urban areas (impacts on local air quality)	✓	Reduce congestion by managing traffic network to optimum level, and so reducing negative impacts on noise and air quality.
Vehicle noise	✓	
E Sustainability	*Medium*	
Traffic/Transport Demand	✓	Reduce congestion by managing traffic demand and network operation to optimum level, reducing emissions levels and increasing public transport capacity and use.
Level(%) of trips that are not car based	➲	
Growth rate of total vehicle travel	➲	
Emission levels (particulates, nitrogen oxides, carbon monoxides, CO_2)	➲	
Levels of service on key routes	✓	
Extent to which the benefits will be sustainable over time	✓	
F Energy Efficiency	*Medium*	
Traffic Congestion	✓	Reduce congestion by managing traffic demand and network operation to optimum level, reducing emissions levels and increasing public transport capacity and use.
Traffic/Transport Demand	✓	
Efficiency of routes taken	✓	
Fuel use	➲	
level of travel in congested conditions	✓	
Use of energy efficient modes	➲	
Quality & efficiency of transport	✓	
G Integration	*High*	
Provision for all modes on key transport corridors	➲	Assist in making provision for all modes. Assist in reducing effects on small communities.
Level of priority given to passenger transport	➲	
Efficiency and convenience of mode transfer points	✓	
Improving rural community access & conditions	✓	

Table 5.1.10.1 (continued)

NZTS / LTMA Objective	Level of contribution	Comment
H Responsiveness	*High*	
Responding to diverse stake holder needs (particularly rural versus urban)	➲	Assist in making provision for all modes. Reduce congestion related delays by managing traffic network to optimum level.
Contributions to national objectives	✓	
Maintain strategic route security / availability / information	✓	
Quality & efficiency of transport	✓	
Travel time reliability	✓	
I Affordability and Cost Effectiveness	*Medium*	
Relative benefit to cost ratio	➲	When implemented in appropriate situations cost effectiveness is good. However cost of operations needs to be fully considered.
Level of operating cost	➲	
J Implementation Risk	*Medium*	
Technical complexity	➲	Generally, the base technologies in this area are well developed; however, the complexity level can be high, particularly when interoperability. The main sources of risk are poor coordination and communication, and interoperability between systems.
Interoperability	➲	
Cost certainty	➲	
Public acceptance	➲	
Implementation constraints – resource consents, legal & others	✓	
✓ = Positive Contribution; ✗ = No Significant Contribution; ➲ = Partial Contribution		

5.1.10.6 Summary and Conclusions

Special event transportation management comprises the use of coordinated ITS facilities to manage the transportation impacts of a special event. The main benefits from the use of these facilities are in minimising disruption to traffic and other transportation services by maximising the efficient use of available services under extreme conditions.

When implemented in appropriate situations cost effectiveness is good. However cost of ongoing operations needs to be fully considered. Generally, the base technologies in this area are well developed; however, the complexity level can be high. The main sources of risk are poor coordination and communication, and interoperability between systems.
The use of ITS in special event transportation management is increasing in New Zealand as ITS facilities are expanded and integrated. Specific examples include the use of the Auckland motorway management system and SCATS during closures of the harbour bridge (for marches etc); and the coordinated use of the Wellington ATMS, SCATS and mobile VMS during special events in Wellington City (Motor sports, Carnivals etc),

In terms of the objectives set out by the NZTS and LTMA, these systems deliver benefits in several areas, including:

- Economic Development
- Safety and Personal Security
- Access and Mobility
- Sustainability

They also have the potential to provide a positive contribution towards the following New Zealand specific target areas:

- Congestion Relief

- Demand Management
- Compliance
- Safety
- Route Security
- Quality and Efficiency
- Travel Time Reliability

5.1.10.7 Example Applications

Table 5.1.10.2 Example applications of Special Event Transportation Management systems.

Location	Description	Observed Benefits & Costs
2000 Olympic Games, Sydney, Australia	The Olympic Games were a driving force in the timely construction of the new $30m Transport management Centre.	In addition to the new TMC, 40 VMS were installed throughout Sydney, these along with supplementary mobile VMS help manage traffic throughout the games. They also provided information regarding public transport as private vehicles were banned from much of the city.
2002 Winter Olympic Games, Utah, USA	February 8-24, 2002, Salt Lake City hosted the XIX Olympic Winter Games. With more than 75 events, 2,500 athletes, 750,000 visitors, and 11,500 representatives of the media.	A new state-of-the-art Traffic Operations Centre (TOC) and extensive use of high-tech and ITS equipment also were part of the Olympic transportation plan. With the provision of reliable real time information via VMS and the web the traffic authorities were able to realise a drop in traffic in Salt Lake City of 30 to 40 percent from background flows, while traffic in other hotspots, such as West Valley and Davis County, decreased by 20 to 30 percent during peak travel times.
2002, Commonwealth Games Manchester, England, UK	A range of ITS facilities were used to manage vehicular and pedestrian traffic.	Making the most of the relatively new MANDIS system, authorities were able to monitor vehicular traffic on the motorways surrounding Manchester. Using the motorway VMS, traffic was successfully diverted to the correct venue. This is combination with RTPI on bus, tram and train services and CCTV and ANPR for security, led to a successful games.
2004 Olympic Games, Athens, Greece	VMS installation.	The installation of 24 large variable message signs, at strategic locations around Athens contributed to the traffic management throughout the 2004 games.

5.1.11 Electronic Safety Screening

5.1.11.1 Description

Electronic safety screening systems are systems designed to monitor passing vehicles for specific safety related conditions. These may include for example abnormal hot spots within a vehicle which may indicate a risk of fire (e.g. when entering a tunnel), or combinations of speed and weight approaching a curve which may present a risk of rollover.

These systems can be used to monitor a range of vehicle conditions including; heat, speed, length, weight, weaving, and may be combined with information on road conditions to assess risk.

Other examples include camera surveillance and number plate recognition to monitor vehicle operations and enforce safety regulations such as speed, driver hours.

A further application of electronic safety screening technologies is in vehicle systems. These can monitor a range of safety related parameters and communicate these to the driver and/or vehicle base. Examples include engine monitoring, brake system and load monitoring, driver fatigue and general stability.

5.1.11.2 Benefits

The main benefits of these systems are reduced number and severity of accidents involving heavy vehicles, or in the case of tunnel systems potentially larger incidents.

5.1.11.3 Potential Problems

The main problems, or limitations are, the privacy issues related to closer monitoring; the level of coverage possible at reasonable cost, and in some cases potential delays where vehicles are required to pass through controls at reduced speed.

5.1.11.4 Applications

The application of on road systems is best targeted where a specific hazard has been identified. For example heat detection on approaches to a tunnel where there is a risk of fire from overheating vehicles, or speed and stability monitoring at the approach to a hazardous curve or grade. In vehicle systems are also best employed to target specific issues, but their broader application is likely to be more feasible and cost effective.

5.1.11.5 Relevance to NZTS / LTMA Objectives

Table 5.1.11.1 Contribution of Electronic Safety Screening to NZTS/LTMA objectives (derived from Contribution Matrix Section 1).

NZTS / LTMA Objective	***Level of contribution***	***Comment***
A. Economic Development	*Low*	
Transport users face the true costs of use	➲	Systems can incorporate checks on RUC payments, and may also incorporate charging systems graded by level of safety etc.
Maintain strategic route security / availability / information	➲	
Quality & efficiency of transport	➲	Can assist in reducing incidents caused by unsafe vehicles (crashes and load problems).

Table 5.1.11.1 (continued)

NZTS / LTMA Objective	Level of contribution	Comment
B Safety and Personal Security	*High*	
Number of traffic crashes	✓	Assist in reducing incidents caused by unsafe vehicles, crashes and load problems, and improving compliance with safety regulations by screening.
Level of fatalities	✓	
Level & severity of personal injury	✓	
Compliance (with traffic / transport regulations)	✓	
C Access & Mobility	*Medium*	
Compliance (with traffic / transport regulations)	✓	Improve compliance by screening, and assists in reducing incidents caused by unsafe vehicles (crashes and load problems).
Strategic route security / availability / information	➲	
Quality & efficiency of transport	➲	
D Public Health	*Medium*	
Vehicle noise	➲	Can assist in improving vehicle standards related to noise and emissions, improving compliance by screening. Assists in reducing incidents caused by unsafe vehicles; crashes and load problems.
Compliance (with emissions regulations)	✓	
Level & severity of personal injury	✓	
E Sustainability	*Low*	
Non road freight volumes as a percentage of total	➲	Assist in the monitoring and management of freight. Can incorporate checks on RUC payments, and may also incorporate charging systems graded by level of safety etc.
Extent to which users face full cost of their road use	➲	
Extent to which the benefits will be sustainable over time	✓	
F Energy Efficiency	*Medium*	
Quality & efficiency of transport	➲	Can assist in reducing incidents caused by unsafe vehicles; crashes and load problems.
G Integration	*Low*	
None	×	No specific contribution to integration.
H Responsiveness	*Low*	
Responding to diverse stake holder needs (particularly rural versus urban)	✓	Assist in reducing incidents caused by unsafe vehicles and load.
Contributions to national objectives	✓	
Maintain strategic route security / availability / information	➲	
Quality & efficiency of transport	➲	
I Affordability and Cost Effectiveness	*Medium*	
Relative benefit to cost ratio	➲	When implemented in appropriate situations cost effectiveness is good. However cost of ongoing operations and maintenance needs to be fully considered.
Level of operating cost	✓	
Contribution direct from users	➲	
J Implementation Risk	*Low*	
Technical complexity	✓	Generally, the base technologies in this area are well developed and the complexity level low. This leads to a high level of cost reliability and low risk. The main sources of risk are inappropriate applications, compatibility with legal process and interoperability with other systems.
Interoperability	✓	
Cost certainty	✓	
Public acceptance	➲	
Implementation constraints – resource consents, legal & others	✓	
✓ = Positive Contribution; × = No Significant Contribution; ➲ = Partial Contribution		

5.1.11.6 Summary and Conclusions

Electronic safety screening systems monitor specific safety related conditions either from within the vehicle or at the road side. These systems can be used to monitor a range of vehicle conditions including; heat, speed, length, weight, weaving, and may be combined with information on road conditions to assess risk.

The main benefits of these systems are reduced number and severity of accidents involving heavy vehicles, or in the case of tunnel systems potentially larger incidents.

Generally, the base technologies in this area are well developed and the complexity level low. This leads to a high level of cost reliability and low risk. The main sources of risk are inappropriate applications, compatibility with legal process and interoperability with other systems.

No such systems are currently being operated in New Zealand, although a facility is being established by Transit NZ to monitor heavy vehicles approaching a known accident black spot.

In terms of the objectives set out by the NZTS and LTMA, these systems deliver benefits in several areas, including:

- Safety and Personal Security
- Access and Mobility
- Public Health

They also have the potential to provide a positive contribution towards the following New Zealand specific target areas:

- Compliance
- Safety
- Route Security
- Travel Time Reliability

5.1.11.7 Example Applications

Table 5.1.11.2 Example applications of Electronic Safety Screening systems.

Location	Description	Observed Benefits & Costs
Automated Commercial Vehicle Safety Enforcement Roads and Traffic Authority New South Wales	System of remote automated cameras linked to a central processing centre to monitor commercial vehicle operations and enforce safety regulations. Cameras are located along interstate highways in New South Wales, along with processors that allow the remote sites to photograph the vehicle, perform vehicle detection and classification, and license plate recognition, forwarding the information to the central processing site over an ISDN-based communications network.	The central site processes the information received to determine average vehicle speeds over highway segments, identify registration infractions or license plate alerts, and determine if there is a need for driver fatigue notification. The central location also issues any necessary citations for recorded infractions. An evaluation of the system, considering the reduction in lives lost and the time lost during unnecessary vehicle stops and inspections, found a benefit/cost ratio of 2.5 to 1.

Table 5.1.11.2 (continued)

Location	Description	Observed Benefits & Costs
Mt Blanc Tunnel, France	Heat screening of all commercial vehicles entering tunnel. Introduced because of a long uphill grade and a previous major incident caused by an overheating truck engine.	All trucks are now screened for overheating engine components and brakes, reducing the risk of a fire within the tunnel.

5.1.12 Electronic Weight Screening

5.1.12.1 Description

Electronic weight screening systems are systems designed to monitor the weight of passing commercial vehicles; there are a range of technologies available some more suited to full speed measurement and others designed for lower speed more accurate measurement.

In most cases high speed weigh in motion (WIM) devices are used to monitor passing traffic to provide date on road use and to screen for overweight vehicles.
Other applications include devices at port access points and main freight terminals and distribution centres to assist operators to check weights and the point of loading. WIM can also be used as a component of broader road user charging systems.

Systems are also available which monitor weight on the vehicle, and these have specific applications for some operators in monitoring the loading for their fleet.

5.1.12.2 Benefits

The main benefits of these systems are reduced impact of overweight vehicles on the road infrastructure; reduced risk of accidents related to overweight vehicles, improved compliance with weight and RUC regulations, and more efficient freight interchange operations.

5.1.12.3 Potential Problems

The main problems with these systems include:

- Limited accuracy of full speed devices meaning they cannot be used as a direct enforcement tool.
- Cost of installation of most devices means they are limited in number and portability
- Privacy issues related to closer monitoring.
- The level of coverage possible at reasonable cost, and in some cases potential delays where vehicles are required to pass through controls at reduced speed.
- Frequent calibration of the system is generally required to maintain robustness of the information attained.

5.1.12.4 Applications

The application of these systems is best targeted on sections of highway where alternative routes are limited; or where there is a specific issue or function (such as port access points). As the cost of installation is relatively high locations should be selected carefully; and with a range of technologies available, selecting the best option to suit the specific needs.

When used in support of enforcement, suitable areas for static weighing facilities need to be provided within a reasonable distance of the WIM site.

5.1.12.5 Relevance to NZTS / LTMA Objectives

Table 5.1.12.1 Contribution of Electronic Weight Screening to NZTS/LTMA objectives (derived from Contribution Matrix Section 1).

NZTS / LTMA Objective	***Level of contribution***	***Comment***
A. Economic Development	*Low*	
Transport users face the true costs of use	➲	Can assist in reducing impact of overweight vehicles on pavement; and ensure users are charged relative to weight. Can assist in reducing impact of overweight vehicles on pavement. Can be used a screening facility to assist in improving freight monitoring a processing.
Maintain strategic route security / availability / information	➲	
Quality & efficiency of transport	✓	
Freight transport and mode transfer	✓	
B Safety and Personal Security	*Low*	
Number of traffic crashes	➲	By reducing crashes related to overweight vehicles Improving compliance by screening.
Compliance (with traffic / transport regulations)	✓	
C Access & Mobility	*Low*	
Compliance (with traffic / transport regulations)	✓	Improving compliance by screening. Can assist in reducing impact of overweight vehicles on pavement.
Strategic route security / availability / information	➲	
Quality & efficiency of transport	✓	
E Sustainability	*Medium*	
Non road freight volumes as a percentage of total	✓	Assists in the monitoring and management of freight. Can assist in reducing impact of overweight vehicles on pavement; and ensure users are charged relative to weight.
Extent to which users face full cost of their road use	➲	
Extent to which the benefits will be sustainable over time	✓	
F Energy Efficiency	*Medium*	
Quality & efficiency of transport	✓	Can assist in reducing impact of overweight vehicles on pavement.
G Integration	*Medium*	
Efficiency and convenience of mode transfer points	✓	Can assist in improving efficiency at mode transfer points. Can assist in limiting impact of heavy traffic on local communities.
Level of integration between road and rail	✓	
Improving rural community access & conditions	✓	
H Responsiveness	*Low*	
Responding to diverse stake holder needs (particularly rural versus urban)	✓	Can assist in reducing impact of overweight vehicles on local environments. Can assist in reducing impact of overweight vehicles on pavement.
Contributions to national objectives	✓	
Maintain strategic route security / availability / information	➲	
Quality & efficiency of transport	✓	
I Affordability and Cost Effectiveness	*Medium*	
Relative benefit to cost ratio	➲	Enforcement is an important component of protecting the road asset and ensuring truck safety. Costs of these units can be high but cost effective when used as part of a planned package of measures
Level of operating cost	✓	
Contribution direct from users	➲	

Table 5.1.12.1 (continued)

NZTS / LTMA Objective	***Level of contribution***	***Comment***
J Implementation Risk	*Low*	
Technical complexity	✓	These technologies are fairly well developed and as such risk is low. Main risks are in poor location or coordination as part of an overall package.
Interoperability	✓	
Cost certainty	✓	
Public acceptance	✓	
Implementation constraints – resource consents, legal & others	✓	
✓ = Positive Contribution; ✗ = No Significant Contribution; ➲ = Partial Contribution		

5.1.12.6 Summary and Conclusions

Electronic weight screening systems monitor the weight of passing commercial vehicles. In most cases high speed weigh in motion (WIM) devices are used to monitor passing traffic to provide data on road use and to screen for overweight vehicles.

Other applications include port access points and main freight terminals. WIM can also be used as a component of broader road user charging systems.

The main benefits are in reducing the impact of overweight vehicles and improved compliance with weight and RUC regulations.

Generally, the base technologies in this area are well developed and the complexity level low. This leads to a high level of cost reliability and low risk. The main sources of risk are inappropriate applications, compatibility with legal process and interoperability with other systems.

In New Zealand there are 5 WIM sites installed on the State highway network which use several different technologies. The information generated by these sites is used mainly for asset management planning purposes.

In terms of the objectives set out by the NZTS and LTMA, these systems deliver benefits in several areas, including:

- Safety and Personal Security
- Sustainability

They also have the potential to provide a positive contribution towards the following New Zealand specific target areas:

- Compliance
- Safety
- Route Security
- Quality and Efficiency
- Environmental Mitigation

5.1.12.7 Example Applications

Table 5.1.12.2 Example applications of Electronic Weight Screening.

Location	Description	Observed Benefits & Costs
Downhill Truck Speed Warning System – I70, Denver, USA	Installed in May 1998, a system was introduced to influence driver behaviour as trucks emerged from the I70 Eisenhower Tunnel and approached a 10-mile section of downhill grade highway. The system used weigh-in-motion sensors to monitor vehicle speeds, weight and axle configurations to determine safe speeds for vehicles weighing over 40,000 pounds. VMS technology relayed the safe-speed information to the vehicles. To evaluate the impact of the system vehicle speeds were monitored up-stream and down-stream of the VMS technology, and a period of evaluation was carried out when the system was operational and when it was turned off.	The analysis showed that the system was successful in warning truck drivers of dangerous behaviour. The average speed of trucks that passed the VMS was 5% lower while the system was operational than when it was switched off. A small survey of truck drivers was carried out at a nearby weigh-station. Of the truck drivers surveyed 21 out of 22 drivers agreed that the system would assist them in travelling at safer speeds over the downhill section of highway.

5.2 Arterial Management Systems

Arterial management systems manage traffic along arterial roadways, employing traffic detectors, traffic signals, and various means of communicating information to travellers. These systems make use of information collected by traffic surveillance devices to smooth the flow of traffic along travel corridors. They also disseminate important information about travel conditions to travellers via technologies such as variable message signs (VMS).

Traffic signal control systems address a number of objectives, primarily improving traffic flow and safety. Bus signal priority systems can improve public transport efficiency on arterial corridors and improve on-time performance. Signal pre-emption for emergency vehicles enhances safety while improving response times. Adaptive signal control systems coordinate control of traffic signals across urban areas, adjusting the lengths of signal phases based on prevailing traffic conditions. Advanced signal systems coordinate signal operations across regions. Pedestrian detectors, specialized signal heads, and bicycle-actuated signals can improve the safety of all road users at signalized intersections.

Sharing information with other components of the ITS infrastructure can also have a positive impact on the operation of the transportation system. Examples include coordinating operations with motorway management systems, or providing arterial information to a traveller information system covering multiple roadway and public transport facilities.

A variety of techniques are available to manage traffic and travel on arterial roadways, and ITS applications can support many of these strategies. The systems that are covered in this section are as follows:

5.2.1 Traffic Monitoring and Surveillance

5.2.2 Adaptive Signal Control

5.2.3 Incident Detection Systems

5.2.4 Variable Message Signs

5.2.5 Parking Management

5.2.6 Traffic Signal Enforcement - Red Light Cameras

5.2.1 Traffic Monitoring and Surveillance

5.2.1.1 Description

Traffic monitoring and surveillance systems provide information to transport planners and controllers for use in traffic management systems, incident detection and travel survey analysis. They generally comprise:

- CCTV surveillance cameras.
- Automated monitoring and detection systems.
- Central control facility with data processing software and visual monitoring equipment.

Surveillance and monitoring facilities also often form part of other traffic and transport management systems, such as:

- Adaptive signal control.
- Parking management systems.
- Enforcement systems for tolling, speed, height etc.
- Safety systems in tunnels.

5.2.1.2 Benefits

The main benefits of traffic surveillance and monitoring systems are that they allow traffic planners and managers to observe traffic movements in real-time and respond to any problems that may arise. In particular, surveillance and monitoring systems can help in the following areas:

- Reducing incident response times leading to more rapid return to maximum capacity.
- Assisting in managing traffic congestion and signal operations.
- Providing a reliable source of information to other systems (such as ATIS).
- Assisting in monitoring regulation compliance (e.g. toll facilities).
- Indirectly improving safety through reduced congestion related or secondary accidents.

5.2.1.3 Potential Problems

The main problems associated with traffic surveillance and monitoring systems are:

- Public concern regarding privacy and civil liberties.
- Recognition of the cost of maintenance and commitment to ongoing operations.

5.2.1.4 Applications

In an arterial environment this type of technology is used most widely where traffic volumes are high and the effect of minor incidents is significant. This translates to mainly urban arterials with high peak traffic flows, or particularly vulnerable sections. Although, with the rapidly reducing costs of camera and communications technology this is changing and the cost/benefit equation for surveillance of less congested sections is improving.

An important component of surveillance systems is the monitoring resource. Where a TMC or other dedicated facility exists this is generally not a significant issue, however, as the deployment of surveillance increases it is important to ensure that these facilities are resourced to deal with the increasing level of demand.

The use of traffic surveillance for purposes other than incident detection and congestion management is also increasing; including toll systems and other regulation enforcement. However, the primary benefits of traffic surveillance in an arterial environment remain the management of incidents and congestion. Therefore the main criteria for deployment should be relatively high traffic volumes and vulnerability of flow to minor incidents.

5.2.1.5 Relevance to NZTS / LTMA Objectives

Table 5.2.1.1 Contribution of Arterial Traffic Monitoring and Surveillance to NZTS/LTMA objectives (derived from Contribution Matrix Section 2).

NZTS / LTMA Objective	*Level of contribution*	*Comment*
A. Economic Development	*High*	
Traffic Congestion	✓	Assist in early detection & management of incidents and traffic signal control, so reducing congestion and delays. Support economic development goals, such as improving the efficient flows of people, goods and services, and extracting maximum capacity from existing infrastructure. In the area of traffic/transport demand management, these facilities contribute mainly as a component of other systems.
Traffic/Transport Demand	➲	
Travel time on key routes	✓	
Transportation Costs	✓	
Travel time for car commuters to key employment centres	✓	
Maintain strategic route security / availability / information	✓	
Quality & efficiency of transport	✓	
Travel time reliability	✓	
B Safety and Personal Security	*Medium*	
Number of traffic crashes	➲	Assist in reducing congestion related secondary crashes, improving response time to critical injuries, so improving personal safety, and assisting in road safety enforcement as a component of other systems.
Level of fatalities	➲	
Level & severity of personal injury	➲	
Compliance (with traffic / transport regulations)	➲	
C Access & Mobility	*High*	
Traffic Congestion	✓	Assist in early detection & management of incidents and traffic signal control on critical and strategic routes, so reducing congestion and delays. Improve access and mobility through the more efficient use of local networks and support traffic/transport demand management as a component of other systems.
Traffic/Transport Demand	➲	
Sector to sector travel times by car	✓	
Frequency and reliability of key passenger transport services	✓	
Convenience (perceived and actual) of public transport services	✓	
Level (%) of commuting trips by passenger transport	➲	
Compliance (with traffic / transport regulations)	➲	
Strategic route security / availability / information	✓	
Quality & efficiency of transport	✓	
Travel time reliability	✓	
D Public Health	*Medium*	
Traffic congestion in urban areas (impacts on local air quality)	✓	Contribute to public health objectives such as enhancing air quality and reducing exposure to transport noise by: Assisting in early detection of incidents and managing traffic; so reducing congestion and related emissions and noise. Improving enforcement of emissions regulations, reducing congestion related crashes and response time to critical injuries.
Vehicle noise	➲	
Compliance (with emissions regulations)	✓	
Level & severity of personal injury	➲	

Table 5.2.1.1 (continued)

NZTS / LTMA Objective	Level of contribution	Comment
E Sustainability	*High*	
Traffic/Transport Demand	➲	Contribute to sustainability objectives such as improving the efficiency of existing networks, and improving mobility for people, goods and services with minimal adverse effects by: Assisting in early detection of incidents and managing traffic; so reducing congestion and related delays, emissions and noise. Supporting traffic/transport demand management as a component of other systems.
Level(%) of trips that are not car based	➲	
Emission levels (particulates, nitrogen oxides, carbon monoxides, CO_2)	➲	
Levels of service on key routes	✓	
Extent to which the benefits will be sustainable over time	✓	
F Energy Efficiency	*High*	
Traffic Congestion	✓	Contribute to energy efficiency objectives such as improving the efficiency of existing networks. Assisting in early detection of incidents and managing traffic, so reducing congestion and related delays. Support traffic/transport demand management as a component of other systems.
Traffic/Transport Demand	➲	
Efficiency of routes taken	➲	
Fuel use	➲	
level of travel in congested conditions	✓	
Use of energy efficient modes	➲	
Quality & efficiency of transport	✓	
G Integration	*Low*	
Non	✗	Although often a component of other integrated systems, does not deliver specifically to any integration objectives.
H Responsiveness	*High*	
Contributions to national objectives	✓	Assist in early detection & management of incidents and traffic signal control, so reducing congestion and delays. Support responsiveness goals, such as improving travel time reliability, maintaining strategic route availability and the general quality and efficiency of transport.
Maintain strategic route security / availability / information	✓	
Quality & efficiency of transport	✓	
Travel time reliability	✓	
I Affordability and Cost Effectiveness	*Medium*	
Relative benefit to cost ratio	✓	When implemented in appropriate situations cost effectiveness is good. However the cost of ongoing operations and maintenance needs to be fully considered.
Level of operating cost	➲	
J Implementation Risk	*Low*	
Technical complexity	✓	Generally, the base technologies in this area are well developed and the complexity level low. This leads to a high level of cost reliability and low risk. The main sources of risk are recognizing the level of operating commitment and cost; and public acceptance of surveillance.
Interoperability	✓	
Cost certainty	✓	
Public acceptance	➲	
Implementation constraints – resource consents, legal & others	✓	
✓ = Positive Contribution; ✗ = No Significant Contribution; ➲ = Partial Contribution		

5.2.1.6 Summary and Conclusions

Traffic surveillance and monitoring systems mainly provide an aid to transport planners and traffic managers in the control of traffic flow.

In an arterial environment the most common uses of this technology are the detection and management of incidents, managing traffic signal operation and the effects of congestion, and to support enforcement of specific regulations such as toll systems. They are also being used increasingly as a reliable source of information to road users through ATIS.

The main benefits of these systems are related to the early detection and management of incidents, and the efficient management of traffic signal control, so reducing congestion and incident related delays.

In New Zealand these systems are now well established in the main urban centres of Auckland, Wellington and Christchurch, and provide support for SCATS operations as well as management of incidents and congestion.

In terms of the objectives set out by the NZTS and LTMA, these systems deliver benefits in several areas, including:

- Economic Development
- Safety and Personal Security
- Access and Mobility
- Public Health
- Sustainability.

They also have the potential to provide a positive contribution towards the following New Zealand specific target areas:

- Congestion Relief
- Demand Management
- Incident Management
- Route Security
- Travel Time Reliability

Implemented in the appropriate areas, and with a suitable level of operations resource, the technologies used are well developed and low risk.

5.2.1.7 Example Applications

Table 5.2.1.2 Example applications of Arterial Traffic Monitoring and Surveillance

Location	Description	Observed Benefits & Costs
Maryland USA	A study carried out in 1999/2000 in the Baltimore-Washington region (USA) examined the effectiveness of incident detection, through surveillance, on the efficiency of response time, and traffic condition recovery time.	In 2000, the average incident duration was about 33 minutes with the systems in place and 77 minutes without. In 1999, the average incident duration was 42 minutes with systems in place and 93 minutes without.

Table 5.2.1.2 (continued)

Location	Description	Observed Benefits & Costs
San Antonio, Texas, USA	This study focused on evaluation of nine ITS implementation projects in the city of San Antonio, Texas, during a period of significant growth in population and travel demand. The nine projects studied were aimed at assisting existing transportation infrastructure to accommodate growth. San Antonio already had a relatively extensive implementation of ITS prior to this study and, consequently, the incremental benefits experienced in San Antonio through expansion and additions to the existing system were expected to be smaller than in areas with little prior implementation of ITS.	The study investigated the impacts of each implementation individually, as well as the combined impact. Results indicated the most effective stand-alone implementation was incident detection and management, recording improvements in all impact measures assessed. Incident detection and management resulted in a 5.7% decrease in delay, a 2.8% decrease in crashes, and 1.2% decrease in fuel consumption annually. Using the fully integrated systems of incident management and VMS along a particular corridor the reduction in delay during a major incident was 16.2 % and with incident management system operating alone this reduced to 4.6 %.
Auckland, NZ	Used in monitoring 'SCATS' intersections.	As part of the Auckland Traffic Management Unit's SCATS operations cameras are used to monitor key intersections, assisting the SCATS operators in improving traffic efficiency at peak times.

5.2.2 Adaptive Signal Control

5.2.2.1 Description

Adaptive traffic signal control is one of the earliest forms of Intelligent Transportation System, having been in operation in various forms since the 1970s. These systems replace traditional fixed-time plans, and basic vehicle actuated modes, with more efficient computer-based adaptive control.

There are several systems in operation with proven track records, the most common being the Sydney Coordinated Adaptive Traffic System (SCATS), and Split Cycle Offset Optimization Technique (SCOOT).

SCATS gathers data on traffic flows in real-time at each intersection. This data is fed via the traffic control signal box to a central computer. The computer makes incremental adjustments to traffic light timings based on minute by minute changes in traffic flow at each intersection. SCATS performs a vehicle count at each stop line, and also measures the gap between vehicles as they pass through each junction. As the gap between vehicles increases the lights are wasting green time, and SCATS seeks to reallocate green time to where demand is greatest. The SCATS system has been operating for many years in New Zealand, Sydney (where it originated), Melbourne, and several US cities.

SCOOT differs from SCATS in that it uses a second set of advance vehicle detectors typically 50-300 metres upstream of the stop line. The advance detectors provide a count of the vehicles approaching at each junction. This gives the system a higher resolution picture of traffic flows and a count of the number of vehicles in each queue, several seconds before they touch the stop line (allowing time for communication between the traffic signal controller and the central SCOOT computer). It also provides exceptional queue length detection information to the system, which is triggered when the traffic queue backs up to the upstream detector. Under the SCOOT system green waves can be dynamically delayed on a ‘just in time’ basis based on the arrival of vehicles at the upstream detector, allowing extra time to the previous green phase where warranted in heavy traffic conditions.

The SCOOT system is used in cities such as Toronto, San Diego, Anaheim, London, and Bangkok.

5.2.2.2 Benefits

The main benefits of these systems are reduced congestion and delay across a network of traffic signals. These result from the system being able to modify signal settings to suit the current traffic conditions and manage demand across a wide area.

Benefits are also achieved through a reduction in congestion related accidents and the ability of the system to adapt to unusual conditions when incidents occur.

5.2.2.3 Potential Problems

The main problems, or limitations, of these systems result from the limitations of the particular network (shape and capacity), the level of control over adjacent systems, and the quality of information available through on-street detection.

5.2.2.4 Applications

The application of adaptive signal control systems is best targeted where there is a network of traffic signals with varying demand patterns. In most cases the application of adaptive signal control will provide benefits over traditional fixed time plans and simple VA operation. However, the cost of the required on road and operations facilities requires consideration to ensure a cost effective application. Exceptions would include smaller groups of traffic signals with relatively static demand profiles; or areas where the level of flexibility of control is limited.

5.2.2.5 Relevance to NZTS / LTMA Objectives

Table 5.2.2.1 Contribution of Adaptive Signal Control to NZTS/LTMA objectives (derived from Contribution Matrix Section 2).

NZTS / LTMA Objective	*Level of contribution*	*Comment*
A Economic Development	*High*	
Traffic Congestion	✓	Optimise traffic signal operation to minimise congestion, and manage demand across the network. This leads to improvements in a range of economic measures including travel time, travel time reliability and operating costs. These systems can also assist in optimising strategic routes and freight corridors at critical times.
Traffic/Transport Demand	✓	
Travel time on key routes	✓	
Transportation Costs (travel time, VOC)	✓	
Travel time for car commuters to key employment centres	✓	
Maintain strategic route security / availability / information	✓	
Quality & efficiency of transport	✓	
Freight transport and mode transfer	➲	
Travel time reliability	✓	
B Safety and Personal Security	*Medium*	
Number of traffic crashes	➲	Reduce conflict by managing the traffic network to optimum level; reducing congestion related incidents and safety at pedestrian and cycle crossings.
Level of conflict between vehicles / cyclists / pedestrians and other road users	✓	

Table 5.2.2.1 (continued)

NZTS / LTMA Objective	Level of contribution	Comment
C Access & Mobility	*High*	
Traffic Congestion	✓	Optimise traffic signal operation to minimise congestion, and managing demand across the network. Improve the ability of bus operators to maintain reliable schedules. Improve the efficiency of pedestrian and cycle signals and assisting in providing pedestrian and bus priority. Also manage availability of strategic routes.
Traffic/Transport Demand	✓	
Sector to sector travel times by car	✓	
Frequency and reliability of key passenger transport services	✓	
Convenience (perceived and actual) of public transport services	✓	
Level (%) of commuting trips by passenger transport	✓	
Level (%) of commuting trips by Cycle	➲	
Level (%) of commuting trips by Pedestrians	✓	
Strategic route security / availability / information	✓	
Quality & efficiency of transport	✓	
Travel time reliability	✓	
D Public Health	*High*	
Traffic congestion in urban areas (impacts on local air quality)	✓	Optimise traffic signal operation to minimise congestion and adverse noise and air quality affects (can be linked to air quality monitoring systems). Assist in managing demand across the network. Improve the efficiency of pedestrian & cycle signals and assisting in providing priority.
Vehicle noise	✓	
Numbers of short trips made by walking or cycling	✓	
Numbers of commuting trips made by walking or cycling	✓	
E Sustainability	*High*	
Traffic/Transport Demand	✓	Optimise traffic signal operation to minimise congestion and adverse noise and air quality affects (can be linked to air quality monitoring systems). Assist in managing demand across the network. Improve the efficiency of pedestrian & cycle signals and assisting in providing priority. Improve the ability of bus operators to maintain reliable schedules.
Level(%) of trips that are not car based	✓	
Emission levels (particulates, nitrogen oxides, carbon monoxides, CO_2)	✓	
Levels of service on key routes	✓	
Extent to which the benefits will be sustainable over time	✓	
F Energy Efficiency	*High*	
Traffic Congestion	✓	Optimise traffic signal operation to minimise congestion; and managing demand across the network. Improve the ability of bus operators to maintain reliable schedules.
Traffic/Transport Demand	✓	
Efficiency of routes taken	✓	
Fuel use	✓	
level of travel in congested conditions	✓	
Use of energy efficient modes	✓	
Quality & efficiency of transport	✓	

Table 5.2.2.1 (continued)

NZTS / LTMA Objective	***Level of contribution***	***Comment***
G Integration	*Medium*	
Provision for all modes on key transport corridors	✓	Assist in making provision for all modes. Can assist in improving efficiency at mode transfer points. Improve the efficiency of pedestrian & cycle signals and assisting in providing priority. Improve the ability of bus operators to maintain reliable schedules.
Efficiency and convenience of mode transfer points	✓	
H Responsiveness	*High*	
Responding to diverse stake holder needs (particularly rural versus urban)	✓	Optimise traffic signal operation to minimise congestion; and managing demand across the network. Optimise traffic signal operation to minimise congestion; and managing availability of strategic routes.
Contributions to national objectives	✓	
Maintain strategic route security / availability / information	✓	
Quality & efficiency of transport	✓	
Travel time reliability	✓	
I Affordability and Cost Effectiveness	*High*	
Relative benefit to cost ratio	✓	When implemented in appropriate situations cost effectiveness is good. However the cost of initial installation and ongoing operations and maintenance is high, and needs to be fully considered.
Level of operating cost	➲	
J Implementation Risk	*Medium*	
Technical complexity	➲	Generally, the base technologies in this area are well developed. Complexity levels are highest in the areas of optimisation software. Cost reliability is generally good and low risk. The main sources of risk are inappropriate applications; lack of maintenance or combinations and recognising the level of operating commitment and cost.
Interoperability	➲	
Cost certainty	➲	
Public acceptance	✓	
Implementation constraints – resource consents, legal & others	✓	

✓ = Positive Contribution; ✗ = No Significant Contribution; ➲ = Partial Contribution

5.2.2.6 Summary and Conclusions

Adaptive traffic signal control systems replace traditional fixed-time plans, and basic vehicle actuated modes with more efficient computer-based adaptive control.

The main benefits of these systems are reduced congestion and delay across a network of traffic signal. These result from the system being able to modify signal settings to suit the current traffic conditions and manage demand across a wide area.

Generally, the base technologies in this area are well developed and cost reliability is generally good and low risk. The main issues are the high cost of initial installation and the commitment to ongoing operations and maintenance.

In New Zealand the SCATS system has been used in the major urban centres for many years. More recently the operation of Auckland's SCATS facilities has been centralised, leading to greater improvements in coordination across a wider area.

In terms of the objectives set out by the NZTS and LTMA, these systems deliver benefits in several areas, including:

- Economic Development
- Safety and Personal Security
- Access and Mobility
- Public Health
- Sustainability

They also have the potential to provide a positive contribution towards the following New Zealand specific target areas:

- Congestion Relief
- Demand Management
- Incident Management
- Safety
- Route Security
- Quality and Efficiency
- Travel Time Reliability

5.2.2.7 Example Applications

Table 5.2.2.2 Example applications of Adaptive Signal Control

Location	Description	Observed Benefits & Costs
State of California, USA	This paper summarizes an evaluation of the benefits of optimizing traffic signal timing plans, coordinating traffic signal control, and implementing adaptive signal control at locations throughout the State of California. The signal timing optimization and coordination projects were carried out during the Fuel Efficient Traffic Signal Management (FETSIM) Program, between 1983 and 1993. This program involved 163 local agencies and 334 projects, improving 12,245 signals.	Timing plans were developed using the TRANSYT-7F software and tested against adaptive control. The study found an average 7.7% reduction in travel time, 13.8% reduction in delays, 12.5% reduction in stops and 7.8% decline in fuel use.
Toronto, Canada	The SCOOT system implemented in Toronto, in 1990 covered 3 signal networks encompassing 75 signalised intersections.	An on-street evaluation conducted from May-June 1993 found an 8% average decrease in travel time, a 22% average decrease in vehicle stops, a 17% average decrease in vehicle delay, a 5.7% average decrease in fuel consumption, a 3.7% average decrease in hydrocarbons, and a 5.0% average decrease in carbon monoxide emissions.

5.2.3 Incident Detection Systems

5.2.3.1 Description

Incident detection systems assist traffic management centre controllers to pick up incidents more rapidly, enabling wider coverage to be achieved without compromising response time.

They generally consist of:

- Video image processors used in conjunction with CCTV cameras.
- Induction loops set at regular intervals and monitored using complex algorithms.
- Virtual loops using video image processing to simulate on road loops.
- Infrared detectors.
- Ultrasonic detectors.

In recent years the advances in Video Image Processing technology have led to an increased use of the video based systems, and an expansion from dedicated fixed camera based systems to VIP applications on existing Pan Tilt Zoom (PTZ) cameras. The application of radar, infrared and ultrasonic detection devices has also increased as these technologies have become more reliable and cost effective.

5.2.3.2 Benefits

The main benefits of automated incident detection (AID) systems are that they allow traffic managers to observe traffic movements across a wider area more effectively and efficiently in real-time and to respond to any problems that may arise more quickly. As with broader surveillance and monitoring systems they can help in the following areas:

- Reducing incident response times leading to more rapid return to maximum capacity.
- Assisting in managing traffic congestion.
- Providing an improved source of information to other systems (such as ATIS).
- Improving traffic efficiency through more effective management of incidents.
- Indirectly improving safety through reduced secondary accidents.

Some of the benefits of specific technologies include;

- Infrared - day/night operation, installation and repair do not require traffic disruption, better detection rates in fog then standard image based systems.
- Ultrasonic - can measure volume, speed, occupancy, presence, and queue length.
- Video image processing - provides live image of traffic and therefore more information to the operator, can monitor multiple lanes, installation and repair do not require traffic disruption.

5.2.3.3 Potential Problems

The main problems associated with automated incident detection are:

- Public concern regarding privacy and civil liberties when video is used.
- False alarm rates or missed incidents if the system is not adjusted correctly.
- Managing multiple incident alarms when congestion developed from the first incident.
- Sensitivity of loop based systems and application to appropriate conditions.
- Achieving full coverage using video can be expensive, even as camera and communications technologies improve; due to the cost of establishing base locations.

Some of the problems with specific technologies include;

- Infrared - sensors have unstable detection zones, and one per lane generally required.
- Ultrasonic - subject to distortion from environmental factors.
- Video image processing - different algorithms usually required for day and night use, susceptible to atmospheric effects and adverse weather.

5.2.3.4 Applications

As with other surveillance technologies, in an arterial environment this type of technology is used most widely where traffic volumes are high and the effect of minor incidents is significant. This translates to mainly urban situations with high peak traffic flows, or particularly vulnerable sections.

An important component of any surveillance systems is the monitoring resource. Where a TMC or other dedicated facilities exist, AID can be an effective tool to help increase coverage and improve response time without major expansion of the operating resource.

A major factor in the successful deployment of AID is designing a system appropriate to the specific needs of the area. This can mean for example combining loop or virtual loop applications on longer open sections with targeted video systems in the most vulnerable sections.

The primary benefits of any traffic surveillance technology in an arterial environment remains the management of incidents and congestion and therefore the main criteria for deployment should be relatively high traffic volumes and vulnerability of flow to minor incidents.

5.2.3.5 Relevance to NZTS / LTMA Objectives

Table 5.2.3.1 Contribution of Incident Detection Systems to NZTS/LTMA objectives (derived from Contribution Matrix Section 2).

NZTS / LTMA Objective	***Level of contribution***	***Comment***
A Economic Development	*High*	
Traffic Congestion	✓	Assist in early detection of incidents, so reducing congestion and incident related delays. Support economic development goals, such as improving the efficient flows of people, goods and services, and assisting in extracting maximum capacity from existing infrastructure. In the area of traffic/transport demand management, these facilities contribute mainly as a component of other systems.
Traffic/Transport Demand	➲	
Travel time on key routes	✓	
Transportation Costs (travel time, VOC)	✓	
Travel time for car commuters to key employment centres	✓	
Maintain strategic route security / availability / information	✓	
Quality & efficiency of transport	✓	
Travel time reliability	✓	
B Safety and Personal Security	*Medium*	
Number of traffic crashes	➲	Assist in reducing congestion related secondary crashes, improving response time to critical injuries, so improving personal safety.
Level of fatalities	➲	
Level & severity of personal injury	➲	

Table 5.2.3.1 (continued)

NZTS / LTMA Objective	***Level of contribution***	***Comment***
C Access & Mobility	*High*	
Traffic Congestion	✓	Assist in early detection of incidents on critical and strategic routes, so reducing congestion and incident related delays. Improve access and mobility through the more efficient use of local networks and supporting traffic/transport demand management as a component of other systems.
Traffic/Transport Demand	➲	
Sector to sector travel times by car	✓	
Frequency and reliability of key passenger transport services	✓	
Convenience (perceived and actual) of public transport services	✓	
Level (%) of commuting trips by passenger transport	✓	
Strategic route security / availability / information	✓	
Quality & efficiency of transport	➲	
Travel time reliability	✓	
D Public Health	*Medium*	
Traffic congestion in urban areas (impacts on local air quality)	✓	Contribute to public health objectives such as enhancing air quality and reduce exposure to transport noise by assisting in early detection of incidents; so reducing congestion and relate, emissions and noise. Reduce congestion related crashes and response time to critical injuries.
Vehicle noise	➲	
Compliance (with emissions regulations)	➲	
Level & severity of personal injury	➲	
E Sustainability	*High*	
Traffic/Transport Demand	➲	Contribute to sustainability objectives such as improving the efficiency of existing networks, and improving mobility for people, goods and services with minimal adverse effects by: Assisting in early detection of incidents; so reducing congestion and related delays, emissions and noise. Supporting traffic/transport demand management as a component of other systems.
Level(%) of trips that are not car based	✓	
Emission levels (particulates, nitrogen oxides, carbon monoxides, CO_2)	✓	
Levels of service on key routes	✓	
Extent to which the benefits will be sustainable over time	✓	
F Energy Efficiency	*High*	
Traffic Congestion	✓	Contribute to energy efficiency objectives such as Improving the efficiency of existing networks. Assist in early detection of incidents; so reducing congestion and related delays. Supporting traffic/transport demand management as a component of other systems.
Traffic/Transport Demand	➲	
Efficiency of routes taken	➲	
Fuel use	✓	
level of travel in congested conditions	✓	
Use of energy efficient modes	✓	
Quality & efficiency of transport	✓	
G Integration	*Low*	
None	✗	Although often a component of other integrated systems, does not deliver specifically to any integration objectives.

Table 5.2.3.1 (continued)

NZTS / LTMA Objective	Level of contribution	Comment
H Responsiveness	High	
Contributions to national objectives	✓	Assist in early detection of incidents, so reducing congestion and incident related delays. Support responsiveness goals, such as improving travel time reliability, maintaining strategic route availability and the general quality and efficiency of transport.
Maintain strategic route security / availability / information	✓	
Quality & efficiency of transport	✓	
Travel time reliability	✓	
I Affordability and Cost Effectiveness	High	
Relative benefit to cost ratio	➲	When implemented in appropriate situations cost effectiveness is good. However the cost of ongoing operations and maintenance needs to be fully considered.
Level of operating cost	✓	
J Implementation Risk	Low	
Technical complexity	✓	Generally, the base technologies in this area are well developed. Complexity levels are highest in the areas of AID algorithms and video image processing. Cost reliability is generally good and low risk. The main sources of risk are inappropriate applications or combinations and recognizing the level of operating commitment and cost.
Interoperability	✓	
Cost certainty	✓	
Public acceptance	✓	
✓ = Positive Contribution; ✗ = No Significant Contribution; ➲ = Partial Contribution		

5.2.3.6 Summary and Conclusions

AID systems mainly provide an aid to traffic operators in the early detection of problems to improve response time.

In an arterial environment the most common uses of this technology are in areas of high traffic flow where minor incidents lead to significant traffic congestion and delay. They are also being used increasingly to improve the reliability of information to road users through ATIS.

The main benefits of these systems are related to the early detection of incidents, so reducing congestion and incident related delays.

In terms of the objectives set out by the NZTS and LTMA, these systems deliver benefits in several areas, including:

- Economic Development
- Safety and Personal Security
- Access and Mobility
- Public Health
- Sustainability.

They also have the potential to provide a positive contribution towards the following New Zealand specific target areas:

- Congestion Relief

- Incident Management
- Safety
- Route Security
- Quality and Efficiency
- Travel Time Reliability

In New Zealand incident detection systems are used as part of the main motorway management systems, but their use on arterial routes is limited. Implemented in the appropriate areas, and with a suitable level of operations resource, the technologies used are well developed and low risk.

5.2.3.7 Example Applications

Table 5.2.3.2 Example applications of Incident Detection Systems.

Location	Description	Observed Benefits & Costs
USA - comparison of accident detection time to fatalities	A study in the early 1990s carried out by the USDOT research authority examined the benefits for accident victims when the accident notification time is reduced, specifically, the relationship between accident fatalities and accident notification time. Considering the benefits of AID in this area, access to emergency medical services (EMS) was shown to positively affect accident fatality rates.	The time period before the arrival of EMS is often critical in determining fatalities. During this period, accident victims receive little or no first aid and unattended injuries may lead to death. In the United States, accident notification time constitutes about forty-five percent of the time period before arrival of EMS. Based on national statistics, the average accident notification time was 5.2 minutes (the accident notification time being the difference between the time the accident occurs and the time that an EMS was notified). Reducing this notification time from 5.2 minutes to 3 minutes using AID was estimated to lead to an 11% reduction in fatalities. If the accident notification time were reduced to 2 minutes, a 15% reduction in fatalities would be achieved.
Gowanus Expressway/ Prospect Expressway rehabilitation project. Brooklyn, NY,USA	The Gowanus Expressway/Prospect Expressway rehabilitation project in Brooklyn, has an advanced incident detection systems consisting of an Autoscope video AID system and 20 closed-circuit television (CCTV) cameras with pan/tilt/zoom capabilities. Other technologies in place include highway advisory radio (HAR), variable message signs (VMS), and a construction information hotline. Processors analyze the data from the CCTVs and determine speed, occupancy, and volume of the vehicles. An alarm sounds if an incident is detected, alerting the traffic control centre operators.	Before the automated incident detection system was introduced it took an average of 1.5 hours to clear any type of incident. Since implementation of the system, the time it takes to aid a motorist whose vehicle has broken down has been reduced to 19 minutes. If an accident occurs, the average time from inception to clearing is now 31 minutes on average.

5.2.4 Variable Message Signs

5.2.4.1 Description

Variable Message Signs (VMS) provide information to road users on incidents, traffic and road conditions. In an arterial environment they are generally large gantry mounted devices using LED technology; operated from a traffic control centre. VMS are also used to provide information on alternative routes, planned works and special events, safety messages and in some instances advertising messages.

VMS are often used as a component of other systems such as:

- Warning systems for speed, height restrictions etc.
- Automated warning of specific hazards such as ice / fog / hidden queues.

5.2.4.2 Benefits

The main benefits of VMS in an arterial environment are providing drivers with rea- time information on congestion and incidents. Allowing improved selection of alternative routes and reducing the risk of secondary accidents when incidents occur. In particular, VMS can help in the following areas:

- Improving traffic efficiency by reducing demand in congested areas.
- Assisting in diverting traffic away from incidents or heavily congested areas.
- Providing up to date information to drivers on hazards and road conditions.
- Improving safety through reduced congestion related or secondary accidents.

5.2.4.3 Potential Problems

The main problems associated with VMS:

- Ensuring they are placed in locations where they deliver optimum value (e.g. where drivers have the best opportunity to benefit from the information provided).
- The cost of units suitable for arterial application is relatively high.
- To be effective there must be a reliable source of information (e.g. Surveillance and TMC).
- Ensuring that systems are interoperable.
- Recognition of the cost of maintenance and commitment to ongoing operations.
- There is some evidence that, where a range of alternative information sources are available, the tangible benefits are limited.

5.2.4.4 Applications

In an Arterial environment this type of technology is used most widely where traffic volumes are high and the effect of incidents leads to a there being benefit in advance warning. As the cost of these facilities is relatively high, they are best deployed where alternative routes are available and accessible, or where there is an identified safety benefit from the advance warning of incidents and congestion. This translates to mainly urban situations with high traffic flows, or particularly vulnerable sections.
The use of automated VMS is also growing in the area of hazard warning.

5.2.4.5 Relevance to NZTS / LTMA Objectives

Table 5.2.4.1 Contribution of Arterial Variable Message Signs to NZTS/LTMA objectives (derived from Contribution Matrix Section 2).

NZTS / LTMA Objective	*Level of contribution*	*Comment*
A Economic Development	*High*	
Traffic Congestion	✓	Assist in providing warning of incidents and congestion; reducing congestion and improving traffic flow. Support economic development goals, such as improving the efficient flows of people, goods and services, and extracting maximum capacity from existing infrastructure. In the area of traffic/transport demand management, these facilities contribute by reducing traffic demand in congested areas.
Traffic/Transport Demand	✓	
Travel time on key routes	✓	
Transportation Costs (travel time, VOC)	✓	
Travel time for car commuters to key employment centres	✓	
Maintain strategic route security / availability / information	✓	
Quality & efficiency of transport	✓	
Travel time reliability	✓	
B Safety and Personal Security	*Low*	
Number of traffic crashes	➲	Contribute indirectly by reducing secondary crashes due to advance warning of congestion and incidents.
Level & severity of personal injury	➲	
C Access & Mobility	*High*	
Traffic Congestion	✓	Assist in providing warning of incidents and congestion; reducing congestion and improving traffic flow on critical and strategic routes. Improve access and mobility through the more efficient use of local networks. In the area of traffic/transport demand management, these facilities contribute by reducing traffic demand in congested areas.
Traffic/Transport Demand	✓	
Sector to sector travel times by car	➲	
Frequency and reliability of key passenger transport services	✓	
Convenience (perceived and actual) of public transport services	✓	
Level (%) of commuting trips by passenger transport	✓	
Strategic route security / availability / information	✓	
Quality & efficiency of transport	✓	
Travel time reliability	✓	
D Public Health	*Low*	
Traffic congestion in urban areas (impacts on local air quality)	✓	Provide advance warning of incidents and congestion, allowing selection of alternatives routes/modes and reducing further build up. Contributes indirectly by reducing secondary crashes due to advance warning of congestion and incidents.
Level & severity of personal injury	➲	

Table 5.2.4.1 (continued)

NZTS / LTMA Objective	Level of contribution	Comment
E Sustainability	*High*	
Traffic/Transport Demand	✓	Contribute to sustainability objectives such as improving the efficiency of existing networks, and improving mobility for people, goods and services with minimal adverse effects. Provide advance warning of incidents and congestion, allowing selection of alternatives routes/modes and reducing further build up; so reducing congestion and related delays, emissions and noise. In the area of traffic/transport demand management, these facilities contribute by reducing traffic demand in congested areas.
Level(%) of trips that are not car based	✓	
Growth rate of total vehicle travel	➲	
Emission levels (particulates, nitrogen oxides, carbon monoxides, CO_2)	✓	
Levels of service on key routes	✓	
Extent to which the benefits will be sustainable over time	✓	
F Energy Efficiency	*High*	
Traffic Congestion	✓	Contribute to energy efficiency objectives, improving the efficiency of existing networks, and improving mobility for people, goods and services. Provide advance warning of incidents and congestion, allowing selection of alternative routes/modes and reducing further build up, so reducing congestion. In the area of traffic/transport demand management, these facilities contribute by reducing traffic demand in congested areas.
Traffic/Transport Demand	✓	
Efficiency of routes taken	✓	
Fuel use	✓	
level of travel in congested conditions	✓	
Use of energy efficient modes	✓	
Quality & efficiency of transport	✓	
G Integration	*Medium*	
Efficiency and convenience of mode transfer points	✓	Assist in providing timely information to users on broader transport alternatives such as rail and bus. Contribute to improving integration between modes.
Level of integration between road and rail	✓	
Improving rural community access & conditions	✓	
H Responsiveness	*High*	
Responding to diverse stake holder needs (particularly rural versus urban)	✓	Assist in providing warning of incidents and congestion; reducing congestion and improving traffic flow. Support responsiveness maintaining strategic route availability, travel time reliability and quality and efficiency of transport.
Contributions to national objectives	✓	
Maintain strategic route security / availability / information	✓	
Quality & efficiency of transport	✓	
Travel time reliability	✓	
I Affordability and Cost Effectiveness	*Medium*	
Relative benefit to cost ratio	➲	When implemented in appropriate situations cost effectiveness is good. However initial cost is high and the cost of ongoing operations and maintenance needs to be fully considered.
Level of operating cost	➲	

Table 5.2.4.1 (continued)

NZTS / LTMA Objective	***Level of contribution***	***Comment***
J Implementation Risk	*Low*	
Technical complexity	✓	Generally, the base technologies in this area are well developed and the complexity level low. This leads to a high level of cost reliability and low risk. The main sources of risk are inappropriate applications, interoperability with broader TMC systems, and recognizing the level of operating commitment and cost.
Interoperability	✓	
Cost certainty	✓	
Public acceptance	➲	
Implementation constraints – resource consents, legal & others	✓	
✓ = Positive Contribution; ✗ = No Significant Contribution; ➲ = Partial Contribution		

5.2.4.6 Summary and Conclusions

Variable Message Signs (VMS) provide information to road users on incidents, traffic and road conditions, alternative routes and occasionally advance warning of planned road works. In an arterial environment they can be large cantilever gantry mounted devices, or smaller road side devices, but generally use LED technology.

The main benefits of VMS in an arterial environment are achieved by providing drivers information on road conditions, congestion and incidents, facilitating improved selection of alternative routes and reducing the risk of secondary accidents.

The use of fixed variable message signs on arterial routes in New Zealand is limited, although they are used widely in Auckland and Wellington in motorway situations. As part of the Wellington system, large fixed VMS have been installed on routes approaching the motorway, their main purpose to warn drivers of incidents or delays before key route decision points.

In terms of the objectives set out by the NZTS and LTMA, these systems deliver benefits in several areas, including:

- Economic Development
- Access and Mobility
- Sustainability

They also have the potential to provide a positive contribution towards the following New Zealand specific target areas:

- Congestion Relief
- Demand Management
- Incident Management
- Safety
- Route Security
- Quality and Efficiency
- Travel Time Reliability

Implemented in the appropriate areas, and with a suitable level of operations resource, the technologies used are well developed and low risk.

5.2.4.7 Example Applications

Table 5.2.4.2 Example applications of Arterial Variable Message Signs.

Location	Description	Observed Benefits & Costs
San Antonio TransGuide System, USA	The first phase of the San Antonio TransGuide System became operational on July 26, 1995 and included 26 miles of city arterials. The system includes dynamic message signs, lane control signs, loop detectors and video surveillance cameras.	Comparing crash statistics for August – December of 1992, 1993, and 1994, with the statistics for August – December 1995, the paper reports that the system reduced primary accidents by 35%, reduced secondary accidents by 30%, reduced inclement weather accidents by 40%, and reduced overall accidents by 41%.
Buffalo, USA	University of Buffalo study of VMS benefits 2004.	A study completed in 2004 by CUBRC / University at Buffalo. Examined a number of VMS deployments on arterial routes. Looking specifically at the use of VMS for diversion; in one section studied it took 361 minutes for the traffic queue that has built up to dissipate after an incident had cleared. Under VMS deployment, the period of time drops continuously from 354 minutes with a rate of traffic diversion of 3% to 178 minutes with a 27% diversion rate. In another section; without VMS deployment, it takes 184 minutes for the traffic queue that has built up to dissipate after an incident is cleared. Under VMS deployment, the period of time drops continuously from 182 minutes with a rate of traffic diversion of 3% to 129 minutes with a 27% diversion rate. Travel time is reduced by a mere 0.2% for a VMS-induced diversion rate of 3% (1% above the normal traffic diversion rate); overall travel time reduction jumps to 43.6% for a diversion rate of 27%.
Detroit, USA	A study of the combined ITS facilities on the Detroit motorways provided evidence that ITS proved most beneficial under conditions of significant supply variations, such as incidents, and to a lesser extent during demand variations.	As part of this study variable message signs were shown to benefit commuters in terms of awareness of traffic activities. Providing psychological/convenience benefits in terms of providing drivers with information about what is causing delays and congestion. In terms of delay reductions, however, commuters acting upon VMS messages of delay found little benefit, and at times also increased delay by diverting. VMS proved no benefit to facility operation in terms of flow or speed.

5.2.5 Parking Management

5.2.5.1 Description

ITS Parking Management Systems include a range of applications from the most basic parking meters, to parking guidance systems and more advanced smart parking information and pricing facilities. Systems are targeted at three main areas;

- Processing payment
- Enforcement
- Information

5.2.5.2 Benefits

Effective management of parking on the street, within parking buildings and at public transport interchanges has several positive effects on the operation of arterial routes, including keeping routes clear and reducing the levels of traffic searching for parking. At public transport interchanges these systems assist in reducing traffic demand by improving the convenience and accessibility of public transport services.

The main benefits of these systems are reduced congestion and delay, improved enforcement and payment efficiency. Benefits are also achieved through improved congestion related environmental and safety effects.

5.2.5.3 Potential Problems

The main problems encountered with these systems are related to interoperability, and in particular interoperability between systems and process. In the fields of payment processing and enforcement, as many parking facilities are now privately operated, the ability to provide a common system and technology is limited.

5.2.5.4 Applications

The application of parking management systems is best targeted in congested urban areas where there is a need to manage demand and keep arterial routes flowing.

5.2.5.5 Relevance to NZTS / LTMA Objectives

Table 5.2.5.1 Contribution of Parking Management systems to NZTS/LTMA objectives (derived from Contribution Matrix Section 2).

NZTS / LTMA Objective	*Level of contribution*	*Comment*
A Economic Development	*High*	
Traffic Congestion	✓	Assist in keeping routes clear and reducing adverse effects of illegal parking. (clearways etc). Assist in operation of parking systems, used as a means of influencing dean through pricing etc. Also used in the management of special access facilities such as bus lanes and clearways etc.
Traffic/Transport Demand	✓	
Travel time on key routes	✓	
Transportation Costs (travel time, VOC)	✓	
Transport users face the true costs of use	➲	
Travel time for car commuters to key employment centres	✓	
Quality & efficiency of transport	✓	
Travel time reliability	✓	

Table 5.2.5.1 (continued)

NZTS / LTMA Objective	Level of contribution	Comment
B Safety and Personal Security	*Low*	
Compliance (with traffic / transport regulations)	✓	Improve compliance with parking and access regulations.
C Access & Mobility	*High*	
Traffic Congestion	✓	Assist in keeping routes clear and reducing adverse effects of illegal parking. (clearways etc). Assist in operation of parking systems, used as a means of influencing dean through pricing etc. Also used in the management of special access facilities such as bus lanes and clearways etc.
Traffic/Transport Demand	✓	
Sector to sector travel times by car	✓	
Frequency and reliability of key passenger transport services	✓	
Convenience (perceived and actual) of public transport services	✓	
Level (%) of commuting trips by passenger transport	✓	
Level (%) of commuting trips by Cycle	✓	
Level (%) of commuting trips by Pedestrians	✓	
Compliance (with traffic / transport regulations)	✓	
Quality & efficiency of transport	✓	
Travel time reliability	✓	
D Public Health	*Med*	
Traffic congestion in urban areas (impacts on local air quality)	✓	Through improved control and reduced impact of on street parking (e.g. clearways). Assist in managing traffic and so reducing congestion related noise.
Vehicle noise	➲	
Numbers of short trips made by walking or cycling	✓	
Numbers of commuting trips made by walking or cycling	✓	
E Sustainability	*High*	
Traffic/Transport Demand	✓	Assist in operation of parking systems, used as a means of influencing demand through pricing etc. Also used in the management of special access facilities such a bus lanes and clearways etc. Assist in keeping routes clear and reducing adverse effects of illegal parking (clearways etc).
Level(%) of trips that are not car based	✓	
Growth rate of total vehicle travel	✓	
Emission levels (particulates, nitrogen oxides, carbon monoxides, CO_2)	✓	
Extent to which users face full cost of their road use	➲	
Levels of service on key routes	✓	
Extent to which the benefits will be sustainable over time	✓	
F Energy Efficiency	*High*	
Traffic Congestion	✓	Assist in operation of parking systems; used as a means of influencing demand through pricing etc. Also used in the management of special access facilities such a bus lanes and clearways etc. Assist in keeping routes clear and reducing adverse effects of illegal parking (clearways etc).
Traffic/Transport Demand	✓	
Efficiency of routes taken	✓	
Fuel use	✓	
level of travel in congested conditions	✓	
Use of energy efficient modes	✓	
Quality & efficiency of transport	✓	

Table 5.2.5.1 (continued)

NZTS / LTMA Objective	***Level of contribution***	***Comment***
G Integration	*High*	
Provision for all modes on key transport corridors	✓	Assist in making provision for all modes. Assist in keeping routes clear and reducing adverse effects of illegal parking (clearways etc).
Level of priority given to passenger transport	✓	
Efficiency and convenience of mode transfer points	✓	
H Responsiveness	*High*	
Responding to diverse stake holder needs (particularly rural versus urban)	✓	Assist in keeping routes clear and reducing adverse effects of illegal parking (clearways etc).
Contributions to national objectives	✓	
Quality & efficiency of transport	✓	
Travel time reliability	✓	
I Affordability and Cost Effectiveness	*High*	
Relative benefit to cost ratio	✓	When appropriately applied, these systems are cost effective.
Level of operating cost	➲	
Contribution direct from users	➲	
J Implementation Risk	*Med*	
Technical complexity	➲	Main risk areas are inappropriate applications, and interoperability between systems and between systems and administrative processes.
Interoperability	➲	
Cost certainty	➲	
Public acceptance	➲	
Implementation constraints – resource consents, legal & others	➲	
✓ = Positive Contribution; ✗ = No Significant Contribution; ➲ = Partial Contribution		

5.2.5.6 Summary and Conclusions

ITS Parking Management Systems include a range of applications targeted at three main areas; processing payment, enforcement and information.

They have positive effects on the operation of arterial routes; including, keeping routes clear, reducing searching movements and traffic demand by improving the convenience of public transport. The main problems are related to interoperability, particularly payment processing.

The application of parking management systems is best targeted in congested urban areas where there is a need to manage demand and keep arterial routes flowing.

In terms of the objectives set out by the NZTS and LTMA, these systems deliver benefits in several areas, including:

- Economic Development
- Access and Mobility
- Public Health
- Environmental Sustainability

They also have the potential to provide a positive contribution towards the following New Zealand specific target areas:

- Congestion Relief
- Demand Management
- Compliance
- Safety
- Quality and Efficiency
- Travel Time Reliability

ITS parking management systems are used in New Zealand in a range of forms, including electronic parking meters and pay and display systems with mobile phone capability.

5.2.5.7 Example Applications

Table 5.2.5.2 Example applications of Parking Management systems.

Location	Description	Observed Benefits & Costs
Cornell University,USA	Cornell University, faced with increased traffic on campus and demand for 2,500 more parking spaces, reduced parking subsidies and offered monetary incentives to carpool or take transit to campus.	More than one-third of Cornell's 9,000 faculty and staff no longer drive to work alone, averting the need for a 1,200 space parking facility and its associated maintenance and security expenditures. The University of Washington decreased the number of solo drivers to campus by 22% by raising solo parking fees and instituting a pass for use on the Seattle transit system. Between 1991 and 1998, campus ridership on the Metro transit system grew by 68%, from 4.7 million to 7.8 million annual trips.

5.2.6 Traffic Signal Enforcement – Red Light Cameras

5.2.6.1 Description

Red light cameras are located at traffic signalled intersections and detect vehicles that have illegally passed across the stop line while a red signal is being shown.

The basic equipment associated with the introduction of red light camera is:

- Camera equipment
- Detectors
- Data storage devices

The cameras that are used at traffic signaled intersections are generally digital, as the amount of information stored is considerably greater and the resolution of the photographs are generally of a higher standard than traditional photographic formats. The cameras usually offer sufficient resolution to capture offenders in all levels of daylight and at speed levels within parameters set by the installing agency.

A range of detectors are available. The most widely used is the induction loop detector, which utilises electro-magnetic strips located in the carriageway on the approach to the stop line. These determine whether a traffic signal violation has occurred by detecting vehicle movement ahead of the stop line. Other technologies used include infra-red, radar and air-tube sensors.

Generally one to four photographs of the offending vehicle are taken, depending on the system installed, one as the vehicle crosses the stop line and also when the vehicle is in the middle of the intersection. As well as the details of the offending vehicle, the system will also superimpose other data on to the photographic image, including:

- Date and time.
- Intersection location.
- Speed of vehicle.
- Elapsed time between the traffic signal turning red and the violation occurring.

5.2.6.2 Benefits

The main benefits of introducing red light cameras at traffic signalled intersections with high numbers of cross-intersection/angled accidents are:

- A reduced occurrence of cross-intersection accidents.
- Lower speeds on the approach to the intersection.

5.2.6.3 Potential Problems

The main problems of introducing red light cameras at traffic signalled intersections are:

- A potential increase in other types of accidents, particularly rear-end shunts. Therefore, other engineering measures may have to be introduced in association with a red light camera.
- Public perception of the introduction of red light cameras can range from strongly in favour to strongly against (as they sometimes associate the cameras with revenue raising) and a period of public consultation/education may therefore, be required.

- Installation and maintenance costs, although these will be offset by saving in costs as a result of lower accident rates and increased revenue raised by fines.

5.2.6.4 Applications

Red light cameras are generally applicable at intersection with a history of traffic signal violations, which is usually evident in a high rate of recorded cross-intersection/angled collisions.

5.2.6.5 Relevance to NZTS / LTMA Objectives

Table 5.2.6.1 Contribution of Traffic Signal Enforcement systems to NZTS/LTMA objectives (derived from Contribution Matrix Section 2).

NZTS / LTMA Objective	**Level of contribution**	***Comment***
A Economic Development	*Low*	
Quality & efficiency of transport	➲	Can help improve safety and reduce crash related delays.
B Safety and Personal Security	*High*	
Number of traffic crashes	✓	Reduce traffic signal related crashes through targeted enforcement. Improve compliance with traffic signals and access regulations.
Level of fatalities	✓	
Level & severity of personal injury	✓	
Level of conflict between vehicles / cyclists / pedestrians and other road users	✓	
Perceived personal safety/security for non car mode trips	➲	
Compliance (with traffic / transport regulations)	✓	
C Access & Mobility	*Low*	
Frequency and reliability of key passenger transport services	➲	Where cycle way signals are provided. Improve the safety and efficiency of pedestrian signals. Improve compliance with traffic signals and access regulations. Can help improve safety and reduce crash related delays. E.g. Enforcement of bus priority signals.
Convenience (perceived and actual) of public transport services	➲	
Level (%) of commuting trips by passenger transport	➲	
Level (%) of commuting trips by Cycle	➲	
Level (%) of commuting trips by Pedestrians	✓	
Compliance (with traffic / transport regulations)	✓	
Quality & efficiency of transport	➲	
D Public Health	*Medium*	
Numbers of short trips made by walking or cycling	✓	Improve the efficiency of pedestrian & Cycle signals and assisting in providing priority. Reduce traffic signal related crashes through targeted enforcement.
Numbers of commuting trips made by walking or cycling	✓	
Level & severity of personal injury	✓	
E Sustainability	*Low*	
Level(%) of trips that are not car based	➲	Can help improve safety and reduce crash related delays. E.g. Enforcement of bus priority signals.
Emission levels (particulates, nitrogen oxides, carbon monoxides, CO_2)	➲	
Extent to which the benefits will be sustainable over time	✓	

Table 5.2.6.1 (continued)

NZTS / LTMA Objective	Level of contribution	Comment
F Energy Efficiency	*Low*	
Fuel use	➲	Can help improve safety and reduce crash related delays. E.g. Enforcement of bus priority signals.
Use of energy efficient modes	➲	
Quality & efficiency of transport	➲	
G Integration	*Low*	
Provision for all modes on key transport corridors	✓	Assist in making provision for all modes. E.g. Enforcement of bus priority signals.
Level of priority given to passenger transport	➲	
H Responsiveness	*Low*	
Responding to diverse stake holder needs (particularly rural versus urban)	✓	Can help improve safety and reduce crash related delays.
Contributions to national objectives	✓	
Quality & efficiency of transport	➲	
I Affordability and Cost Effectiveness	*Medium*	
Relative benefit to cost ratio	✓	Highly cost effective means of reducing accidents.
Level of operating cost	✓	
J Implementation Risk	*Medium*	
Technical complexity	✓	Technology is well developed but there were some issues in the application & operation areas.
Interoperability	✓	
Cost certainty	✓	
Public acceptance	➲	
Implementation constraints – resource consents, legal & others	✓	

✓ = Positive Contribution; ✗ = No Significant Contribution; ➲ = Partial Contribution

5.2.6.6 Summary and Conclusions

Red light cameras are generally installed at locations with high cross-intersection accident rates. Digital technology is generally used at sites where cameras are required, and induction loops are generally considered to be the most suitable method of detection. The main problems include the increase in other accident types and poor public perception.

The cost of installation is generally recouped by the reduction in costs associated with a lower accident rate at the intersection and increased revenue raised by fines.

In terms of the objectives set out by the NZTS and LTMA, these systems deliver benefits in several areas, including:

- Safety and Personal Security
- Public Health

They also have the potential to provide a positive contribution towards the following New Zealand specific target areas:

- Compliance
- Safety
- Route Security

Red light cameras are not used widely in New Zealand, although some have been installed in parts of Auckland.

5.2.6.7 Example Applications

Table 5.2.6.2 Example applications of Traffic Signal Enforcement – Red Light Cameras.

Location	Description	Observed Benefits & Costs
Charlotte, North Carolina, USA	Comparison of 20 intersections over a three year period, commencing in 1998, at locations where red light cameras had been introduced. Before implementation the intersections had in the region of 400-500 red light violation per week in total.	An estimated reduction in red light violations of 34% based on comparisons before and after introduction. Cross-intersection accidents reduced by 37% at intersections with cameras. Cross-intersection accidents reduced by 60% on approaches with cameras. All crash types on approaches with cameras were reduced by 19%. Crash severity of all accidents reduced by 16%. A survey of the local population indicated that 98% were aware of the program, 84% thought the program was beneficial and had helped reduce the number of accidents, and 76% supported the program.
Regina, Saskatchewan, Canada	Introduction of two red light cameras at five locations in the city (rotated as part of a two-year test period).	Total number of violations down by more than 30% at the sites where cameras were located. However, a higher total number of accidents were recorded at some sights, with one intersection showing an increase in total accidents of 51%, of which most were rear-end collisions.
New York City, USA	Red light cameras installed at 18 intersections between 1993 and 1997. The system was introduced so that it 'would be at no cost to the city', in so much that the revenue raised would offset the cost of installation and maintenance.	The number of violations was reduced by 38% since its introduction. The revenue raised over the three year period was $18.5m. The cost of installation was $15.5m over the same period. A further 8 cameras were planned as a result of the initial program.

5.3 Integrated Urban Traffic Control

The main intent of Urban Traffic Control (UTC) systems is to reduce congestion, air pollution and fuel consumption through reductions in vehicle delay (during high-volume periods) and/or reductions in the number of stops (during less-saturated travel periods). Computerised traffic signal control using central control and monitoring of hundreds of intersections began in Toronto, Canada in the late 1950's, and by the early 1970's expanded to New York, Tokyo and other major cities. These systems utilized mainframe (and later, minicomputer) technologies to enact once-per-second (or more frequent) control of signalized intersections or junctions.

Most of the earlier systems used time-of-day, day-of-week operations plans, but today the use of real-time traffic data to adjust signal timings on a cycle-by-cycle basis is most common. The Split-Cycle-Offset Optimisation Technique (SCOOT) and Sydney Coordinated Adaptive Traffic System (SCATS) control concepts, are now two of the most common 'traffic adaptive' UTC systems. As UTC systems have grown a number of other related systems have been incorporated such as parking management, environmental facilities and payment systems.

The systems that are included in this section are:

5.3.1 Parking Management and Availability

5.3.2 Environmental Monitoring and Forecasting

5.3.3 Real-Time Public Transport Passenger Information Systems

5.3.4 Access Control Systems

5.3.5 Integrated Smart Cards / Multi-use Payment Systems

5.3.1 Parking Management and Availability

5.3.1.1 Description

Parking availability monitoring and information systems often form part of a broader urban traffic control system. Many urban signal management facilities monitor car parks as part of their primary function and this data is increasingly being used to develop and deliver information on available spaces to drivers. These systems inform drivers where the nearest available parking spaces are located. They do this by calculating the occupancy rate in each car park and subtracting this from the total capacity and displaying this number on signs around the city.

5.3.1.2 Benefits

The main benefits of these systems in terms of the operation of the traffic network are; reduced levels of circulating traffic searching for parking spaces, reduced driver frustration levels and improved awareness of parking availability in future trip decisions. These systems can assist in promoting public transport use by informing drivers ahead of park and ride facilities when city centre parking is limited; and encourage longer term mode shifts.

5.3.1.3 Potential Problems

Where existing traffic signal management systems are in place, the development of these types of facilities is relatively simple, at least for the larger parking areas where vehicle counters are already in place. However the costs will be higher where these do not exist or there are a large number of smaller parking areas. These systems are generally limited to dedicated parking buildings or lots and do not cover on street spaces. The location of signs, particularly in the central city areas, can be a problem, due to the limited space available.

5.3.1.4 Applications

These systems are best applied to congested urban centres where there are large parking lots and buildings, areas where traffic searching for parking is a recognised problem, and ideally where park and ride alternatives are available.

In most cases existing traffic signal systems will be in place to provide base counts of major parking facilities.

5.3.1.5 Relevance to NZTS / LTMA Objectives

Table 5.3.1.1 Contribution of Parking Management and Availability systems to NZTS/LTMA objectives (derived from Contribution Matrix Section 2).

NZTS / LTMA Objective	***Level of contribution***	***Comment***
A Economic Development	*High*	
Traffic Congestion	✓	Assist in keeping routes clear and reducing adverse effects of illegal parking (clearways etc). Assist in operation of parking systems, used as a means of influencing demand through pricing etc. Also used in the management of special access facilities such as bus lanes and clearways etc. Can be used as a mechanism for more direct charging.
Traffic/Transport Demand	✓	
Travel time on key routes	✓	
Transportation Costs (travel time, VOC)	✓	
Transport users face the true costs of use	➲	
Travel time for car commuters to key employment centres	✓	
Quality & efficiency of transport	✓	
Quality & efficiency of transport	✓	
B Safety and Personal Security	*Low*	
Number of traffic crashes	➲	Can lead to reduced crashes related to illegal parking. Improve compliance with parking and access regulations.
Level of conflict between vehicles / cyclists / pedestrians and other road users	➲	
Compliance (with traffic / transport regulations)	✓	
C Access & Mobility	*High*	
Traffic Congestion	✓	Assist in keeping routes clear and reducing adverse effects of illegal parking (clearways etc). Assist in operation of parking systems; used as a means of influencing demand through pricing etc. Also used in the management of special access facilities such as bus lanes and clearways etc. Through reduced congestion resulting from searching etc. Through improved control and reduced impact of on street parking (e.g. clearways).
Traffic/Transport Demand	✓	
Sector to sector travel times by car	✓	
Frequency and reliability of key passenger transport services	➲	
Convenience (perceived and actual) of public transport services	➲	
Level (%) of commuting trips by passenger transport	➲	
Level (%) of commuting trips by Cycle	➲	
Level (%) of commuting trips by Pedestrians	✓	
Compliance (with traffic / transport regulations)	✓	
Quality & efficiency of transport	✓	
Travel time reliability	✓	
D Public Health	*Medium*	
Traffic congestion in urban areas (impacts on local air quality)	✓	Assist in keeping routes clear and reducing adverse effects of searching for parking. Through improved control and reduced impact of on street parking.
Vehicle noise	➲	
Numbers of short trips made by walking or cycling	✓	
Numbers of commuting trips made by walking or cycling	✓	

Table 5.3.1.1 (continued)

NZTS / LTMA Objective	Level of contribution	Comment
E Sustainability	*High*	
Traffic/Transport Demand	✓	Assist in operation of parking systems, used as a means of influencing demand through pricing etc. Also used in the management of special access facilities such as bus lanes and clearways etc. Through reduced congestion resulting from searching etc. Through improved control and reduced impact of on street parking (e.g. clearways). Can be used as a mechanism for more direct charging. Assist in keeping routes clear and reducing adverse effects of illegal parking (clearways etc).
Level(%) of trips that are not car based	➲	
Growth rate of total vehicle travel	✓	
Emission levels (particulates, nitrogen oxides, carbon monoxides, CO_2)	➲	
Extent to which users face full cost of their road use	➲	
Levels of service on key routes	✓	
Extent to which the benefits will be sustainable over time	✓	
F Energy Efficiency	*High*	
Traffic Congestion	✓	Assist in keeping routes clear and reducing adverse effects of illegal parking (clearways etc). Assist in operation of parking systems, used as a means of influencing dean through pricing etc. Also used in the management of special access facilities such as bus lanes and clearways etc. Through reduced congestion resulting from searching etc.
Traffic/Transport Demand	✓	
Efficiency of routes taken	✓	
Fuel use	➲	
level of travel in congested conditions	✓	
Use of energy efficient modes	➲	
Quality & efficiency of transport	✓	
G Integration	*High*	
Provision for all modes on key transport corridors	✓	Assist in making provision for all modes. Through reduced congestion resulting from searching etc. Through improved control and reduced impact of on street parking (e.g. clearways).
Level of priority given to passenger transport	➲	
Efficiency and convenience of mode transfer points	✓	
H Responsiveness	*High*	
Responding to diverse stake holder needs (particularly rural versus urban)	✓	Assists in keeping routes clear and reducing adverse effects of illegal parking (clearways etc).
Contributions to national objectives	✓	
Quality & efficiency of transport	✓	
Travel time reliability	✓	
I Affordability and Cost Effectiveness	*High*	
Relative benefit to cost ratio	✓	Can be used as a mechanism for more direct charging.
Level of operating cost	✓	
Contribution direct from users	➲	
J Implementation Risk	*Medium*	
Technical complexity	➲	Operates best as an extension of traffic control system. Requires adequate maintenance to deliver reliable information.
Interoperability	➲	
Cost certainty	➲	
Public acceptance	✓	
Public acceptance	➲	
✓ = Positive Contribution; ✗ = No Significant Contribution; ➲ = Partial Contribution		

5.3.1.6 Summary and Conclusions

Parking availability monitoring and information systems inform drivers where the nearest available parking spaces are located. The main benefits of these systems are reduced levels of searching traffic and improved awareness of parking availability. These systems are generally limited to dedicated parking buildings or lots and do not cover on street spaces. They are best applied to congested urban centres where park and ride alternatives are available.

In terms of the objectives set out by the NZTS and LTMA, these systems deliver benefits in several areas, including:

- Economic Development
- Access and Mobility
- Public Health
- Environmental Sustainability

They also have the potential to provide a positive contribution towards the following New Zealand specific target areas:

- Congestion Relief
- Demand Management
- Safety
- Quality and Efficiency
- Travel Time Reliability
- Environmental Mitigation

Integrated parking management and information systems of this type are not currently operated in New Zealand.

5.3.1.7 Example Applications

Table 5.3.1.2 Example applications of Parking Management and Availability systems.

Location	Description	Observed Benefits & Costs
Nottingham, England, UK	Research was carried out into the effects of parking information on driver behaviour.	Results indicated that disseminating parking information including parking facility location and providing frequent updates on parking availability could influence the demand for parking at various locations. They determined that parking information dissemination efforts were likely to increase the use of commuter parking facilities and deemed such efforts a useful expenditure of public funds.

Table 5.3.1.2 (continued)

Location	Description	Observed Benefits & Costs
Minnesota Department of Transportation City of St. Paul, USA	The Minnesota Department of Transportation concluded an ITS operational test of an advanced parking information system in downtown St. Paul. The test consisted of the implementation and operation of electronic signs displaying real-time parking availability information for special events in downtown St. Paul.	Advanced Parking is perceived beneficial to parking operators and the city; each would like the system to continue and be expanded throughout the downtown, and be used weekdays. Most motorists thought the system had value. There were some improvements on the surface transportation system, but the improvements could not be attributed directly to Advanced Parking; Estimated delay per vehicle decreased at critical intersections, and travel time on selected routes decreased. Advanced Parking performed well technically after the system was debugged; Advanced Parking provides real-time parking information. The accuracy of the information is directly dependent on the parking operators' cooperation in setting the counters.
Southampton, England, UK	The system consists of 26 parking guidance signs, directing drivers to 13 off-street car parks.	The effects of its use are significant especially at times of peak demand. The willingness to use PGI is very time-depended, being most effective at peak periods when drivers' uncertainty as to availability of parking is at its highest level. Furthermore, research indicates an increased number of drivers influenced by the information from the parking system.
Frankfurt, Germany	It has three phases: first, guiding drivers to 1 of 5 areas; second, guiding them to a more specific sub-area; finally, guiding them to parking facilities. Guidance is provided by VMS, which display information provided by the parking facilities' main computer.	Studies that were carried out in local authorities in Germany claim that between 50% and 100 per cent of the local users and between 30% and 79% non-local users were aware of their PGI systems. A series of surveys in Frankfurt allowed a detailed analysis of the effects of a PGI system on driver behaviour. The main results show that awareness of the system appears to have developed rapidly and stood at about 80% after three months of operation, growing only marginally and slowly thereafter. Therefore, to increase the effectiveness of PGI systems, designers will have to find ways of reaching a greater proportion of drivers and persuading those drivers already aware of, but not yet using, the system that it does offer them real further benefits.

5.3.2 Environmental Monitoring and Forecasting

5.3.2.1 Description

These technologies are used to detect the adverse environmental effects caused by traffic such as high carbon dioxide and carbon monoxide levels in congested areas. They generally also include related measures on the local environmental and weather conditions that may combine with vehicle emissions to cause a problem.

In several cases these systems are combined with traffic control systems and information systems in order to influence and manage traffic demand in an affected area.

5.3.2.2 Benefits

The main benefits of these systems are the opportunity they provide to identify problems early and influence the manageable factors either immediately or as part of a longer term strategy.

Examples of actions that can be taken include, adjusting traffic controls to restrict demand in an affected area, adjust toll levels to reduce demand or, longer term, adjust signal plans to take account of seasonal effects.

5.3.2.3 Potential Problems

As weather and environmental conditions are constantly changing, the ability of these systems to have a significant short term effects are limited. Often the time lag between detecting problems and achieving any meaningful effect through traffic control will restrict the benefits and the ability to clearly establish a connection between action taken and any short term improvement. It is therefore more effective to target these systems at recognised problem areas.

5.3.2.4 Applications

To achieve meaningful improvements these systems are best targeted at areas where there is a recognised and measurable environmental problem that can be usefully improved by either short or long term management of demand.

5.3.2.5 Relevance to NZTS / LTMA Objectives

Table 5.3.2.1 Contribution of Environmental Monitoring and Forecasting systems to NZTS/LTMA objectives (derived from Contribution Matrix Section 2).

NZTS / LTMA Objective	*Level of contribution*	*Comment*
A. Economic Development	*Low*	
Traffic Congestion	➲	Air quality effects of congestion can be used as an input to traffic management systems.
Traffic/Transport Demand	➲	
Transportation Costs (travel time, VOC)	➲	
Transport users face the true costs of use	➲	
Quality & efficiency of transport	➲	

Table 5.3.2.1 (continued)

NZTS / LTMA Objective	***Level of contribution***	***Comment***
B Safety and Personal Security	*Low*	
Level of fatalities	➲	Air quality effects of congestion can be used as an input to traffic management systems.
Level & severity of personal injury	➲	
Compliance (with traffic / transport regulations)	➲	
C Access & Mobility	*Low*	
Traffic Congestion	➲	When used in conjunction with other systems that promote alternative modes. May be a component of future systems to regulate air quality/noise regulations. Air quality effects of congestion can be used as an input to traffic management systems.
Traffic/Transport Demand	➲	
Level (%) of commuting trips by Cycle	➲	
Compliance (with traffic / transport regulations)	➲	
Quality & efficiency of transport	➲	
D Public Health	*High*	
Traffic congestion in urban areas (impacts on local air quality)	➲	Air quality effects of congestion can be used as an input to traffic management systems. Noise monitoring can be used as an input to traffic management systems. When used in conjunction with other systems that promote improved pedestrian environment. Compliance; Component of future systems to regulate air quality regulations. Possibly as a result of claimed fatalities from emissions etc.
Vehicle noise	➲	
Numbers of short trips made by walking or cycling	✓	
Numbers of commuting trips made by walking or cycling	✓	
Compliance (with emissions regulations)	✓	
Level & severity of personal injury	➲	
E Sustainability	*High*	
Traffic/Transport Demand	➲	Air quality effects of congestion can be used as an input to traffic management systems. Assists in the monitoring and management of freight. Can be used as a input to more direct charging related to impact.
Non road freight volumes as a percentage of total	➲	
Growth rate of total vehicle travel	➲	
Extent to which users face full cost of their road use	➲	
Extent to which the benefits will be sustainable over time	✓	
F Energy Efficiency	*High*	
Traffic Congestion	➲	Air quality effects of congestion can be used as an input to traffic management systems.
Traffic/Transport Demand	➲	
Efficiency of routes taken	➲	
level of travel in congested conditions	➲	
Quality & efficiency of transport	➲	
H Responsiveness	*High*	
Responding to diverse stakeholder needs (particularly rural vs urban)	➲	Air quality effects of congestion can be used as an input to traffic management systems.
Contributions to national objectives	✓	
Quality & efficiency of transport	➲	
I Affordability and Cost Effectiveness	*Medium*	
Relative benefit to cost ratio	➲	Wide range of facilities can be low or high cost. Best cost effectiveness is achieved with systems designed to target a specific issue.
Level of operating cost	✓	
Contribution direct from users	➲	

Table 5.3.2.1 (continued)

NZTS / LTMA Objective	***Level of contribution***	***Comment***
J Implementation Risk	*Medium*	
Technical complexity	✓	Can be difficult to provide reliable forecasts.
Interoperability	✓	
Cost certainty	✓	
Public acceptance	✓	
Implementation constraints – resource consents, legal & others	✓	
✓ = Positive Contribution; ✗ = No Significant Contribution; ➲ = Partial Contribution		

5.3.2.6 Summary and Conclusions

These technologies are used to monitor and detect adverse environmental effects, often combined with traffic control systems and information systems.

Benefits are achieved through the identification or forecasting of problems and an improved ability to react and influence contributing factors either immediately or longer term.

Examples include, adjusting traffic controls to restrict demand in an affected area, adjusting Toll levels to reduce demand or, longer term, adjust signal plans to take account of seasonal effects.

These systems are best targeted at areas where there is a recognised and measurable environmental condition problem, which can be usefully improved by either short or long term management of demand.

In terms of the objectives set out by the NZTS and LTMA, these systems deliver benefits in several areas, including:

- Public Health
- Environmental Sustainability

They also have potential to provide a positive contribution towards the following New Zealand specific target areas:

- Demand Management
- Environmental Mitigation

Integrated monitoring systems of this type are not currently operated in New Zealand.

5.3.2.7 Example Applications

Table 5.3.2.2 Example applications of Environmental Monitoring and Forecasting systems.

Location	Description	Observed Benefits & Costs
Athens, Greece	Athens is an urban area with 4 million inhabitants and suffers the same significant air pollution problems shared by all the large cities of the world. These problems are becoming worse because of bad city planning and Athens' topographical features. Mapping the pollution distribution by relying solely on the ground network of monitoring stations presents difficulties. The European Commission's CORINE land cover map indicates the apportionment of stationary sources, including industrial areas, quarries (classified as 'mineral extraction'), and domestic heating, comprising the categories 'continuous urban fabric' and 'discontinuous urban fabric'.	A database describing the temporal variation of gaseous and particulate pollutants has been available since 1980. Compared with previous years, air pollution in Athens showed a general decrease during 1996. As a result, the air pollution in Athens was ranging approximately 94% of the days in 1996 from low to moderate levels. Still there is a problem with ozone levels.
City of Bern and Bern Canton, Switzerland	The City of Bern and Bern Canton have adopted a traffic management system that aims to reduce emissions from motor vehicles on main streets by about 15-25% The planning for air quality should consider the needs of all traffic participants without designing new road capacity. The transportation policy can be regarded as an example of good practice for the following reasons: (1) Implementation of a steady traffic flow; (2) Combination of all transport modes and a correspondingly suitable street design; (3) Orientation towards a supply-orientated transport planning.	On Bernstrasse in Zollikofen the two most important junctions were replaced by roundabouts. By dividing the carriageway in the centre and the creating of centre islands, times for crossovers could be shortened and crossings could be made possible on the whole link. Altogether there were little conflicts to resolve with the public transport. It will be assumed that the number of crossings and turnings will not change but that stops will be replaced by deceleration. The general saving potential for fuel consumption and emissions is 15-25% compared with the undeveloped condition. In comparison with the earlier light signal, the roundabout leads to the saving of fuel and emissions by about 17%.

5.3.3 Real-Time Public Transport Passenger Information Systems

5.3.3.1 Description

At-stop real-time passenger information systems (ASRTIS) incorporate public interactive terminals, dynamic bus stop signs and variable message signs to disseminate information to passengers relating to the status of public service vehicles that utilise the stop at which they are located. The information relayed can include:

- Route number of the vehicle
- Destination of the vehicle
- Waiting time in minutes

The dynamic or variable message signs are located in close proximity to the bus stop or shelter in the direction of the approaching vehicle so that they can be easy viewed by waiting passengers. The public interactive terminals are located so that they are easily accessed by waiting passengers, and may also include audio facilities to relay information to visually impaired passengers.

The systems rely upon the collection of robust information to determine the current location of the bus or tram. This is generally achieved using Global Positioning System (GPS) technology incorporated within the public service vehicle.
In addition to conveying information relating to arrival times of services, the use of variable message signs also enables information regarding service interruptions to be relayed to passengers.

5.3.3.2 Benefits

The main benefits include:

- Improved service information for passengers waiting at the stops.
- Reliable information to enable public service vehicle drivers to determine the status of their vehicle with regards to the timetable and make improvements where necessary.
- Perception of improved reliability of public service vehicles.

5.3.3.3 Potential Problems

The main problems associated with these systems are;

- Ensuring the accuracy and reliability of the information, and the set up, installation and maintenance costs of achieving this.
- Interoperability of systems can present a problem, where several bus operators are running services across the same area.

5.3.3.4 Applications

These systems are most cost effective in areas where bus services suffer from congestion related delays. In these situations providing passengers with a level of certainty of bus times, under variable conditions, leads to an improved level of perceived reliability and so to increased public transport use.

5.3.3.5 Relevance to NZTS / LTMA Objectives

Table 5.3.3.1 Contribution of Real-Time Public Transport Passenger Information Systems to NZTS/LTMA objectives (derived from Contribution Matrix Section 2).

NZTS / LTMA Objective	***Level of contribution***	***Comment***
A. Economic Development	*Medium*	
Traffic Congestion	➲	Assist by encouraging increased use of public transport and enhances accessibility of services.
Traffic/Transport Demand	➲	
Quality & efficiency of transport	✓	
Travel time reliability	✓	
B Safety and Personal Security	*Low*	
Perceived personal safety/security for non car mode trips	✓	Assist by improving experience and reliability of public transport services.
C Access & Mobility	*High*	
Traffic Congestion	➲	Assist by encouraging increased use of public transport and enhances accessibility of services. Assist by improving experience and reliability of public transport services.
Traffic/Transport Demand	➲	
Frequency and reliability of key passenger transport services	✓	
Convenience (perceived and actual) of public transport services	✓	
Level (%) of commuting trips by passenger transport	✓	
Level (%) of commuting trips by Pedestrians	➲	
Quality & efficiency of transport	✓	
Travel time reliability	✓	
D Public Health	*Medium*	
Traffic congestion in urban areas (impacts on local air quality)	➲	Assist by encouraging increased use of public transport and enhances accessibility of services. Contribute indirectly as a component of other systems.
Numbers of short trips made by walking or cycling	➲	
Numbers of commuting trips made by walking or cycling	➲	
E Sustainability	*High*	
Traffic/Transport Demand	➲	Assist by encouraging increased use of public transport and enhances accessibility of services. Assist by improving experience and reliability of public transport services.
Level(%) of trips that are not car based	✓	
Growth rate of total vehicle travel	✓	
Emission levels (particulates, nitrogen oxides, carbon monoxides, CO_2)	✓	
Extent to which the benefits will be sustainable over time	✓	

Table 5.3.3.1 (continued)

NZTS / LTMA Objective	***Level of contribution***	***Comment***
F Energy Efficiency	*High*	
Traffic Congestion	➲	Assist by encouraging increased use of public transport and enhances accessibility of services. Assist by improving experience and reliability of public transport services.
Traffic/Transport Demand	➲	
Efficiency of routes taken	➲	
Fuel use	✓	
level of travel in congested conditions	➲	
Use of energy efficient modes	✓	
Quality & efficiency of transport	✓	
Implementation constraints – resource consents, legal & others	✓	
G Integration	*High*	
Provision for all modes on key transport corridors	➲	Assist in providing timely information to users. Assist by improving experience and reliability of public transport services. Assist in making provision for all modes.
Level of priority given to passenger transport	✓	
Efficiency and convenience of mode transfer points	✓	
Level of integration between road and rail	✓	
Improving rural community access & conditions	✓	
H Responsiveness	*High*	
Responding to diverse stake holder needs (particularly rural versus urban)	✓	Assist by encouraging increased use of public transport and enhances accessibility of services.
Contributions to national objectives	✓	
Quality & efficiency of transport	✓	
Travel time reliability	✓	
I Affordability and Cost Effectiveness	*Medium*	
Relative benefit to cost ratio	✓	These systems are most cost effective in areas where bus services suffer from congestion related delays. In these situations providing passengers with a level of certainty of bus times, under variable conditions, leads to an improved level of perceived reliability.
Level of operating cost	➲	
J Implementation Risk	*Medium*	
Technical complexity	➲	The main problems associated with these systems are ensuring the accuracy and reliability of the information, and the set up, installation and maintenance costs of achieving this. Interoperability of systems can present a problem, where several bus operators are running services across the same area.
Interoperability	➲	
Cost certainty	➲	
Public acceptance	✓	

✓ = Positive Contribution; ✗ = No Significant Contribution; ➲ = Partial Contribution

5.3.3.6 Summary and Conclusions

At-stop real-time passenger information systems provide up-to-the-minute service details to passengers waiting at stops relating to the status of the service that is due to arrive. The information is collected by GPS technology, enabling an estimate of the arrival time to be made and the information to be relayed to the passengers via interactive terminals, dynamic and variable message signs.

In terms of the objectives set out by the NZTS and LTMA, these systems deliver benefits in several areas, including:

- Economic Development
- Access and Mobility
- Public Health
- Environmental Sustainability

They also have the potential to provide a positive contribution towards the following New Zealand specific target areas:

- Congestion Relief
- Quality and Efficiency
- Travel Time Reliability
- Environmental Mitigation

Currently two systems of this type operate in New Zealand, in Auckland and Christchurch.

5.3.3.7 Example Applications

Table 5.3.3.2 Example applications of Real-Time Public Transport Passenger Information Systems.

Location	Description	Observed Benefits & Costs
Real-time bus & tram passenger information system – Helsinki, Finland.	Introduced in 1999, the real-time passenger information system incorporates part of the 423 Public Transport Telematic System. It covers one tram line (Route 4) and one bus line (Route 23), but will be expanded to cover all trams and bus services in central Helsinki, serving 250,000 daily passengers. The numbers of daily passengers that used the services during the pilot project were 37,000 for Tram Line 4 and 5,000 for Bus Line 23. Passenger surveys were undertaken between 1998 and 2000 to determine the costs and benefits of the scheme.	**Customer Satisfaction Personal Interviews:** Approximately half the passengers interviewed used the routes each day. 71% of the tram passengers and 83% of the bus passengers noticed the traveller information displays. Of those, 66% of tram passengers and 78% of bus passengers regarded the displays as useful. The most desirable features included: • Information on remaining wait time • Option to choose another route • Understandability of the display • Knowing if the vehicle they were waiting for had already passed. **Customer Satisfaction Surveys:** More than 90% of the respondents noticed the information displays. Of those, 95% said the information displays were useful, with the most desirable features being: • Information on remaining wait time • Knowing if the vehicle they were expecting had already passed. Some drivers were initially unaware of the requirements to enter their vehicle into the system as they left the depot each morning, resulting in some vehicles not being registered in the system. This affected the early performance of the system. After further driver training the problem was reduced and the system operated satisfactorily.

Table 5.3.3.2 (continued)

<table>
<tr><th>Location</th><th>Description</th><th>Observed Benefits & Costs</th></tr>
<tr><td>London, UK</td><td>Countdown is an electronic information display system that gives people waiting at bus stops real time information on bus arrivals in a similar fashion to the information service that's taken for granted by those using the London Underground. As well as indicating which routes are running and their arrival times, Countdown can display special messages to passengers regarding information on traffic delays or forthcoming road works.</td><td>There has been strong overall support for the Countdown system amongst passengers during the first three years of its operation (October 1992 to 1995). Patrons were asked to comment on their attitude towards bus travel following the implementation of Countdown.
<table>
<tr><th></th><th>Route 18</th><th>Uxbridge</th><th>Road Nag's Head</th></tr>
<tr><td>Sample size</td><td>452</td><td>510</td><td>616</td></tr>
<tr><td>Attitude has:</td><td colspan="3"></td></tr>
<tr><td>improved</td><td>68%</td><td>57%</td><td>53%</td></tr>
<tr><td>not changed</td><td>31%</td><td>39%</td><td>44%</td></tr>
<tr><td>worsened</td><td>1%</td><td>4%</td><td>3%</td></tr>
</table>
Patrons were asked to give there perception of waiting time following countdown implantation.
<table>
<tr><th></th><th>Route 18</th><th>Uxbridge</th><th>Road Nag's Head</th></tr>
<tr><td>Sample size</td><td>452</td><td>510</td><td>616</td></tr>
<tr><td>Passengers believe they now wait for;</td><td colspan="3"></td></tr>
<tr><td>A shorter time</td><td>65%</td><td>24%</td><td>21%</td></tr>
<tr><td>About the same time</td><td>27%</td><td>61%</td><td>65%</td></tr>
<tr><td>A longer time</td><td>6%</td><td>7%</td><td>6%</td></tr>
</table>
</td></tr>
<tr><td>Southampton, UK</td><td>STOPWATCH is a real time passenger information system which uses automatic vehicle location technology to track buses. The reported position of the bus is then processed and arrival times are calculated and transmitted to electronic signs at stops further along the bus route. Currently a STOPWATCH system operates in Winchester with new systems proposed for Southampton, Portsmouth and some major bus routes within Hampshire.</td><td>When asked what effect the Stopwatch system would have on their use of buses the responses given by passengers waiting at bus stops are given in the table below.
<table>
<tr><th></th><th>No effect</th><th>Increased usage</th><th>Not sure</th></tr>
<tr><td>Before study</td><td>73.5%</td><td>16.3%</td><td>10.2%</td></tr>
<tr><td>After study</td><td>95.1%</td><td>3.7%</td><td>1.2%</td></tr>
</table>
When passengers at the stop were informed of a long waiting time by the information shown on the real-time display, 12.6% of the respondents left the bus stop.</td></tr>
</table>

5.3.4 Access Control Systems

5.3.4.1 Description

These are systems that control access to certain parts of the transport system either through access rights or as part of a charging scheme. Examples include restricted service areas, public transport lanes and charging zones.

Access control technologies include:

- Vehicle monitoring and enforcement for systems such as congestion charging.
- Bus lane violation cameras.
- Access control barriers for dedicated bus routes and service lanes.

5.3.4.2 Benefits

Benefits of this type of system are that they are able to support the use of restricted access as a tool in managing traffic congestion and demand, as part of a broader demand management strategy.

5.3.4.3 Potential Problems

The problems with access control systems are specific to the type of system. For enforcement based systems the problems tend to be linked to managing access to transport registry information, managing high volume information processing and dealing with local geographic issues. With physical access controls the problems tend to be related to managing delays at control points.

5.3.4.4 Applications

As these systems are designed to control a range of access restrictions it is important to develop a solution suitable to meet the specific needs. For example a barrier based system may be appropriate for a restricted service lane area, but may not be an appropriate for a congestion charging facility with high volumes of traffic. In general terms, automated access control systems are best targeted at areas where traditional enforcement methods are either ineffective or are not cost effective.

5.3.4.5 Relevance to NZTS / LTMA Objectives

Table 5.3.4.1 Contribution of Access Control Systems to NZTS/LTMA objectives (derived from Contribution Matrix Section 2).

NZTS / LTMA Objective	*Level of contribution*	*Comment*
A Economic Development	*Medium*	
Traffic Congestion	✓	Improve traffic flow by controlling access to congested areas. Provide improvement for those with legitimate access rights. Improve strategic routes by controlling access to congested sections. Provide improvement for those with legitimate access rights. Can be used as an element of more direct charging system. Regulate demand by controlling access to congested areas.
Traffic/Transport Demand	✓	
Transport users face the true costs of use	➲	
Travel time for car commuters to key employment centres	➲	
Maintain strategic route security / availability / information	➲	
Quality & efficiency of transport	➲	
Freight transport and mode transfer	➲	
Travel time reliability	✓	

Table 5.3.4.1 (continued)

NZTS / LTMA Objective	***Level of contribution***	***Comment***
B Safety and Personal Security	*Medium*	
Number of traffic crashes	✓	Improve ability to monitor compliance with a range of traffic regulations. Reduce ttraffic conflicts by controlling access to congested areas.
Level of conflict between vehicles / cyclists / pedestrians and other road users	✓	
Compliance (with traffic / transport regulations)	✓	
C Access & Mobility	*Medium*	
Traffic Congestion	✓	Improve traffic flow by controlling access to congested areas. Regulate demand by controlling access to congested areas. Provide improvement for those with legitimate access rights. When used in conjunction with other systems that promote alternative modes.
Traffic/Transport Demand	✓	
Sector to sector travel times by car	➲	
Frequency and reliability of key passenger transport services	✓	
Convenience (perceived and actual) of public transport services	✓	
Level (%) of commuting trips by passenger transport	✓	
Level (%) of commuting trips by Cycle	➲	
Level (%) of commuting trips by Pedestrians	➲	
Compliance (with traffic / transport regulations)	✓	
Strategic route security / availability / information	➲	
Quality & efficiency of transport	➲	
Travel time reliability	✓	
D Public Health	*Medium*	
Traffic congestion in urban areas (impacts on local air quality)	✓	Improve traffic flow by controlling access to congested areas. When used in conjunction with other systems that promote alternative modes. Improve ability to monitor compliance with a range of traffic regulations.
Vehicle noise	✓	
Numbers of short trips made by walking or cycling	➲	
Numbers of commuting trips made by walking or cycling	➲	
Compliance (with emissions regulations)	✓	
E Sustainability	*High*	
Traffic/Transport Demand	✓	Regulate demand by controlling access to congested areas. Improve traffic flow by controlling access to congested areas. Assist in the monitoring and management of freight. Can be used as an element of more direct charging system.
Level(%) of trips that are not car based	✓	
Non road freight volumes as a percentage of total	✓	
Growth rate of total vehicle travel	✓	
Emission levels (particulates, nitrogen oxides, carbon monoxides, CO_2)	✓	
Extent to which users face full cost of their road use	➲	
Extent to which the benefits will be sustainable over time	✓	

Table 5.3.4.1 (continued)

NZTS / LTMA Objective	***Level of contribution***	***Comment***
F Energy Efficiency	*High*	
Traffic Congestion	✓	Improve traffic flow by controlling access to congested areas. Regulate demand by controlling access to congested areas.
Traffic/Transport Demand	✓	
Efficiency of routes taken	✓	
Fuel use	✓	
level of travel in congested conditions	✓	
Use of energy efficient modes	✓	
Quality & efficiency of transport	➲	
G Integration	*High*	
Provision for all modes on key transport corridors	✓	Improve traffic flow by controlling access to congested areas. Assist in making provision for all modes.
Level of priority given to passenger transport	✓	
Efficiency and convenience of mode transfer points	✓	
H Responsiveness	*High*	
Responding to diverse stake holder needs (particularly rural versus urban)	➲	Improve traffic flow by controlling access to congested areas.
Contributions to national objectives	✓	
Maintain strategic route security / availability / information	➲	
Quality & efficiency of transport	➲	
Travel time reliability	✓	
I Affordability & Cost Effectiveness	*Medium*	
Relative benefit to cost ratio	➲	Cost effectiveness is directly related to the application of appropriate schemes for appropriate problems, and adequate consideration of operational costs and maintenance.
Level of operating cost	➲	
Contribution direct from users	➲	
J Implementation Risk	*Medium*	
Technical complexity	➲	Main risk areas are inappropriate application of systems; underestimating of operational costs and maintenance, and adequately considering the effectiveness of more traditional options.
Interoperability	➲	
Cost certainty	➲	
Public acceptance	➲	
Implementation constraints – resource consents, legal & others	➲	
✓ = Positive Contribution; ✗ = No Significant Contribution; ➲ = Partial Contribution		

5.3.4.6 *Summary and Conclusions*

These systems control access to certain parts of the transport system using monitoring and enforcement technologies, violation cameras and access control barriers.

Benefits accrue through more effective management of access restrictions used to manage traffic congestion and demand.

Successful applications are those that develop a solution suitable to meet the specific needs.

The main risk areas are inappropriate application of systems, underestimating of operational costs and maintenance, and adequately considering the effectiveness of more traditional options.

In terms of the objectives set out by the NZTS and LTMA, these systems deliver benefits in several areas, including:

- Economic Development
- Safety and Personal Security
- Access and Mobility
- Public Health
- Environmental Sustainability

These systems have the potential to provide a positive contribution towards the following New Zealand specific target areas:

- Congestion Relief
- Demand Management
- Compliance
- Safety
- Route Security
- Quality and Efficiency
- Travel Time Reliability
- Environmental Mitigation

Currently there are no such systems operating in New Zealand.

5.3.4.7 Example Applications

Table 5.3.4.2 Example applications of Access Control Systems.

Location	Description	Observed Benefits & Costs
London Congestion Charging Scheme, UK	This scheme restricts access to the central city area to vehicles that have paid a flat rate charge. The systems are based on video number plate monitoring, checking these against the database of vehicles that have either paid the charge or have another right of access.	Traffic delays inside the charging zone are 30% lower than before charging was introduced. Estimates of year-on-year changes in traffic levels during charging hours show a reduction of 18% in traffic entering the zone during charging hours, with a reduction of 30% in cars. Buses demonstrate significant gains in reliability in and around the charging zone, experiencing up to a 60% reduction in disruption caused by traffic delays. There is no evidence of any significant adverse traffic impacts from the charge. Congestion charging contributes £50 million of net transport benefits to London's economy per year, mainly through quicker and more reliable journeys for road and bus users.

Table 5.3.4.2 (continued)

Location	Description	Observed Benefits & Costs
London, UK Bus lane cameras	Bus Lane cameras have been installed on buses in London to reduce the level of violations of these restrictions. The cameras are built into the London buses and records twin images on to a video. A close up of vehicles rear license plate in the bus lane, and recordings of the surrounding traffic conditions in the bus lane and the adjacent lane. Thereby the cameras identify both the offenders and possible mitigating circumstances that should be taken into consideration.	The system consists of 2 CCTV cameras installed together in a secure and waterproof housing on the nearside of the bus adjacent to the rate and destination sign. Camera 1 is fitted with an angle lens to provide a general overview to allow enforcement personnel to assess the circumstances relating to an offence. Camera 2 provides a detailed view of the bus lane providing sufficient details to read the license plate of vehicles in the bus lane. The introduction of these cameras has helped to improve bus reliability through improved compliance with these restrictions, and reduce journey times for buses across London.

5.3.5 Integrated Smart Cards / Multi-Use Payment Systems

5.3.5.1 Description

Electronic payment systems or Smart Cards use electronic communication, data processing and data storage technology to automate fare storage and collection, allowing patrons a single method of payment for:

- Public transport fares
- Parking fees
- Toll road levies

A multi use payment system allows users to carry one payment device that can be used for parking, bus fares, train fares and other goods and services.
The basic types of card available are:

- Magnetic strip cards
- Smart cards with micro-processors
- Proximity cards

Magnetic strip cards can be made of heavy paper or plastic depending on requirements. The thicker, plastic versions tend to have a very long life, whereas heavy paper is generally only useable for short periods, such as day-tickets. The magnetic strip cards are generally only suitable for fixed fare payments.

Smart cards with micro-processors can be used to retain data relating to the cash amount stored on the card, the travel habits of the user and other information likely to change over its useful life. This can be useful information to the travel planning authority, allowing a more flexible fare structure to be introduced. Given the higher cost of this type of card, they are generally only suitable for use where with longer life spans are required.

Many modern systems use proximity cards, which utilise radio frequency technology to remove the need for physical contact between the card and the fare reading device. The distance over which the card can be read can be extended to up to 300 millimetres, although most systems require the patron to touch a pad on the card reading machine in order for the card to be read. The cards can also be ‘charged’ prior to travel using prepaid accounts or credit/debit payment systems.

5.3.5.2 Benefits

The main benefits of introducing smart cards are:

- Elimination of cash and coin handling facilities which improves security.
- Reduced time required for the technology to read the information stored on the card, thereby improving transfer time between modes and for patrons entering the system.
- Reduced operating costs, such as paper used for the cards.
- Fewer moving parts in the fare reading technology, thereby increasing reliability.

5.3.5.3 Potential Problems

The main problems of introducing these technologies are:

- Achieving standardisation and interoperability between systems.

- It is often necessary to operate smart-card system along side existing systems while patrons adjust to the new technology.

5.3.5.4 Applications

Smart card technology has a wide range of applications. The main benefits from a transport perspective are the improved convenience for users of transport toll and parking facilities, and reduced overall operating costs.

The use of these technologies is therefore best targeted at payment streams where there is a relatively high volume of repeat users, ideally across a range of transport services.

Examples include city parking, toll facilities, and public transport services fare payment.

5.3.5.5 Relevance to NZTS / LTMA Objectives

Table 5.3.5.1 Contribution of Integrated Smart Cards/Multi-Use Payment Systems to NZTS/LTMA objectives (derived from Contribution Matrix Section 2).

NZTS / LTMA Objective	*Level of contribution*	*Comment*
A Economic Development	*Medium*	
Traffic/Transport Demand	➲	As a component of other systems. Assist by encouraging increased use of public transport and enhances accessibility of services. Can be used as an element of more direct charging system.
Travel time on key routes	➲	
Transport users face the true costs of use	➲	
Quality & efficiency of transport	✓	
Freight transport and mode transfer	➲	
B Safety and Personal Security	*Low*	
Compliance (with traffic / transport regulations)	➲	As a component of other systems.
C Access & Mobility	*Medium*	
Traffic Congestion	➲	Assist by encouraging increased use of public transport and enhances accessibility of services. When used with cycle rental schemes. Assist by improving experience and reliability of public transport services. As a component of other systems.
Traffic/Transport Demand	➲	
Frequency and reliability of key passenger transport services	✓	
Convenience (perceived and actual) of public transport services	✓	
Level (%) of commuting trips by passenger transport	✓	
Level (%) of commuting trips by Cycle	➲	
Quality & efficiency of transport	✓	
D Public Health	*Low*	
Numbers of short trips made by walking or cycling	➲	When used with cycle rental schemes.
Numbers of commuting trips made by walking or cycling	➲	

Table 5.3.5.1 (continued)

NZTS / LTMA Objective	Level of contribution	Comment
E Sustainability	Medium	
Traffic/Transport Demand	➲	As a component of other systems. Assist by improving experience and reliability of public transport services. Can be used as an element of more direct charging system.
Level(%) of trips that are not car based	✓	
Growth rate of total vehicle travel	✓	
Emission levels (particulates, nitrogen oxides, carbon monoxides, CO_2)	✓	
Extent to which users face full cost of their road use	➲	
Levels of service on key routes	➲	
Extent to which the benefits will be sustainable over time	✓	
F Energy Efficiency	Low	
Traffic/Transport Demand	➲	As a component of other systems. Assist by improving experience and reliability of public transport services. Assist by encouraging increased use of public transport and enhances accessibility of services.
Efficiency of routes taken	➲	
Fuel use	✓	
Use of energy efficient modes	✓	
Quality & efficiency of transport	✓	
G Integration	High	
Provision for all modes on key transport corridors	✓	Assist in making provision for all modes. Assist by improving experience and reliability of public transport services. Assist by encouraging increased use of public transport and enhances accessibility of services.
Efficiency and convenience of mode transfer points	✓	
Level of integration between road and rail	✓	
Improving rural community access & conditions	✓	
H Responsiveness	High	
Responding to diverse stake holder needs (particularly rural versus urban)	✓	Assist by encouraging increased use of public transport and enhances accessibility of services.
Contributions to national objectives	✓	
Quality & efficiency of transport	✓	
I Affordability and Cost Effectiveness	Medium	
Relative benefit to cost ratio	➲	Cost effectiveness is related to achieving a suitable level of transactions to support back end systems. A challenge in this area is to achieve standardisation and interoperability between systems in order to raise the transaction base.
Level of operating cost	✓	
Contribution direct from users	➲	
J Implementation Risk	Medium	
Technical complexity	➲	The main risks are achieving suitable levels of transactions to meet costs; and achieving and maintaining interoperability between systems. Base costs need to take account of operating smart-card system along side existing systems while patrons adjust to the new technology.
Interoperability	➲	
Cost certainty	➲	
Public acceptance	✓	
Implementation constraints – resource consents, legal & others	✓	

✓ = Positive Contribution; ✗ = No Significant Contribution; ➲ = Partial Contribution

5.3.5.6 Summary and Conclusions

Smart-card technology enables patron to pay for public transport, parking and toll levies without the need for cash or to have the correct change available. This can help improve efficiency, reduce travel time, reduce on-going costs and increase the planning capabilities of the responsible travel authority by using cards that can be charged in advance and can store information relating to the patrons travel habits.

The main problems are achieving interoperability across a range of systems, and that the systems generally have to be operated along side existing systems for extensive periods while patrons adjust to the new technology.

In terms of the objectives set out by the NZTS and LTMA, these systems deliver benefits in several areas, including:

- Economic Development
- Access and Mobility
- Sustainability.

They also have the potential to provide a positive contribution towards the following New Zealand specific target areas:

- Demand Management
- Compliance
- Safety
- Quality and Efficiency
- Travel Time Reliability

The use of these types of systems in New Zealand is growing, but most are stand alone electronic payment facilities implemented and used for specific services. The level of integration and cross service payment opportunity is extremely limited.

5.3.5.7 Example Applications

Table 5.3.5.2 Example applications of Access Control Systems.

Location	Description	Observed Benefits & Costs
Golden Gate Translink, San Francisco, USA	Installed as a pilot project in February 2002. 5000 volunteers tested the smart card fare payment system incorporating 9 BART stations.	76% of cardholders ranked the system with the highest mark of satisfaction. 35 out of 36 members of a focus group recommended that the system be expanded to all Bay Area transit systems. Over 10% of all daily Golden Gate Transit Ferry riders use the Translink Smartcard.

5.4 Bus Management Systems

Bus management ITS services include a number of applications that can help bus agencies increase safety and improve operational efficiency. Advanced software and communications enable data as well as voice to be transferred between bus management centres and vehicles for increased safety and security, improved demand management, and more efficient fleet operations.

Bus demand management services increase public accessibility where coverage is limited. Fleet management systems can improve reliability through implementation of automated vehicle location (AVL) and computer-aided dispatch (CAD) systems which can reduce passenger wait times.

This section contains summaries of the following systems:

5.4.1 Priority Signal Pre-Emption and Advance Stop Line Intersection

5.4.2 On-Vehicle and Facility Surveillance

5.4.3 Dynamic Routing/Scheduling

5.4.1 Priority Signal Pre-Emption and Advance Stop Line Intersection

5.4.1.1 Description

A traffic signal pre-emption system (TSPS) remotely controls traffic signal operations to give priority to nominated vehicles on the approach to intersections. They are specifically designed to:

- Improve the operating efficiency and reliability of public transport vehicles.
- Improve response times for emergency service vehicles
- Increase safety for other road users.

Advanced Stop Line Intersection arrangements provide a further advantage for buses by providing them with a dedicated lane to bypass traffic queuing at an intersection.

Pre-emption systems generally comprise a facility that allows a nominated vehicle to communicate with the traffic signal control system so that the operational cycle of the traffic signals can be modified to give priority as a vehicle approaches.

The systems that are generally employed are:

- Global Positioning Systems (GPS).
- On-board radio transponder with road-side detection devices.

The GPS system requires an electronic device to be installed within the vehicle that communicates with the satellite technology and allows the vehicle to be located along the route. The traffic signal timings can then be amended as the vehicle approaches the intersection.

The on-board radio transponder system requires a transmitting device to be located within the vehicle and a receiving device to be installed in the traffic signal controller cabinet and at various locations along the route. It is then possible to locate any vehicle along the route and to amend the traffic signal timings where appropriate.

With both systems, the traffic signal cycle may be amended in two ways:

- When the required approach is showing green the phase time is extended to allow vehicles to continue through the signals during the current phase.
- When the required approach is not within the green phase, the green phases on conflicting approaches are truncated to give priority to the required approach.

Traffic signal pre-emption systems are usually installed in association with other intelligent transport applications such as real-time passenger information systems.

5.4.1.2 Benefits

The main benefits of introducing signal pre-emption for buses are:

- Reduced public service vehicle journey times.
- Improved journey time reliability for public service vehicles.
- Increased ability to plan timetables and reduce headways.
- Reduction in fuel consumption and emissions due to less time spent in congested traffic at intersections.

- Quicker emergency service response times.

5.4.1.3 Potential Problems

The main problems associated with signal pre-emption for buses are:

- Increased delays to vehicles on other approaches to the intersection.
- Installation and maintenance costs.

5.4.1.4 Applications

Signal Pre-emption systems can generally be installed:

- On bus routes where delays at traffic signals are frequently experienced.
- At intersections close to emergency service vehicle depots to provide easy access and egress.

5.4.1.5 Relevance to NZTS / LTMA Objectives

Table 5.4.1.1 Contribution of Priority Signal Pre-Emption and Advance Stop Line Intersection systems to NZTS/LTMA objectives (derived from Contribution Matrix Section 3).

NZTS / LTMA Objective	***Level of contribution***	***Comment***
A Economic Development	*Medium*	
Traffic Congestion	➲	Contribute to improving travel time for public transport. Promote the use of public transport through improved access, travel times and reliability. Improve the ability of bus operators to maintain reliable schedules.
Traffic/Transport Demand	✓	
Travel time on key routes	✓	
Transportation Costs (travel time, VOC)	➲	
Quality & efficiency of transport	✓	
Quality & efficiency of transport	✓	
B Safety and Personal Security	*Medium*	
Level of conflict between vehicles / cyclists / pedestrians and other road users	✓	Reduce conflict by improving merging and providing managed priority.
Perceived personal safety/security for non car mode trips	✓	
C Access & Mobility	*Medium*	
Traffic Congestion	➲	Contribute to improving travel time for public transport. Contribute as part of an integrated demand management to strategy; improving travel time and reliability of public transport. Assist by improving experience and reliability of public transport services. Where cycleway signals are provided. Improve compliance by providing managed priority. Improve the ability of bus operators to maintain reliable schedules.
Traffic/Transport Demand	➲	
Frequency and reliability of key passenger transport services	✓	
Convenience (perceived and actual) of public transport services	✓	
Level (%) of commuting trips by passenger transport	✓	
Level (%) of commuting trips by Cycle	➲	
Compliance (with traffic / transport regulations)	➲	
Quality & efficiency of transport	✓	
Travel time reliability	✓	

Table 5.4.1.1 (continued)

NZTS / LTMA Objective	***Level of contribution***	***Comment***
D Public Health	*Low*	
Traffic congestion in urban areas (impacts on local air quality)	➲	Contribute to improving travel time for public transport. Improve flow of bus traffic, reducing stop start noise. Where cycleway signals are provided.
Vehicle noise	✓	
Numbers of short trips made by walking or cycling	➲	
Numbers of commuting trips made by walking or cycling	➲	
E Sustainability	*High*	
Traffic/Transport Demand	✓	Promote the use of public transport through improved access, travel times and reliability. Assist by improving experience and reliability of public transport services. Improve the ability of bus operators to maintain reliable schedules.
Level(%) of trips that are not car based	✓	
Growth rate of total vehicle travel	✓	
Emission levels (particulates, nitrogen oxides, carbon monoxides, CO_2)	✓	
Levels of service on key routes	✓	
Extent to which the benefits will be sustainable over time	✓	
F Energy Efficiency	*High*	
Traffic Congestion	➲	Contribute to improving travel time for public transport. Promote the use of public transport through improved access, travel times and reliability. Assist by improving experience and reliability of public transport services. Improve the ability of bus operators to maintain reliable schedules.
Traffic/Transport Demand	✓	
Efficiency of routes taken	✓	
Fuel use	✓	
level of travel in congested conditions	➲	
Use of energy efficient modes	✓	
Quality & efficiency of transport	✓	
G Integration	*High*	
Provision for all modes on key transport corridors	✓	Assist in making provision for all modes. Assist by improving experience and reliability of public transport services.
Level of priority given to passenger transport	✓	
Efficiency and convenience of mode transfer points	✓	
H Responsiveness	*High*	
Responding to diverse stake holder needs (particularly rural versus urban)	✓	Improve the ability of bus operators to maintain reliable schedules.
Contributions to national objectives	✓	
Quality & efficiency of transport	✓	
Travel time reliability	✓	

Table 5.4.1.1 (continued)

NZTS / LTMA Objective	Level of contribution	Comment
I Affordability and Cost Effectiveness	*High*	
Relative benefit to cost ratio	✓	The costs of implementing this type of system can be relatively high, depending on the level of existing systems in place and the number of buses that need to be fitted with equipment.
Level of operating cost	✓	
J Implementation Risk	*Medium*	
Technical complexity	➲	The complexity levels of these types of systems can be high, particularly where they are linked to existing traffic signal management systems.
Interoperability	➲	
Cost certainty	➲	
Public acceptance	➲	
Public acceptance	✓	
✓ = Positive Contribution; ✗ = No Significant Contribution; ➲ = Partial Contribution		

5.4.1.6 Summary and Conclusions

Traffic signal pre-emption systems can be installed along public transport routes to reduce journey times and increase reliability, allowing for improved planning of timetables and lowering of headways between services. The system can also be introduced at signal controlled intersections to give priority to emergency service vehicles to enable response times to be reduced.

The systems can either be based on Global Satellite Positioning technology or on a system of radio transponders located within designated vehicles where roadside receivers detect the vehicle as it moves along the route.

In terms of the objectives set out by the NZTS and LTMA, these systems deliver benefits in several areas, including:

- Economic Development
- Safety and Personal Security
- Access and Mobility
- Sustainability.

They also have the potential to provide a positive contribution towards the following New Zealand specific target areas:

- Congestion Relief
- Demand Management
- Compliance
- Safety
- Route Security
- Quality and Efficiency
- Travel Time Reliability
- Environmental Mitigation

Bus priority facilities are used in New Zealand, and in recent years these have been expanding in the main urban centres. However, most are based on physical lane restrictions and the use of technology to provide 'smarter' access is limited.

5.4.1.7 Example Applications

Table 5.4.1.2 Example applications of Priority Signal Pre-Emption and Advance Stop Line Intersection systems.

Location	Description	Observed Benefits & Costs
Uxbridge Road – London, UK	22km long section of a radial route running from Uxbridge to Shepherd Bush in West London. 2 Bus routes operate along the road in two overlapping sections, and in the peak hour there are over 20 buses operating in each direction carrying 60,000 passengers per day. Physical bus priority measures introduced in 1996 reduced average journey times by 4 minutes. However, buses still experienced delays at traffic signalled intersections. A Bus SCOOT system was trialled in 1998, with green extensions & saturation recall.	Significant saving in bus delay and delay variability of up to 20%. Estimated savings of up to £290,000 in reduced delays, reliability and vehicle operating costs. No significant effects on traffic flow.
Transit Signal Priority System – Portland, USA	Trails undertaken in 2001 using GPS and existing roadside automatic vehicle locating system. Priority was only given to public service vehicles that were running behind schedule.	Median inbound journey times in the pm peak period were 2.4% lower when the system was operating compared to when it was switched off. Median outbound journey times in the pm peak period were 4.2% lower when the system was operating compared to when it was switched off. Average public service vehicle speeds were 7.7% higher in the am peak and 13.7% higher in the pm peak.

5.4.2 On-Vehicle and Facility Surveillance

5.4.2.1 Description

These surveillance systems monitor the interior of buses and bus facilities to identify any problems and generally improve the safety and security of the travelling public and the operator's staff.

These systems generally comprise video cameras linked to a central control facility; the on bus units being run using wireless data links. Similar systems are also used for rail based public transport with similar benefits.

In recent years the use of these systems has increased significantly in the US on school buses in particular.

5.4.2.2 Benefits

The benefits gained from these systems are improved safety and security for users and staff, which translates to users feeling more comfortable about using public transport on a regular basis, leading to improved patronage and associated improvements for the broader transport system.

5.4.2.3 Potential Problems

The main problem areas with these types of systems are related to vandalism of cameras and other equipment, understanding of the level of commitment required to monitor, and maintaining communications with mobile bus cameras where used.

5.4.2.4 Applications

These systems are best targeted at bus routes and facilities with identified problems of vandalism, or where users have identified a concern over safety and security. They are particularly suited to late night city routes and remote facilities.

5.4.2.5 Relevance to NZTS / LTMA Objectives

Table 5.4.2.1 Contribution of On-Vehicle and Facility Surveillance systems to NZTS/LTMA objectives (derived from Contribution Matrix Section 3).

NZTS / LTMA Objective	***Level of contribution***	***Comment***
A Economic Development	*Low*	
Quality & efficiency of transport	✓	Improve public experience a quality of services.
B Safety and Personal Security	*Medium*	
Perceived personal safety/security for non car mode trips	✓	Improve public experience and quality of services.
Compliance (with traffic / transport regulations)	➲	Improve compliance by providing a means of surveillance (e.g. bus lanes).

Table 5.4.2.1 (continued)

NZTS / LTMA Objective	Level of contribution	Comment
C Access & Mobility	*Low*	
Frequency and reliability of key passenger transport services	➲	When used to assist in enforcement of bus priority etc.
Convenience (perceived and actual) of public transport services	✓	Assist by improving experience and reliability of public transport services.
Level (%) of commuting trips by passenger transport	✓	Improve compliance by providing a means of surveillance (e.g. bus lanes).
Compliance (with traffic / transport regulations)	➲	
Quality & efficiency of transport	✓	Improve public experience and quality of services.
E Sustainability	*Medium*	
Level(%) of trips that are not car based	✓	Assist by improving experience and reliability of public transport services.
Growth rate of total vehicle travel	✓	
Emission levels (particulates, nitrogen oxides, carbon monoxides, CO_2)	✓	
Extent to which the benefits will be sustainable over time	✓	
F Energy Efficiency	*Medium*	
Fuel use	✓	Assist by improving experience and reliability of public transport services.
Use of energy efficient modes	✓	Improve public experience a quality of services.
Quality & efficiency of transport	✓	
G Integration	*Medium*	
Level of priority given to passenger transport	✓	Assist by improving experience and reliability of public transport services.
Efficiency and convenience of mode transfer points	✓	
H Responsiveness	*High*	
Contributions to national objectives	✓	Improve public experience and quality of services.
Quality & efficiency of transport	✓	
I Affordability and Cost Effectiveness	*Medium*	
Relative benefit to cost ratio	➲	Costs of installation are relatively low, however the monitoring commitment can be expensive and requires adequate justification.
Level of operating cost	➲	
J Implementation Risk	*Low*	
Technical complexity	✓	These systems are relatively simple with the technologies used fairly well developed. There can be problems maintaining communication with mobile bus cameras where these are used in place of basic recording.
Interoperability	✓	
Cost certainty	✓	
Public acceptance	➲	
Implementation constraints – resource consents, legal & others	➲	
✓ = Positive Contribution; ✗ = No Significant Contribution; ➲ = Partial Contribution		

5.4.2.6 *Summary and Conclusions*

These systems generally comprise video cameras linked to a central control facility. The benefits gained are improved safety and security for users and staff, leading to improved patronage and associated improvements for the broader transport system.

The main problem areas with these types of systems are related to vandalism and the level of commitment required to monitor, and maintaining.

These systems are best targeted at bus routes and facilities with identified problems.

In terms of the objectives set out by the NZTS and LTMA, these systems deliver benefits in several areas, including:

- Safety and Personal Security
- Sustainability

They also have the potential to provide a positive contribution towards the following New Zealand specific target areas:

- Safety
- Quality and Efficiency

Currently these systems are not used in New Zealand.

5.4.2.7 Example Applications

Table 5.4.2.2 Example applications of On-Vehicle and Facility Surveillance systems.

Location	Description	Observed Benefits & Costs
"The Witness" School Bus Video Observation System - USA	These systems have been installed on many school buses across the US. They comprise a Video Observation Systems linked to recorders and in some cases real time monitoring.	Benefits reported by users over a 6year period include: The students who damage the bus are very conscious of the cameras. Vandalism and behaviour problems dropped significantly. Time spent investigating complaints from parents concerning student to student behaviour and driver complaints are resolved in minutes when parents see the video instead of hours or days as was required before the video tape. Driver training is improved by videotape review.
Queensland Busway, Australia	On the Queensland Busway: 140 cameras are positioned at stations, in tunnels and along the Busway. Most stations have 12 -16 cameras. The footage is monitored on 21 screens at the Busways Operations Centre through a series of 4 second programmed scan sequences for daytime, night-time and after-hours surveillance. The after-hours sequence relies on motion detection technology. Preset positions are programmed into the cameras for the daytime, night-time and after hours scenarios. These positions are set using macros for each station. All footage is recorded 24 hours a day and kept for 2 weeks. The video data is compressed and transmitted to the BOC through a multiplexer.	Benefits reported by the operators and users include: Passengers feel safer about using the facilities. Reduced vandalism of facilities and reduced maintenance costs. Reported increased use of services as a direct result of combined safety and security systems.

5.4.3 Dynamic Routing / Scheduling

5.4.3.1 Description

These systems assist in the scheduling of bus services so that they coordinate with other transport modes and services. The objective being to minimise waiting time for commuters and other travellers transferring between services, so reducing waiting time and improving convenience.

Dynamic route scheduling is generally implemented as a secondary service, built on the infrastructure and systems of vehicle tracking and timing systems implemented for real time passenger information and pre-emption.

The technologies used are therefore:

- Global Positioning Systems (GPS).
- On-board radio transponder with road-side detection devices.

The GPS requires an electronic device to be installed within the vehicle that communicates with the satellite technology and allows the vehicle to be located along the route.

The on-board radio transponder system requires a transmitting device to be located within the vehicle and a receiving device to be installed in the traffic signal controller cabinet and at various locations along the route. It is then possible to locate any vehicle along the route and to amend schedules to optimise the coordination of services.

In many cases these systems will be integrated with signal management and pre-emption facilities which can be used to assist a bus behind schedule to meet a connection target.

5.4.3.2 Benefits

The benefits are mainly from lower waiting time, and the resulting improvement in the convenience of public transport systems, leading to greater patronage, reduce congestion and improved economic benefits.

5.4.3.3 Potential Problems

The problems associated with these systems are mainly related to the costs and complexity of setting up an operating vehicle tracking system, integration of systems and optimisation management.

5.4.3.4 Applications

These systems are most often implemented as an extension of a wider vehicle tracking systems set up for passenger information or signal pre-emption. The particular benefits of dynamic scheduling are best achieved where there is an identified problem of waiting times between services; often caused by congestion effects, or at major bus/rail interchanges.

5.4.3.5 Relevance to NZTS / LTMA Objectives

Table 5.4.3.1 Contribution of Dynamic Routing / Scheduling systems to NZTS / LTMA objectives (derived from Contribution Matrix Section 3).

NZTS / LTMA Objective	***Level of contribution***	***Comment***
A Economic Development	*Medium*	
Traffic Congestion	➲	Contribute to improving travel time for public transport. Contribute only to improving travel time and VOC for public transport. Improve public experience a quality of services. Contribute to improving travel time for public transport.
Traffic/Transport Demand	➲	
Travel time on key routes	➲	
Transportation Costs (travel time, VOC)	➲	
Quality & efficiency of transport	✓	
Travel time reliability	✓	
B Safety and Personal Security	*Low*	
Level of conflict between vehicles / cyclists / pedestrians and other road users	✓	Reduce conflict by improving ability to avoid congestion. Improve public experience and quality of services.
Perceived personal safety/security for non car mode trips	✓	
C Access & Mobility	*Medium*	
Traffic Congestion	➲	Contribute to improving travel time for public transport. Assist by improving experience and reliability of public transport services. Improve public experience and quality of services.
Traffic/Transport Demand	➲	
Frequency and reliability of key passenger transport services	✓	
Convenience (perceived and actual) of public transport services	✓	
Level (%) of commuting trips by passenger transport	✓	
Quality & efficiency of transport	✓	
Travel time reliability	✓	
D Public Health	*Low*	
Traffic congestion in urban areas (impacts on local air quality)	➲	Contribute to improving travel time for public transport.
E Sustainability	*High*	
Traffic/Transport Demand	➲	Contribute to improving travel time for public transport. Assist by improving experience and reliability of public transport services.
Level(%) of trips that are not car based	✓	
Growth rate of total vehicle travel	✓	
Emission levels (particulates, nitrogen oxides, carbon monoxides, CO_2)	✓	
Levels of service on key routes	➲	
Extent to which the benefits will be sustainable over time	✓	
F Energy Efficiency	*High*	
Traffic Congestion	➲	Contribute to improving travel time for public transport. Assist by improving experience and reliability of public transport services. Improve public experience a quality of services.
Traffic/Transport Demand	➲	
Efficiency of routes taken	➲	
Fuel use	✓	
level of travel in congested conditions	➲	
Use of energy efficient modes	✓	
Quality & efficiency of transport	✓	

Table 5.4.3.1 (continued)

NZTS / LTMA Objective	Level of contribution	Comment
G Integration	*High*	
Level of priority given to passenger transport	✓	Assist by improving experience and reliability of public transport services.
Efficiency and convenience of mode transfer points	✓	
Level of integration between road and rail	✓	
Improving rural community access & conditions	✓	
H Responsiveness	*High*	
Contributions to national objectives	✓	Improve public experience a quality of services. Contributes to improving travel time for public transport.
Quality & efficiency of transport	✓	
Travel time reliability	✓	
I Affordability and Cost Effectiveness	*Medium*	
Relative benefit to cost ratio	✓	Cost effectiveness good provided scheduling has flexibility and need.
Level of operating cost	➲	
J Implementation Risk	*Medium*	
Technical complexity	➲	Relatively complex technically and some interoperability issues.
Interoperability	➲	
Cost certainty	➲	
Public acceptance	✓	
Implementation constraints – resource consents, legal & others	✓	
✓ = Positive Contribution; ✗ = No Significant Contribution; ➲ = Partial Contribution		

5.4.3.6 Summary and Conclusions

Dynamic route scheduling is generally implemented as a secondary service, built on the infrastructure and systems of vehicle tracking and timing systems implemented for real time passenger information and signal pre-emption.

The benefits are mainly from lower waiting time and the resulting improvement in the convenience of public transport systems, leading to greater patronage, reduce congestion and improved economic benefits.

The particular benefits of dynamic scheduling are best achieved where there is an identified problem of waiting times between services; often caused by congestion effects, or at major bus/rail interchanges.

In terms of the objectives set out by the NZTS and LTMA, these systems deliver benefits in several areas, including:

- Economic Development
- Access and Mobility
- Environmental Sustainability

They also have the potential to provide a positive contribution towards the following New Zealand specific target areas:

- Demand Management

- Safety
- Quality and Efficiency
- Travel Time Reliability

The use of these systems In New Zealand is limited, but in the areas where bus tracking has been introduced some integration with real time scheduling is used.

5.4.3.7 Example Applications

Table 5.4.3.2 Example applications of Dynamic Routing / Scheduling systems.

Location	Observed Benefits & Costs
Kansas City, USA	On-time performance improved from 80% to 90%, reductions in scheduled running times generating operations and maintenance cost savings of $400,000 annually.
Baltimore, USA	Increased on-time bus performance by 23%.
London, Ontario, Canada	Provided continuous schedule adherence saving $40K to $50K on money needed for schedule adherence surveys.
Milwaukee, USA	On-time performance improved from 90% to 94%.

5.5 Rural Highway Systems

The application of ITS to rural highway issues has increased over recent years, as the costs of communications in particular have fallen. This has led to increasing innovation in many countries, aimed at better resolving their rural highway safety and route security problems.

There are six major Rural Highway Systems covered in this section:

5.5.1 Speed Enforcement

5.5.2 Intersection Enforcement

5.5.3 Incident Detection

5.5.4 VMS and Information Dissemination

5.5.5 Electronic Safety Screening

5.5.6 Electronic Weight Screening

5.5.1 Speed Enforcement

5.5.1.1 Description

In speed enforcement a range of technologies are available to assist police. Most fall under the general types listed below.

- Speed cameras: Radar signals can be used to trigger cameras that photograph speeding vehicles as they pass a specified point. These devices use a low-powered doppler radar speed sensor to detect speeding vehicles and trigger a motor-driven camera and flash unit to photograph vehicles travelling faster than a set speed. The date, time, and speed are recorded along with a photo.
- VASCAR: A vehicle average speed calculator and recorder uses a portable computer to accurately clock, calculate, and display speed based on the time a vehicle takes to travel a known length of road. The benefits of a VASCAR system is that the speed of a vehicle that is travelling over a long stretch of highway that has no turnoffs can be monitored so that you can tell if they have been speeding consistently. This stops people from slowing down just past a speed camera before speeding up again once passed a speed camera.
- Other speed measures: These include electronic roadside signs displaying vehicle speeds or other messages and other types of roadway design measures.

5.5.1.2 Benefits

The strict enforcement of current speed limits in New Zealand is resulting in a declining rate of death and injury from road crashes. This approach is also supported by surveys by the Land Transport Safety Authority. 56% of drivers say they want more enforcement on the roads, 39% say they want it kept about the same, and only 3% want less. Since the introduction in 2000 of Highway Patrols, and the zero tolerance approach to drivers travelling more than 10 km/h over the limit, the road toll has dropped from 462 that year to 403 in 2002 – the lowest in 40 years.

5.5.1.3 Potential Problems

The main problems associated with speed enforcement systems are:

- The level of coverage is generally limited to spot locations.
- Increasing coverage across a wider area is expensive.
- Operational procedures can be complicated and costly.
- Public opposition, particularly where no specific safety problem is recognised.
- When used in conjunction with variable speed limits results are mixed.

5.5.1.4 Applications

In a rural environment this type of technology is used most widely where there is a specific speed related accident problem, such as the approaches to intersections, areas of unusual geometry or grades.

The specific locations of these devices can be critical, and consideration needs to be given to the potential safety problems they can cause (such as causing sharp breaking at hazardous locations).

Other considerations include:

- Technology and privacy restrictions of legislation (eg acceptability of digital images).
- Compatibility with police and court processes.
- Access to cameras for servicing and calibration.
- Interoperability with variable speed systems.

5.5.1.5 Relevance to NZTS / LTMA Objectives

Table 5.5.1.1 Contribution of Rural Highway Speed Enforcement systems to NZTS/LTMA objectives (derived from Contribution Matrix Section 3).

NZTS / LTMA Objective	***Level of contribution***	***Comment***
A Economic Development	*Low*	
Quality & efficiency of transport	➲	Can help improve safety and reduce crash related delays.
B Safety and Personal Security	*High*	
Number of traffic crashes	✓	Reduce speed related crashes through targeted enforcement. Improve compliance with fixed and variable speed limits.
Level of fatalities	✓	
Level & severity of personal injury	✓	
Compliance (with traffic / transport regulations)	✓	
C Access & Mobility	*Low*	
Level (%) of commuting trips by Pedestrians	✓	Reduced speed pedestrian zones. Improve compliance with fixed and variable speed limits. Can help improve safety and reduce crash related delays.
Compliance (with traffic / transport regulations)	✓	
Quality & efficiency of transport	➲	
D Public Health	*Medium*	
Numbers of short trips made by walking or cycling	✓	Reduce speed related crashes through targeted enforcement. Reduced speed pedestrian zones.
Numbers of commuting trips made by walking or cycling	✓	
Level & severity of personal injury	✓	
E Sustainability	*Low*	
Extent to which the benefits will be sustainable over time	✓	In general the ability of speed cameras to maintain speed reductions where implemented is good.
F Energy Efficiency	*Low*	
Quality & efficiency of transport	➲	Can help improve safety and reduce crash related delays.
G Integration	*Medium*	
Improving rural community access & conditions	✓	Assist in reducing speed through small communities.
H Responsiveness	*Medium*	
Contributions to national objectives	✓	Can help improve safety and reduce crash related delays.
Quality & efficiency of transport	➲	
I Affordability and Cost Effectiveness	*High*	
Relative benefit to cost ratio	✓	Cost effectiveness is good with tried and tested technologies.
Level of operating cost	✓	

Table 5.5.1.1 (continued)

NZTS / LTMA Objective	***Level of contribution***	***Comment***
J Implementation Risk	*Low*	
Technical complexity	✓	Implementation risk is relatively low with many sites in operation.
Interoperability	✓	
Cost certainty	✓	
Public acceptance	➲	
Implementation constraints – resource consents, legal & others	✓	
✓ = Positive Contribution; ✗ = No Significant Contribution; ➲ = Partial Contribution		

5.5.1.6 Summary and Conclusions

Speed Enforcement Technologies are used to improve compliance with fixed and variable speed limits. They contribute to reducing speed related crashes through targeted enforcement, and in doing so can help reduce crash related delays. They can contribute to reducing crash rates on vulnerable sections of strategic routes, and assists in reducing speed through small communities.

When implemented in appropriate situations cost effectiveness is good. However cost of ongoing operations and maintenance needs to be fully considered. Generally, the base technologies in this area are well developed and the complexity level low. This leads to a high level of cost reliability and low risk. The main sources of risk are inappropriate applications, compatibility with legal process and interoperability with other systems.

In terms of the objectives set out by the NZTS and LTMA, these systems deliver benefits in several areas, including:

- Safety and Personal Security
- Public Health

They also have the potential to provide a positive contribution towards the following New Zealand specific target areas:

- Compliance
- Safety
- Route Security

In New Zealand the use of speed cameras is well established. However, the constraints of the current legal process limit the use of digital image technologies used in many overseas systems.

5.5.1.7 Example Applications

Table 5.5.1.2 Example applications of Rural Highway Speed Enforcement systems.

Location	Description	Observed Benefits & Costs
The District of Columbia, USA	Implementation of speed cameras in 2001.	Average speeds declined 14% and the proportion of vehicles exceeding the speed limit by more than 10 m/h declined 82%. In Garland, Utah, a speed camera system plus extensive media coverage and strong support by city officials successfully reduced average speeds in a 20 m/h school zone from 36 to 22 m/h. Crashes and injuries had been high in the school zone, but eight months after installation there were fewer crashes and not a single injury collision.
New Zealand, Identified Black Spots	Speed cameras are sited on stretches of road that have a high number of speed-related crashes. In 2003 there were 13 static cameras operating from more than 50 sites in New Zealand and 31 mobile cameras operating from Police vehicles at more than 1,100 sites. Police choose sites after consultation with the Land Transport Safety Authority, Automobile Association and road controlling authorities. All speed camera sites are signposted.	A study of crash data in the 20 months following the introduction of speed cameras in New Zealand in 1993 found: A 23% reduction in fatal and serious crashes at urban speed camera sites. An 11% reduction in fatal and serious crashes at rural speed camera sites.

5.5.2 Intersection Enforcement

For details refer to section 5.2.6

5.5.2.1 Relevance to NZTS / LTMA Objectives

Table 5.5.2.1 Contribution of Rural Intersection Enforcement systems to NZTS/LTMA objectives (derived from Contribution Matrix Section 3).

NZTS / LTMA Objective	***Level of contribution***	***Comment***
A. Economic Development	*Low*	
None	✗	Although often a component of other integrated systems, does not deliver specifically to any integration objectives.
B Safety and Personal Security	*High*	
Number of traffic crashes	✓	Reduce intersection crashes at problem sites through targeted enforcement. Improve compliance with intersection regulations.
Level of fatalities	✓	
Level & severity of personal injury	✓	
Level of conflict between vehicles / cyclists / pedestrians and other road users	✓	
Compliance (with traffic / transport regulations)	✓	
C Access & Mobility	*Low*	
Compliance (with traffic / transport regulations)	✓	Improve compliance with intersection regulations.
D Public Health	*Low*	
Level & severity of personal injury	✓	Reduce intersection crashes at problem sites through targeted enforcement.
G Integration	*Medium*	
Improving rural community access & conditions	✓	Improve safety of rural intersections.
H Responsiveness	*Medium*	
Responding to diverse stake holder needs (particularly rural versus urban)	✓	Improve compliance with intersection regulations.
Contributions to national objectives	✓	
I Affordability and Cost Effectiveness	*Medium*	
Relative benefit to cost ratio	➲	Highly cost effective means of reducing accidents.
Level of operating cost	✓	
J Implementation Risk	*Medium*	
Technical complexity	➲	Technology is well developed but there were some issues in the application & operation areas.
Interoperability	➲	
Cost certainty	➲	
Public acceptance	➲	
Implementation constraints – resource consents, legal & others	➲	
✓ = Positive Contribution; ✗ = No Significant Contribution; ➲ = Partial Contribution		

5.5.3 Incident Detection

5.5.3.1 Description

Incident detection systems assist traffic authorities in identifying and responding to incidents more rapidly. Although common on motorways and urban arterials, they are increasingly being used to monitor strategic routes outside of the main urban centres.

In rural situations these facilities generally consist of:

- Video image processors used in conjunction with CCTV cameras.
- Induction loops set at regular intervals and monitored using complex algorithms.
- Virtual loops using video image processing to simulate on road loops.
- Infrared detectors.
- Ultrasonic detectors.

The key differences with their deployment on rural strategic routes are the targeting of coverage and the power and communications technologies used. As the cost effectiveness of some of the above technologies has improved, along with reduced power demands, advances in solar cells and improved wireless telecommunications coverage, it has been possible to deploy these types of facilities more widely.

5.5.3.2 Benefits

The main benefits of incident detection systems in these situations are that they allow traffic managers to observe traffic movements at strategically important section of the network (vulnerable gorges, critical links between major corridors etc) more effectively and efficiently, and to respond to any problems that may arise more quickly. They can assist in the following areas:

- Reducing incident response times leading to more rapid reopening of important links.
- Assisting in avoidance of the build up of traffic congestion.
- Providing an improved source of information to other systems (such as ATIS).
- Indirectly improving safety through reduced secondary accidents.

5.5.3.3 Potential Problems

The main problems associated with automated incident detection are:

- Public concern regarding privacy and civil liberties when video is used.
- False alarm rates or missed incidents if the system is not adjusted correctly.
- Managing multiple incident alarms when congestion developed from the first incident.
- Sensitivity of loop based systems and application to appropriate conditions.
- Developing appropriate targeting of coverage and appropriate technologies.

Some of the problems with specific technologies include;

- Infrared - sensors have unstable detection zone, susceptible to atmospheric obscurants and weather, one per lane required.
- Ultrasonic - subject to distortion from environmental factors.
- Video image processing - different algorithms usually required for day and night use, susceptible to atmospheric effects and adverse weather.

5.5.3.4 Applications

As with other surveillance technologies, in a rural highway environment this type of technology is used most widely where traffic volumes are high and the effect of minor incidents is significant. This translates to key vulnerable links either on or between major corridors.

An important component of any surveillance systems is the monitoring resource. Where a TMC or other dedicated facilities exist, AID can be an effective tool to help increase coverage and improve response time without major expansion of the operating resource.

A major factor in the successful deployment of AID is designing a system appropriate to the specific needs of the area. This can mean for example combining loop or virtual loop applications on longer open sections with targeted video systems in the most vulnerable sections.

5.5.3.5 Relevance to NZTS / LTMA Objectives

Table 5.5.3.1 Contribution of Incident Detection systems to NZTS/LTMA objectives (derived from Contribution Matrix Section 3).

NZTS / LTMA Objective	***Level of contribution***	***Comment***
A Economic Development	*High*	
Traffic Congestion	✓	Assist in early detection of incidents, so reducing congestion and incident related delays. Contribute indirectly and infrequently by assisting in more rapid clearance of incidents.
Travel time on key routes	➲	
Transportation Costs (travel time, VOC)	➲	
Maintain strategic route security / availability / information	✓	
Quality & efficiency of transport	✓	
Freight transport and mode transfer	✓	
Travel time reliability	✓	
B Safety and Personal Security	*Medium*	
Number of traffic crashes	➲	By reducing secondary crashes due to congestion and incident delays. By reducing secondary crashes and improving response time to crashes. Can assist by providing means of compliance monitoring.
Level of fatalities	➲	
Level & severity of personal injury	➲	
Compliance (with traffic / transport regulations)	➲	
C Access & Mobility	*High*	
Traffic Congestion	✓	Assist in early detection of incidents, so reducing congestion and incident related delays. Assist in managing traffic and so reducing congestion and incident delays. Can assist by providing means of compliance monitoring.
Frequency and reliability of key passenger transport services	✓	
Convenience (perceived and actual) of public transport services	✓	
Level (%) of commuting trips by passenger transport	✓	
Compliance (with traffic / transport regulations)	➲	
Strategic route security / availability / information	✓	
Quality & efficiency of transport	✓	
Travel time reliability		

Table 5.5.3.1 (continued)

NZTS / LTMA Objective	***Level of contribution***	***Comment***
D Public Health	*Low*	
Traffic congestion in urban areas (impacts on local air quality)	✓	Assist in early detection of incidents and managing traffic, so reducing congestion and related emissions. By reducing secondary crashes due to congestion and incident delays.
Level & severity of personal injury	➲	
E Sustainability	*Medium*	
Level(%) of trips that are not car based	✓	Assist in managing traffic and so reducing congestion and incident delays. Assist in early detection of incidents, so reducing congestion and incident related delays.
Emission levels (particulates, nitrogen oxides, carbon monoxides, CO_2)	✓	
Levels of service on key routes	➲	
Extent to which the benefits will be sustainable over time	✓	
F Energy Efficiency	*Medium*	
Traffic Congestion	✓	Assist in early detection of incidents, so reducing congestion and incident related delays. Assist in managing traffic and so reducing congestion and incident delays.
Fuel use	✓	
level of travel in congested conditions	✓	
Use of energy efficient modes	✓	
Quality & efficiency of transport	✓	
H Responsiveness	*High*	
Responding to diverse stake holder needs (rural versus urban)	✓	Assist in early detection of incidents, so reducing congestion and incident related delays.
Contributions to national objectives	✓	
Maintain strategic route security / availability / information	✓	
Quality & efficiency of transport	✓	
Travel time reliability	✓	
I Affordability and Cost Effectiveness	*Medium*	
Relative benefit to cost ratio	✓	When well targeted in locations where incidents are a recognized problem and improved response times a factor these systems are cost effective. An important consideration is the availability and cost of a monitoring resource.
Level of operating cost	➲	
J Implementation Risk	*Low*	
Technical complexity	✓	The technologies used are relatively well established; the main risk areas are inappropriate application and failure to identify suitable monitoring resources.
Interoperability	✓	
Cost certainty	✓	
Public acceptance	✓	
Implementation constraints – resource consents, legal & others	✓	
✓ = Positive Contribution; ✗ = No Significant Contribution; ➲ = Partial Contribution		

5.5.3.6 Summary and Conclusions

Incident detection systems assist traffic authorities in identifying and responding to incidents more rapidly. Although common on motorways and urban arterials, they are increasingly being used to monitor strategic routes outside of the main urban centres. The main benefits of incident detection systems in these situations are that they allow traffic managers to observe traffic movements at strategically important section of the network (vulnerable gorges, critical links between major corridors etc) more effectively and efficiently, and to respond to any problems that may arise more quickly.

As with other surveillance technologies, in a rural highway environment this type of technology is used most widely where traffic volumes are high and the effect of minor incidents is significant. This translates to key vulnerable links either on or between major corridors.

In terms of the objectives set out by the NZTS and LTMA, these systems deliver benefits in several areas, including:

- Economic Development
- Safety and Personal Security
- Access and Mobility
- Sustainability

They also have the potential to provide a positive contribution towards the following New Zealand specific target areas:

- Congestion Relief
- Incident Management
- Safety
- Route Security
- Quality and Efficiency
- Travel Time Reliability

In New Zealand the use of these types of systems is currently limited to a small number of strategic locations.

5.5.3.7 Example Applications

Table 5.5.3.2 Example applications of Rural Highway Incident Detection systems.

Location	Description	Observed Benefits & Costs
Minnesota, USA	Advanced Rural Transportation Information and Coordination (ARTIC) - since December 1996 Monitors road condition and incidents on strategic parts of the rural road network.	Improved and more reliable traveller and traffic information. Improved response times of emergency vehicles to emergency situations.

Table 5.5.3.2 (continued)

Location	Description	Observed Benefits & Costs
North Lanarkshire, Scotland, UK.	Intelligent road studs used for fog guidance, surface water detection, incident detection and hazard warning.	This is a trial site with the results hopefully published later in the year. Intelligent Road Studs have been fitted to a 3 kilometre stretch of Scotland's busiest motorway as part of a national road traffic management system. New hardwired, Intelligent Road Studs, each fitted with 14 red LEDs for high brightness, were installed between the hard shoulder and the inside lane of the motorway, providing a clear delineation that could be seen day and night, up to a kilometre away. The detector studs deployed at 500 metre intervals in the centre of the lane, are connected to a series of roadside control cabinets. In these are located a fog sensor and the computer software for analysing the data from the detector studs. As soon as fog (or mist or heavy surface spray) is detected or the speed of traffic falls below a pre-set limit due to heavy traffic or an accident, a signal is sent to the red LEDs within the Intelligent Road Studs to increase their level of brightness and if necessary begin flashing.
Tennessee, USA	Fog Detection and Warning System, that covers 19 miles including a three-mile, fog-prone section above the Hiwassee River and eight-mile sections on each side.	There have been over 200 crashes, 130 injuries and 18 fatalities due to fog on this highway section since 1973. Since the installation of the fog detection and warning system in 1994, no fog-related accidents have occurred.

5.5.4 VMS and Information Dissemination

5.5.4.1 Description

Variable Message Signs (VMS) provide information to road users on incidents, traffic and road conditions. In a motorway environment they are generally large gantry mounted devices using LED technology, operated from a traffic control centre. VMS are also used to provide information on alternative routes, planned works and special events, safety messages and in some instances advertising messages.

VMS are often used as a component of other systems such as:

- Automated warning of specific hazards such as ice / fog / animal crossings / road status.
- Tourist/Rest spots.
- Warning systems for speed, height restrictions etc.

5.5.4.2 Benefits

The main benefits of VMS in a rural environment are; providing drivers with real time information on incidents. Allowing improved selection of alternative routes and reducing the risk of secondary accidents when incidents occur. In particular, VMS can help in the following areas:

- Providing up to date information to drivers on hazards and road conditions.
- Assisting in diverting traffic away from incidents.
- Improving safety through reduced secondary accidents.
- Providing local area information to casual drivers.

5.5.4.3 Potential Problems

The main problems associated with VMS:

- Ensuring they are placed in locations where they deliver optimum value (e.g. where drivers have the best opportunity to benefit from the information provided).
- To be effective there must be a reliable source of information (e.g. surveillance and TMC).
- Ensuring that systems are interoperable.
- Recognition of the cost of maintenance and commitment to ongoing operations.
- The cost of units suitable for rural application is relatively high; and there is some evidence that, where a range of alternative information sources are available, the tangible benefits are limited.

5.5.4.4 Applications

In a rural highway environment this type of technology is used most widely where traffic volumes are high and the effect of incidents leads to a there being benefit in advance warning. As the cost of these facilities is relatively high, they are best deployed where alternative routes are available and accessible, or where there is an identified safety benefit from the advance warning of incidents and road conditions. This translates to mainly long hazardous routes that are easily affected by the weather and have a viable alternative that can be taken if there are major incidents or extreme weather conditions. The use of automated VMS is also growing in the area of hazard warning.

5.5.4.5 Relevance to NZTS / LTMA Objectives

Table 5.5.4.1 Contribution of Rural Highway VMS and Information Dissemination systems to NZTS/LTMA objectives (derived from Contribution Matrix Section 3).

NZTS / LTMA Objective	Level of contribution	Comment
A Economic Development	High	
Traffic Congestion	✓	Provide advance warning of incidents and congestion, allowing selection of alternative routes/modes and reducing further build up. Provide advance warning of incidents and congestion, allowing selection of alternative routes/modes and reducing further build up. Assist in reducing congestion and efficient route/mode selection by providing advance warning of incidents and congestion.
Traffic/Transport Demand	✓	
Travel time on key routes	➲	
Transportation Costs (travel time, VOC)	➲	
Transport users face the true costs of use	➲	
Travel time for car commuters to key employment centres	➲	
Maintain strategic route security / availability / information	✓	
Quality & efficiency of transport	✓	
Travel time reliability	✓	
B Safety and Personal Security	Medium	
Number of traffic crashes	➲	By reducing secondary crashes due to congestion and incident delays.
Level & severity of personal injury	➲	By reducing secondary crashes and improving response time to crashes.
C Access & Mobility	High	
Traffic Congestion	✓	Provide advance warning of incidents and congestion, allowing selection of alternative routes/modes and reducing further build up. Contribute indirectly and only during times of adverse conditions and incidents. Assist in reducing congestion and efficient route/mode selection by providing advance warning of incidents and congestion.
Traffic/Transport Demand	✓	
Sector to sector travel times by car	➲	
Frequency and reliability of key passenger transport services	➲	
Convenience (perceived and actual) of public transport services	➲	
Level (%) of commuting trips by passenger transport	✓	
Strategic route security / availability / information	✓	
Quality & efficiency of transport	✓	
Travel time reliability	✓	
D Public Health	Low	
Traffic congestion in urban areas (impacts on local air quality)	✓	Provide advance warning of incidents and congestion, allowing selection of alternative routes/modes and reducing further build up.
Level & severity of personal injury	➲	By reducing secondary crashes and improving response time to crashes.

Table 5.5.4.1 (continued)

NZTS / LTMA Objective	Level of contribution	Comment
E Sustainability	*High*	
Traffic/Transport Demand	✓	Provide advance warning of incidents and congestion, allowing selection of alternative routes/modes and reducing further build up. Contribute indirectly and only during times of adverse conditions and incidents. Assist in reducing congestion and efficient route/mode selection by providing advance warning of incidents and congestion.
Level(%) of trips that are not car based	➲	
Growth rate of total vehicle travel	➲	
Emission levels (particulates, nitrogen oxides, carbon monoxides, CO_2)	➲	
Extent to which users face full cost of their road use	➲	
Levels of service on key routes	➲	
Extent to which the benefits will be sustainable over time	➲	
F Energy Efficiency	*High*	
Traffic Congestion	✓	Provide advance warning of incidents and congestion, allowing selection of alternative routes/modes and reducing further build up. Contribute indirectly and only during times of adverse conditions and incidents. Assist in reducing congestion and efficient route/mode selection by providing advance warning of incidents and congestion.
Traffic/Transport Demand	✓	
Efficiency of routes taken	✓	
Fuel use	➲	
level of travel in congested conditions	✓	
Use of energy efficient modes	➲	
Quality & efficiency of transport	✓	
G Integration	*Medium*	
Efficiency and convenience of mode transfer points	✓	Assist in providing timely information to users.
Level of integration between road and rail	✓	
Improving rural community access & conditions	✓	
H Responsiveness	*High*	
Responding to diverse stake holder needs (particularly rural versus urban)	✓	Assist in reducing congestion and efficient route/mode selection by providing advance warning of incidents and congestion.
Contributions to national objectives	✓	
Maintain strategic route security / availability / information	✓	
Quality & efficiency of transport	✓	
Travel time reliability	✓	
I Affordability and Cost Effectiveness	*Medium*	
Relative benefit to cost ratio	➲	When implemented in appropriate situations cost effectiveness is good. However initial cost is high and the cost of ongoing operations and maintenance needs to be fully considered.
Level of operating cost	➲	
Contribution direct from users	➲	

Table 5.5.4.1 (continued)

NZTS / LTMA Objective	Level of contribution	Comment
J Implementation Risk	*Low*	
Technical complexity	✓	Generally, the base technologies in this area are well developed and the complexity level low. This leads to a high level of cost reliability and low risk. The main sources of risk are inappropriate applications, interoperability with broader TMC systems, and recognizing the level of operating commitment and cost.
Interoperability	✓	
Cost certainty	✓	
Public acceptance	✓	
Implementation constraints – resource consents, legal & others	✓	
✓ = Positive Contribution; ✗ = No Significant Contribution; ➲ = Partial Contribution		

5.5.4.6 Summary and Conclusions

Variable Message Signs (VMS) provide information to road users on incidents, traffic and road conditions, alternative routes and occasionally advance warning of planned road works. In a rural environment they are generally smaller road side devices using LED technology.

The main benefits of VMS in a rural environment are achieved by providing drivers information on road conditions and incidents, facilitating improved selection of alternative routes and reducing the risk of secondary accidents.

In terms of the objectives set out by the NZTS and LTMA, these systems deliver benefits in several areas, including:

- Economic Development
- Safety and Personal Security
- Access and Mobility
- Sustainability

They also have the potential to provide a positive contribution towards the following New Zealand specific target areas:

- Incident Management
- Safety
- Route Security
- Quality and Efficiency
- Travel Time Reliability

Implemented in the appropriate areas, and with a suitable level of operations resource, the technologies used are well developed and low risk.

Rural VMS are used in several areas of New Zealand, including the Desert Road, and in strategic areas of the Bay of Plenty. They are also currently being implemented more widely by Transit New Zealand in areas around the main south island alpine passes.

5.5.4.7 Example Applications

Table 5.5.4.2 Example applications of Rural Highway VMS and Information Dissemination systems.

Location	Description	Observed Benefits & Costs
Wisconsin, USA	In December 2001, the University of Wisconsin surveyed drivers to assess the impacts of traveller information made available on a Variable Message Sign (VMS) system.	Approximately 68% of respondents reported adjusting their travel routes based on the traffic information provided by the VMS system during the winter months (December – March). About 12% of respondents adjusted their travel routes more than 5 times per month using this information. Approximately 72% of respondents reported adjusting their travel routes based on the traffic information provided by the VMS system during non-winter months (April – November). About 18% of respondents adjusted their travel routes more than 5 times per month using this information.
Detroit, USA	A study of the combined ITS facilities in Detroit provided evidence that ITS proved most beneficial under conditions of significant supply variations, such as incidents, and to a lesser extent during demand variations.	As part of this study variable message signs were shown to benefit commuters in terms of awareness of traffic activities. Providing psychological/convenience benefits in terms of providing drivers with information about what is causing delays and congestion. In terms of delay reductions, however, commuters acting upon VMS messages of delay found little benefit, and at times also increased delay by diverting. VMS proved no benefit to facility operation in terms of flow or speed.
Desert Road, the North Island, New Zealand	VMS have been in use on the approaches to the Desert Road for several years, used to warn drivers of hazardous conditions (mainly related to Ice and Snow) and road closures.	First installed in 1997 the benefits of these signs include assisting in closing this section of road more rapidly and warning drivers of adverse conditions. This has helped in reducing the numbers of vehicles stranded during snow.

5.5.5 Electronic Safety Screening

For details refer to section 5.1.11.

5.5.5.1 Relevance to NZTS / LTMA Objectives.

Table 5.5.5.1 Contribution of Rural Highway Electronic Safety Screening systems to NZTS/LTMA objectives (derived from Contribution Matrix Section 3).

NZTS / LTMA Objective	*Level of contribution*	*Comment*
A Economic Development	*Low*	
Transport users face the true costs of use	➲	Can be used as a input to more direct charging related to impact. Can assist in reducing incidents caused by unsafe vehicles; crashes and load problems.
Quality & efficiency of transport	➲	
B Safety and Personal Security	*High*	
Number of traffic crashes	✓	Improve compliance by screening. Assist in reducing incidents caused by unsafe vehicles; crashes and load problems.
Level of fatalities	✓	
Level & severity of personal injury	✓	
Compliance (with traffic / transport regulations)	✓	
C Access & Mobility	*Low*	
Compliance (with traffic / transport regulations)	✓	Improve compliance by screening. Can assist in reducing incidents caused by unsafe vehicles; crashes and load problems.
Quality & efficiency of transport	➲	
D Public Health	*Medium*	
Vehicle noise	➲	Can assist in improving vehicle standards related to noise. Improve compliance by screening. Assist in reducing incidents caused by unsafe vehicles; crashes and load problems.
Compliance (with emissions regulations)	✓	
Level & severity of personal injury	✓	
E Sustainability	*Medium*	
Non road freight volumes as a percentage of total	➲	Assist in the monitoring and management of freight. Can be used as a input to more direct charging related to impact.
Extent to which users face full cost of their road use	➲	
Extent to which the benefits will be sustainable over time	✓	
F Energy Efficiency	*Low*	
Quality & efficiency of transport	➲	Can assist in reducing incidents caused by unsafe vehicles; crashes and load problems.
G Integration	*Low*	
None	✗	Although often a component of other integrated systems, does not deliver specifically to any integration objectives.
H Responsiveness	*Medium*	
Responding to diverse stake holder needs (particularly rural versus urban)	➲	Can assist in reducing incidents caused by unsafe vehicles; crashes and load problems.
Contributions to national objectives	✓	
Quality & efficiency of transport	➲	

Table 5.5.5.1 (continued)

NZTS / LTMA Objective	***Level of contribution***	***Comment***
I Affordability and Cost Effectiveness	*Medium*	
Relative benefit to cost ratio	➲	Can be used as a input to more direct charging related to impact.
Level of operating cost	✓	
Contribution direct from users	➲	
J Implementation Risk	*Low*	
Technical complexity	✓	Generally, the base technologies in this area are well developed and the complexity level low. This leads to a high level of cost reliability and low risk. The main sources of risk are inappropriate applications, compatibility with legal process and interoperability with other systems.
Interoperability	✓	
Cost certainty	✓	
Public acceptance	➲	
Implementation constraints – resource consents, legal & others	➲	
✓ = Positive Contribution; ✗ = No Significant Contribution; ➲ = Partial Contribution		

5.5.6 Electronic Weight Screening

For details refer to section 5.1.12.

5.5.6.1 Relevance to NZTS / LTMA Objectives.

Table 5.5.6.1 Contribution of Rural Highway Electronic Safety Screening systems to NZTS/LTMA objectives (derived from Contribution Matrix Section 3).

NZTS / LTMA Objective	*Level of contribution*	*Comment*
A Economic Development	*Low*	
Transport users face the true costs of use	➲	Reduce adverse effects of overweight vehicles on pavement; ensuring users are charged relative to weight. Can be used a screening facility to assist in improving freight monitoring a processing.
Quality & efficiency of transport	✓	
Freight transport and mode transfer	✓	
B Safety and Personal Security	*Low*	
Number of traffic crashes	➲	By reducing crashes related to overweight vehicles. Improving compliance by screening.
Compliance (with traffic / transport regulations)	✓	
C Access & Mobility	*Low*	
Compliance (with traffic / transport regulations)	✓	Improving compliance by screening. Enforcement; can assist in reducing impact of overweight vehicles on pavement.
Quality & efficiency of transport	✓	
E Sustainability	*Medium*	
Non road freight volumes as a percentage of total	✓	Assist in the monitoring and management of freight. Can assist in reducing impact of overweight vehicles on pavement and ensure users are charged relative to weight.
Extent to which users face full cost of their road use	➲	
Extent to which the benefits will be sustainable over time	✓	
F Energy Efficiency	*Low*	
Quality & efficiency of transport	✓	Can assist in reducing impact of overweight vehicles on pavement.
G Integration	*Medium*	
Level of integration between road and rail	✓	Can assist in improving efficiency at mode transfer points. Can assist in limiting impact of heavy traffic on local communities.
Improving rural community access & conditions	✓	
H Responsiveness	*Medium*	
Responding to diverse stake holder needs (particularly rural vs urban)	✓	Can assist in reducing impact of overweight vehicles on pavement.
Contributions to national objectives	✓	
Quality & efficiency of transport	✓	
I Affordability and Cost Effectiveness	*Medium*	
Relative benefit to cost ratio	➲	Can be used as a input to more direct charging related to impact
Level of operating cost	✓	
Contribution direct from users	➲	

Table 5.5.6.1 (continued)

NZTS / LTMA Objective	***Level of contribution***	***Comment***
J Implementation Risk	*Low*	
Technical complexity	✓	These technologies are fairly well developed and as such risk is low. Main risks are in poor location or coordination as part of an overall package.
Interoperability	✓	
Cost certainty	✓	
Public acceptance	✓	
Implementation constraints – resource consents, legal & others	✓	
✓ = Positive Contribution; ✗ = No Significant Contribution; ➲ = Partial Contribution		

5.6 Emergency Management Systems

Benefits of emergency management include those derived from improved notification, dispatch, and guidance of emergency responders to the scene of an incident. These benefits are sometimes highly dependent on the ability of an incident management system to detect the need for emergency management on the transportation network. ITS applications in emergency management cover hazardous materials management, the deployment of emergency medical systems, and large and small-scale emergency responses. Each of these systems can improve public safety by decreasing response times and increasing the operational efficiency of safety professionals during emergency situations.

Advanced automated collision notification (ACN) and telemedicine address the detection of and response to incidents requiring emergency response. In rural areas, response time for emergency medical services is greater than in urban areas, resulting in more severe consequences or impacts. Advanced automated collision notification systems can notify emergency personnel and provide them with valuable information on the crash, including location, crash characteristics, and possibly relevant medical information regarding the vehicle occupants. Telemedicine systems provide a link between responding ambulances and nearby emergency medical facilities, enabling doctors to advise emergency medical personnel on treatment of patients en route to the hospital.

The emergency management systems in this section are:

5.6.1 Mobilisation, Response and Recovery / Hazardous Materials Management / Emergency Medical Services

5.6.1 Mobilisation, Response and Recovery / Hazardous Materials Management / Emergency Medical Services

5.6.1.1 Description

These systems assist emergency services to respond quickly to incidents and to coordinate services more efficiently to ensure the optimum is delivered.

The systems used involve links with incident detection facilities, traffic control centres, and specifically designed communications between services. A key objective of these facilities is to provide relevant and reliable information to the responding authorities on the nature of the incident; level and type of any injuries etc in order that the most appropriate response can be delivered in optimum time.

Another area where improved communications between services is critical is the management of incidents involving hazardous materials, ensuring appropriate equipment and measures are put in place quickly. In this area there is a growing use of on-vehicle devices able to alert authorities of an incident and provide information on the materials being carried.

5.6.1.2 Benefits

The benefits are that emergency response services are coordinated and any problems that the first response team encounters can be overcome by the mobilization of agents with the appropriate skill sets. A major benefit of these systems is the improved response to critical injuries, particularly head injuries where rapid and appropriate response can have a significant effect on survival rates.

5.6.1.3 Potential Problems

The main challenges in developing and implementing these systems are in overcoming interoperability between the systems of emergency services, traffic control centres and other agencies.

5.6.1.4 Applications

The implementation of improvements to response coordination systems has benefit in all areas where traffic incidents occur. Although the nature of the response and agencies involved is likely to be more extensive in urban situations, improving response times to critical injuries in particular is a factor in all situations.

5.6.1.5 Relevance to NZTS / LTMA Objectives

Table 5.6.1.1 Contribution of Mobilisation, Response and Recovery / Hazardous Materials Management / Emergency Medical Services to NZTS / LTMA objectives (derived from Contribution Matrix Section 4).

NZTS / LTMA Objective	Level of contribution	Comment
A Economic Development	Medium	
Traffic Congestion	✓	Assist in more rapid clearance of incidents. Contribute infrequently by assisting in more rapid clearance of incidents. Contribute indirectly and only during times of adverse conditions and incidents.
Travel time on key routes	➲	
Transportation Costs (travel time, VOC)	➲	
Maintain strategic route security / availability / information	✓	
Quality & efficiency of transport	✓	
Freight transport and mode transfer	➲	
Travel time reliability	➲	
B Safety and Personal Security	High	
Number of traffic crashes	➲	By reducing secondary crashes due to congestion and incident delays. By reducing secondary crashes and improving response time to crashes. Can assist by providing means of compliance monitoring.
Level of fatalities	✓	
Level & severity of personal injury	✓	
Compliance (with traffic / transport regulations)	➲	
C Access & Mobility	Medium	
Traffic Congestion	✓	Assist in more rapid clearance of incidents. Can assist by providing means of compliance monitoring.
Compliance (with traffic / transport regulations)	➲	
Strategic route security / availability / information	✓	
Quality & efficiency of transport	✓	
Travel time reliability	➲	
D Public Health	Medium	
Traffic congestion in urban areas (impacts on local air quality)	➲	By reducing secondary crashes and improving response time to crashes. Assist in more rapid clearance of incidents, leading to reduced congestion related emissions.
Level & severity of personal injury	✓	
E Sustainability	Medium	
Non road freight volumes as a percentage of total	✓	Contribute infrequently by assisting in more rapid clearance of incidents.
Levels of service on key routes	➲	
Extent to which the benefits will be sustainable over time	✓	
F Energy Efficiency	Medium	
Traffic Congestion	✓	Assist in more rapid clearance of incidents.
level of travel in congested conditions	✓	
Quality & efficiency of transport	✓	
G Integration	Low	
None	✗	No significant contribution.

Table 5.6.1.1 (continued)

NZTS / LTMA Objective	***Level of contribution***	***Comment***
H Responsiveness	*High*	
Responding to diverse stake holder needs (particularly rural versus urban)	✓	Assist in more rapid clearance of incidents.
Contributions to national objectives	✓	
Maintain strategic route security / availability / information	✓	
Quality & efficiency of transport	✓	
Travel time reliability	➲	
I Affordability and Cost Effectiveness	*High*	
Relative benefit to cost ratio	✓	Where interoperability issues can be overcome, the cost effectiveness of these systems is high.
Level of operating cost	✓	
J Implementation Risk	*Low*	
Technical complexity	✓	Interoperability of systems and technologies is the biggest risk.
Interoperability	✓	
Cost certainty	✓	
Public acceptance	✓	
Implementation constraints – resource consents, legal & others	✓	
✓ = Positive Contribution; ✗ = No Significant Contribution; ➲ = Partial Contribution		

5.6.1.6 Summary and Conclusions

These systems assist emergency services to respond quickly to incidents and to coordinate services more efficiently to ensure the optimum is delivered.

The benefits are that emergency response services are coordinated and any problems that the first response team encounters can be overcome by the mobilization of agents with the appropriate skill sets. A major benefit of these systems is the improved response to critical injuries, particularly head injuries where rapid and appropriate response can have a significant effect on survival rates.

Interoperability of systems and technologies is the biggest risk to effective implementation and operation.

In terms of the objectives set out by the NZTS and LTMA, these systems deliver benefits in several areas, including:

- Economic Development
- Safety and Personal Security
- Access and Mobility
- Public Health
- Sustainability

They also have the potential to provide a positive contribution towards the following New Zealand specific target areas:

- Incident Management
- Safety
- Route Security

- Travel Time Reliability

The use of these types of systems in New Zealand is limited to assistance provided to emergency response vehicles from traffic management units in the main urban centres. These are generally through radio communication and do not involve any specific technology based aspects.

5.6.1.7 Example Applications

Table 5.6.1.2 Example applications of Mobilisation, Response and Recovery / Hazardous Materials Management / Emergency Medical Services.

Location	Description	Observed Benefits & Costs
US National ITS Architecture, USA	The US national ITS Architecture sets out a structure of systems to assist in breaking the interoperability problem cycle.	This Architecture sets out the structure of all systems that seek national funding, which leads to improved interoperability between agency systems and technologies.
US Federal Highway initiatives to enhance interagency Communications, USA	A range of programs are in place to improve interagency communications including: Communications standards IEEE1512 for incident management data communications between transportation and emergency management centres. Field operational test for CAD-TMC integration now underway in Washington and Utah 21st Century Operations and Security Traffic Incident Management	These are improving on-scene application of multi-agency operational procedures to achieve diverse but related activities. Results in the safe and rapid clearance of the incident scene. Experience gained from multi-agency coordination of operations and communications among the same partners for traffic incidents that occur daily provides the framework for efficient and coordinated response to major emergencies.
UK	Airwave is a secure digital radio network dedicated for the exclusive use of the UK's emergency and public safety services. Designed to carry voice and data communications, the service offers guaranteed levels of coverage across England, Wales and Scotland.	Benefits of Airwave include; Police can have radio coverage wherever they need it - even in radio 'cold spots'. And Airwave filters out background noise - ensuring clearer communications. Because all Airwave communications are encrypted, they cannot be scanned or monitored by outsiders, so helping police stay one step ahead of criminals. The system's unique, multi-functional handsets can double as data terminals - enabling officers in the field to access local and national databases, including driving license information and records on the Police National Computer. Because Airwave also offers the option to set up talk groups and enables direct officer-to-officer communications (without the need to route all calls through control centres) it will be of real help at major incidents and emergencies, at which effective communications really can help to save lives.

Table 5.6.1.2 (continued)

Location	Description	Observed Benefits & Costs
Israel	AwareNess is a field-proven, incident management system for emergency & security forces incorporating advanced vehicle tracking, dispatch and decision support capabilities.	Benefits include; Automated Vehicle Location (AVL) and Computer Aided Dispatch (CAD). Digital mapping: real-time mapping engine for Command & Control (C&C) applications. Mobile computing platform: applications such as telemedicine, emergency-specific touch screen HMI (Human-Machine Interface) , multiple mission handling and communications with command centres. Decision support modules for selecting the best route to the incident, the best evacuation route, best resources and best voice channel. Coordinated inter-region and inter-service (police, ambulance, fire, other) incident management.

5.7 Advanced Traveller Information Systems

Providing traveller information on several modes of travel through a variety of media can be beneficial to both the traveller and service providers. These services allow users to make a more informed decision for trip departures, routes, and mode of travel, especially in adverse weather conditions for traffic. They may help to reduce congestion when travellers choose to defer or postpone trips, or to select alternate routes. Ride share information may also lead to a reduction in congestion if more people share transport and thereby reducing the number of cars that would otherwise be on the road.

While travellers are en-route, the ability to update them with traffic conditions can lead to a reduction in the level of congestion that would otherwise build up due to accidents or changes in road conditions and improve safety.

The systems included in this section are:

5.7.1 Detection, Information Collection and Processing
5.7.2 Ride Share Information
5.7.3 En-Route and Pre-Trip Information
5.7.4 In-Vehicle and Handheld Devices

5.7.1 Detection, Information Collection and Processing

5.7.1.1 Description

These systems provide the base information source for many other services; they collect and manage information that can then be passed on to travellers or transmitted directly to VMS (Variable Message Signs) and other ATIS facilities, to advise the travelling public of incidents or other relevant information regarding the route ahead. The sooner road users have information about road conditions ahead the more able they are to select alternative routes or retime their journeys. This helps ease congestion, reduce delays and cause fewer secondary accidents. The information collection process may already be in place in existing systems.

5.7.1.2 Benefits

The main benefits of systems like this are that they provide a trusted and reliable source of information, and by giving travellers information in advance they can better plan their journeys, to select alternative routes or retime their journeys. This leads to reduced congestion following incidents such as accidents or roadwork's. Ideally, travellers are able to access the information through a range of mediums best suited to their location and situation (E.g. Internet at work, TV or radio at home etc).

5.7.1.3 Potential Problems

The main problem areas with these types of systems are; the significant cost of developing the facility and adequate level of information collection; the ongoing costs of maintaining an acceptable level of reliability, and the costs associated with keeping the information relevant, reliable and timely.

5.7.1.4 Applications

These systems are best suited to congested urban areas with traffic surveillance technology already in place, a level of coordination between agencies and recognised long term benefit in supporting such a facility.

5.7.1.5 Relevance to NZTS / LTMA Objectives

Table 5.7.1.1 Contribution of Detection, Information Collection and Processing systems to NZTS/LTMA objectives (derived from Contribution Matrix Section 4).

NZTS / LTMA Objective	*Level of contribution*	*Comment*
A Economic Development	*High*	
Traffic Congestion	✓	Assist in early detection of incidents and managing traffic, so reducing congestion and incident related delays. Contribute to more rapid clearance of incidents. Assist in managing traffic; so reducing congestion and delays on strategic routes.
Traffic/Transport Demand	➲	
Travel time on key routes	➲	
Transportation Costs (travel time, VOC)	➲	
Travel time for car commuters to key employment centres	➲	
Maintain strategic route security / availability / information	✓	
Quality & efficiency of transport	✓	
Freight transport and mode transfer	✓	
Travel time reliability	✓	
B Safety and Personal Security	*Medium*	
Number of traffic crashes	➲	By reducing secondary crashes due to congestion and incident delays. By reducing secondary crashes and improving response time to crashes.
Level of fatalities	➲	
Level & severity of personal injury	➲	
C Access & Mobility	*High*	
Traffic Congestion	✓	Assist in early detection of incidents and managing traffic, so reducing congestion and incident related delays. Contribute to more rapid clearance of incidents. Assist in managing traffic, so reducing congestion and delays on strategic routes.
Traffic/Transport Demand	➲	
Sector to sector travel times by car	✓	
Frequency and reliability of key passenger transport services	✓	
Convenience (perceived and actual) of public transport services	✓	
Level (%) of commuting trips by passenger transport	✓	
Strategic route security / availability / information	✓	
Quality & efficiency of transport	✓	
Travel time reliability	✓	
D Public Health	*Medium*	
Traffic congestion in urban areas (impacts on local air quality)	✓	Assist in early detection of incidents and managing traffic, so reducing congestion and related emissions. Assist in early detection of incidents and managing traffic, so reducing congestion and related noise. By reducing secondary crashes and improving response time to crashes
Vehicle noise	➲	
Level & severity of personal injury	➲	

Table 5.7.1.1 (continued)

NZTS / LTMA Objective	Level of contribution	Comment
E Sustainability	*High*	
Traffic/Transport Demand	➲	As a component of other systems. Assist in managing traffic and so reducing congestion and incident delays. Assist in the monitoring and management of freight. Contribute infrequently by assisting in more rapid clearance of incidents.
Level(%) of trips that are not car based	✓	
Non road freight volumes as a percentage of total	➲	
Growth rate of total vehicle travel	✓	
Emission levels (particulates, nitrogen oxides, carbon monoxides, CO_2)	✓	
Levels of service on key routes	➲	
Extent to which the benefits will be sustainable over time	✓	
F Energy Efficiency	*High*	
Traffic Congestion	✓	Assist in early detection of incidents and managing traffic, so reducing congestion and incident related delays. As a component of other systems. Assist in managing traffic and so reducing congestion and incident delays. Assist in early detection of incidents, so reducing congestion and incident related delays.
Traffic/Transport Demand	➲	
Efficiency of routes taken	➲	
Fuel use	✓	
level of travel in congested conditions	✓	
Use of energy efficient modes	✓	
Quality & efficiency of transport	✓	
G Integration	*Medium*	
Efficiency and convenience of mode transfer points	➲	As a component of other systems.
Level of integration between road and rail	➲	
Improving rural community access & conditions	➲	
H Responsiveness	*High*	
Contributions to national objectives	✓	Assist in early detection of incidents and managing traffic, so reducing congestion and delays on strategic routes. Assist in early detection of incidents, so reducing congestion and incident related delays.
Maintain strategic route security / availability / information	✓	
Quality & efficiency of transport	✓	
Travel time reliability	✓	
I Affordability and Cost Effectiveness	*Medium*	
Relative benefit to cost ratio	✓	Cost of set up & operation is high but can deliver high benefits in the right situation.
Level of operating cost	➲	
J Implementation Risk	*Medium*	
Technical complexity	✓	Generally the technologies used are well developed & reliable. Risks lie in the operational set up. Costs and interoperability between systems & technologies.
Interoperability	✓	
Cost certainty	✓	
Public acceptance	✓	
Implementation constraints – resource consents, legal & others	✓	

✓ = Positive Contribution; ✗ = No Significant Contribution; ➲ = Partial Contribution

5.7.1.6 Summary and Conclusions

These facilities form the foundation of effective traveller information systems, by ensuring a trusted and reliable source of information. This allows travellers to better plan their journeys at a range of stages, and leads to benefits of reduced congestion, improved public transport reliability and user convenience.

A key benefit area in urban situations is reduced congestion following incidents.

In terms of the objectives set out by the NZTS and LTMA, these systems deliver benefits in several areas, including:

- Economic Development
- Safety and Personal Security
- Access and Mobility
- Public Health
- Sustainability.

They also have the potential to provide a positive contribution towards the following New Zealand specific target areas:

- Congestion Relief
- Demand Management
- Incident Management
- Route Security
- Quality and Efficiency
- Travel Time Reliability

In New Zealand the use of centralised traffic management resources to assist in providing traveller information is limited to Auckland, and to a limited extent in Wellington.

5.7.1.7 Example Applications

Table 5.7.1.2 Example applications of Detection, Information Collection and Processing systems.

Location	Description	Observed Benefits & Costs
Washington DC, USA	This study used the Mitretek Systems HOWLATE method (Heuristic On-Line Web-Linked Arrival Time Estimator) to quantify the potential benefits of implementing Advanced Traveller Information Services (ATIS) in the Washington DC area. Software applications were used to collect travel time information for major arterial and freeway links in the region as they were posted on the internet. Then used to compare the on-time reliability and travel time performance for ATIS users and ATIS non-users.	The analysis indicated that ATIS users realized substantial time management benefits from on-time arrival performance and trip predictability, but realized only marginal reductions in in-vehicle travel time. The following table summarizes the travel performance for a sample of more than 75,000 trips in the DC area during peak periods.

Table 5.7.1.2 (continued)

AM Peak (6:30-9:30) and

PM Peak (3:30-6:30).

COMMUTER	ON-TIME RELIABILITY	LATENESS RISK
Conservative Non-User	92%	8%
Aggressive Non-User	81%	19%
ATIS User	97%	3%

The following table summarises travel performance for a commute between Laurel, Maryland and Dale City, Virginia from 6:30 AM to 6:30 PM. It was noted that during this period, ATIS users demonstrated better performance than conservative non-users.

COMMUTER	ON-TIME RELIABILITY	LATENESS RISK
Conservative Non-User	90%	10%
Aggressive Non-User	78%	22%
ATIS User	92%	8%

5.7.2 Ride Share Information

5.7.2.1 *Description*

Ride share information aims to assist people who both live and work in the same area to coordinate travel plans. This would help to allow them to share rides to and from work increasing the occupancy rate of vehicles. This can help to reduce congestion and travel time during peak periods.

Common examples of these types of systems are web based registers, some run by transport authorities and some community based.

5.7.2.2 *Benefits*

These facilities have been proved to increase ride share rates, leading to a reduction in congestion and associated reduction in pollution level, and economic gains from the reduced time spent in congested traffic.

5.7.2.3 *Potential Problems*

The setting up of these facilities is relatively straightforward; however, they do rely on potential users having access to internet and suitable advertising of the service.

5.7.2.4 *Applications*

Ride share facilities are most successful in areas with high numbers of regular commuters, with reasonably regular and common schedules.

5.7.2.5 *Relevance to NZTS / LTMA Objectives*

Table 5.7.2.1 Contribution of Ride Share Information systems to NZTS/LTMA objectives (derived from Contribution Matrix Section 4).

NZTS / LTMA Objective	*Level of contribution*	*Comment*
A Economic Development	*High*	
Traffic Congestion	✓	Improve opportunity for increased vehicle occupancy and so reducing level of demand. Contribute indirectly and only during times of adverse conditions and incidents.
Traffic/Transport Demand	✓	
Transportation Costs (travel time, VOC)	➲	
Travel time for car commuters to key employment centres	✓	
Maintain strategic route security / availability / information	✓	
Quality & efficiency of transport	✓	
Freight transport and mode transfer	✓	
Travel time reliability	✓	
B Safety and Personal Security	*Low*	
Number of traffic crashes	➲	By reducing secondary crashes due to congestion and incident delays.
Level & severity of personal injury	➲	By reducing secondary crashes and improving response time to crashes.
Compliance (with traffic / transport regulations)	➲	Can assist by providing means of compliance monitoring.

Table 5.7.2.1 (continued)

NZTS / LTMA Objective	Level of contribution	Comment
C Access & Mobility	*Medium*	
Traffic Congestion	✓	Improve opportunity for increased vehicle occupancy and so reducing level of demand. Assist by improving experience and reliability of public transport services. Assist by improving information on routes and interchanges. Can assist by providing means of compliance monitoring.
Traffic/Transport Demand	✓	
Frequency and reliability of key passenger transport services	➲	
Convenience (perceived and actual) of public transport services	➲	
Level (%) of commuting trips by passenger transport	➲	
Level (%) of commuting trips by Cycle	➲	
Level (%) of commuting trips by Pedestrians	➲	
Level (%) of commuting trips by passenger transport	➲	
Strategic route security / availability / information	✓	
Quality & efficiency of transport	✓	
Travel time reliability	✓	
D Public Health	*Low*	
Traffic congestion in urban areas (impacts on local air quality)	✓	Improve opportunity for increased vehicle occupancy and so reducing level of demand.
Numbers of short trips made by walking or cycling	➲	
Numbers of commuting trips made by walking or cycling	➲	
Level & severity of personal injury	➲	
E Sustainability	*High*	
Traffic/Transport Demand	✓	Improve opportunity for increased vehicle occupancy and so reducing level of demand. Assist by improving experience and reliability of public transport services.
Level(%) of trips that are not car based	➲	
Non road freight volumes as a percentage of total	➲	
Growth rate of total vehicle travel	➲	
Emission levels (particulates, nitrogen oxides, carbon monoxides, CO_2)	➲	
Extent to which the benefits will be sustainable over time	✓	
F Energy Efficiency	*High*	
Traffic Congestion	✓	Improve opportunity for increased vehicle occupancy and so reducing level of demand. As a component of other systems. Assists by improving experience and reliability of public transport services. Improve opportunity for increased vehicle occupancy and so reducing level of demand.
Traffic/Transport Demand	✓	
Efficiency of routes taken	✓	
Fuel use	➲	
level of travel in congested conditions	✓	
Use of energy efficient modes	➲	
Quality & efficiency of transport	✓	

Table 5.7.2.1 (continued)

NZTS / LTMA Objective	Level of contribution	Comment
G Integration	High	
Provision for all modes on key transport corridors	✓	Improve opportunity for increased vehicle occupancy and so reducing level of demand. Assist by improving experience and reliability of public transport services. Improve opportunity for increased vehicle occupancy and so reducing level of demand.
Level of priority given to passenger transport	➲	
Efficiency and convenience of mode transfer points	✓	
Level of integration between road and rail	✓	
Improving rural community access & conditions	✓	
H Responsiveness	High	
Responding to diverse stake holder needs (particularly rural versus urban)	✓	Improve opportunity for increased vehicle occupancy and so reducing level of demand.
Contributions to national objectives	✓	
Maintain strategic route security / availability / information	✓	
Quality & efficiency of transport	✓	
Travel time reliability	✓	
I Affordability & Cost Effectiveness	High	
Relative benefit to cost ratio	✓	Relatively low cost facility with good benefit received.
Level of operating cost	✓	
J Implementation Risk	Low	
Technical complexity	✓	Low technology risk, relatively easy to set up. Some risk in ongoing operation.
Interoperability	✓	
Cost certainty	✓	
Public acceptance	✓	
Implementation constraints – resource consents, legal & others	✓	
✓ = Positive Contribution; ✗ = No Significant Contribution; ➲ = Partial Contribution		

5.7.2.6 Summary and Conclusions

Ride share information aims to assist people who both live and work in the same area to coordinate travel plans. The setting up of these facilities is relatively straightforward; however, they do rely on potential users having access to internet and suitable advertising of the service. Ride share facilities are most successful in areas with high numbers of regular commuters, with reasonably regular schedules.

In terms of the objectives set out by the NZTS and LTMA, these systems deliver benefits in several areas, including:

- Economic Development
- Access and Mobility
- Sustainability

They also have the potential to provide a positive contribution towards the following New Zealand specific target areas:

- Congestion Relief
- Demand Management
- Incident Management

- Safety
- Quality and Efficiency
- Travel Time Reliability

The use of these types of system in New Zealand is limited.

5.7.2.7 Example Applications

Table 5.7.2.2 Example applications of Ride Share Information systems.

Location	Description	Observed Benefits & Costs
San Francisco Bay Bridge, California, USA	Drivers and riders meet near BART stations and Almeda-Contra Costa Transit (AC Transit) bus stops where three-person, one-way carpools are formed spontaneously. Drivers and passengers generally do not know each other; carpool members change daily. Passengers are dropped off near the Transbay bus terminal (where all AC Transit buses terminate) in downtown San Francisco; two BART stations are also located in this vicinity. No money is exchanged between drivers and passengers. Drivers benefit by using the high occupancy vehicle (HOV) bypass lanes at the Bay Bridge toll plaza saving 10 to 20 minutes and $1.00 toll (c1990 prices) to cross the bridge. The obvious benefit to passengers is a free, relatively fast commute to San Francisco.	In 1990 it was estimated that 8000 commuters formed casual carpools to cross the San Francisco Bay Bridge - a toll bridge - every morning. This number could now be as many as 10,000. This is significantly more than the 3000 and 5000 estimated in 1985 and 1987 respectively.

5.7.3 En-Route and Pre-Trip Information

5.7.3.1 Description

Systems of information delivery that allow people to plan and alter their trips more efficiently. They are likely to integrate a number of information sources from travel patterns and predictions to weather forecasts, planned roadworks and incidents. Information delivery can be via many medium including, but not limited to:

- Variable Message Signs
- Internet
- Text Messages to Cellular Phones
- Radio
- Television
- Telephone (0800/0900) services

Limited to some form of information collection and processing. Sometimes these facilities deliver information to travellers at various stages through travel planning and journey. Pre-trip information provides information (Web, TXT, Radio, TV and Phone) that is designed to assist in travel planning and route selection. En-route information (VMS, TXT and Radio) provides information designed to assist drivers to make route choices or simply to advertise of adverse conditions to reduce frustration and provide opportunity for rescheduling appointments etc.

5.7.3.2 Benefits

The benefits of a real time information system are that people have more information available to make decisions. This leads to better planning of trips at congested times. Reducing congestion and improving safety and traffic flows.

5.7.3.3 Potential Problems

An important aspect of any traveller information system is its delivery and accuracy. If inaccurate data is fed in or inaccurate predictions are made then the system could deliver incorrect data to travellers that may actually increase congestion or travel time. This is unlikely to happen often however as if the system doesn't work well then people are unlikely to continue to use it and many of the positive benefits will be lost.

A problem with en-route information delivery systems is that drivers may become distracted when driving their vehicles and may take their eyes off the road to look at a screen or sign while driving.

5.7.3.4 Applications

These systems are best applied in areas where traffic patterns are not regular but are frequently affected by congestion. They allow drivers to plan their trips before hand and change their plans while en-route with the help of real time information. As the availability of reliable information is the key component of these systems, the better applications tend to be found where some form of traffic monitoring / information source already exists.

5.7.3.5 Relevance to NZTS / LTMA Objectives

Table 5.7.3.1 Contribution of En-Route and Pre-Trip Information systems to NZTS/LTMA objectives (derived from Contribution Matrix Section 4).

NZTS / LTMA Objective	*Level of contribution*	*Comment*
A Economic Development	*High*	
Traffic Congestion	✓	Provide advance warning of incidents and congestion, allowing selection of alternative routes/modes and reducing further build up. Contribute through demand management during times of congestion. Can be used as an element of more direct and variable charging systems. Assist in reducing congestion and efficient route/mode selection by providing advance warning of incidents and congestion.
Traffic/Transport Demand	✓	
Travel time on key routes	✓	
Transportation Costs (travel time, VOC)	✓	
Transport users face the true costs of use	➲	
Travel time for car commuters to key employment centres	✓	
Maintain strategic route security / availability / information	✓	
Quality & efficiency of transport	✓	
Freight transport and mode transfer	✓	
Travel time reliability	✓	
B Safety and Personal Security	*Low*	
Number of traffic crashes	➲	By reducing secondary crashes due to congestion and incident delays. By reducing secondary crashes and improving response time to crashes. Can assist by providing means of compliance monitoring.
Level & severity of personal injury	➲	
Compliance (with traffic / transport regulations)	➲	
C Access & Mobility	*High*	
Traffic Congestion	✓	Provide advance warning of incidents and congestion, allowing selection of alternatives routes/modes and reducing further build up. Contribute through demand management during times of congestion. Assist by improving experience and reliability of public transport services. Assist by improving information on routes and interchanges.
Traffic/Transport Demand	✓	
Sector to sector travel times by car	✓	
Frequency and reliability of key passenger transport services	➲	
Convenience (perceived and actual) of public transport services	➲	
Level (%) of commuting trips by passenger transport	➲	
Level (%) of commuting trips by Cycle	➲	
Level (%) of commuting trips by Pedestrians	➲	
Compliance (with traffic / transport regulations)	➲	
Strategic route security / availability / information	✓	
Quality & efficiency of transport	✓	
Travel time reliability	✓	
D Public Health	*Low*	
Traffic congestion in urban areas (impacts on local air quality)	✓	Provide advance warning of incidents and congestion, allowing selection of alternatives routes/modes and reducing related emissions. Assist by improving information on routes and interchanges. By reducing secondary crashes and improving response time to crashes.
Numbers of short trips made by walking or cycling	➲	
Numbers of commuting trips made by walking or cycling	➲	
Level & severity of personal injury	➲	

Table 5.7.3.1 (continued)

NZTS / LTMA Objective	*Level of contribution*	*Comment*
E Sustainability	*High*	
Traffic/Transport Demand	✓	Provide advance warning of incidents and congestion, allowing selection of alternative routes/modes and reducing further build up. Assist by improving experience and reliability of public transport services. Assist in the monitoring and management of freight. Can be used as an element of more direct and variable charging systems. Contribute through demand management during times of congestion.
Level(%) of trips that are not car based	➲	
Non road freight volumes as a percentage of total	➲	
Growth rate of total vehicle travel	➲	
Emission levels (particulates, nitrogen oxides, carbon monoxides, CO_2)	✓	
Extent to which users face full cost of their road use	➲	
Levels of service on key routes	✓	
Extent to which the benefits will be sustainable over time	✓	
F Energy Efficiency	*High*	
Traffic Congestion	✓	Provide advance warning of incidents and congestion, allowing selection of alternative routes/modes and reducing further build up. Assist by improving experience and reliability of public transport services. Assist in reducing congestion and efficient route/mode selection by providing advance warning of incidents and congestion.
Traffic/Transport Demand	✓	
Efficiency of routes taken	✓	
Fuel use	✓	
level of travel in congested conditions	✓	
Use of energy efficient modes	➲	
Quality & efficiency of transport	✓	
G Integration	*Medium*	
Provision for all modes on key transport corridors	✓	Assist by improving experience and reliability of public transport services. Assist in providing timely information to users. Assist in making provision for all modes.
Level of priority given to passenger transport	➲	
Efficiency and convenience of mode transfer points	✓	
Level of integration between road and rail	✓	
Improving rural community access & conditions	✓	
H Responsiveness	*High*	
Responding to diverse stake holder needs (particularly rural versus urban)	✓	Assist in reducing congestion and efficient route/mode selection by providing advance warning of incidents and congestion. Provide advance warning of incidents and congestion, allowing selection of alternative routes/modes and reducing further build up.
Contributions to national objectives	✓	
Maintain strategic route security / availability / information	✓	
Quality & efficiency of transport	✓	
Travel time reliability	✓	
I Affordability and Cost Effectiveness	*High*	
Relative benefit to cost ratio	✓	Cost effective when information collection & processing available.
Level of operating cost	✓	
Contribution direct from users	➲	

Table 5.7.3.1 (continued)

NZTS / LTMA Objective	***Level of contribution***	***Comment***
J Implementation Risk	*Medium*	
Technical complexity	✓	Most technologies used are relatively low risk. Some risk in interoperability between systems.
Interoperability	✓	
Cost certainty	✓	
Public acceptance	✓	
Implementation constraints – resource consents, legal & others	✓	
✓ = Positive Contribution; ✗ = No Significant Contribution; ➲ = Partial Contribution		

5.7.3.6 Summary and Conclusions

This type of information delivered to travellers in a range of situations provides assistance in planning and altering trips more efficiently. The systems involved are likely to integrate a number of information sources from travel patterns and predictions to weather forecasts, planned roadworks and incidents.

The benefits of real time information are that people have more information available to make decisions. This leads to better planning of trips at congested times. Reducing congestion and improving safety and traffic flows.

In terms of the objectives set out by the NZTS and LTMA, these systems deliver benefits in several areas, including:

- Economic development
- Access and mobility
- Sustainability.

They also have the potential to provide a positive contribution towards the following New Zealand specific target areas:

- Congestion Relief
- Demand Management
- Incident Management
- Safety
- Route Security
- Quality and Efficiency
- Travel Time Reliability

Traveller information services are growing in New Zealand, particularly in the main centres but currently there is no centralised planning or coordination between systems.

5.7.3.7 Example Applications

Table 5.7.3.2 Example applications of En-Route and Pre-Trip Information systems.

Location	Description	Observed Benefits & Costs
Auckland, New Zealand	ATTOMS is a 24x7x365 operation with access to dynamic traffic information through the Advanced Traffic Management System (ATMS).	Operators constantly monitor automatic systems and live video to feed back information to partner organisations to assist in clearing traffic incidents effectively and update variable message signs and web based information. Vehicle-detection technology, cameras and communications links with contractors, Police and emergency services are the tools used to achieve this.
Oregon, USA	ODOT's TripCheck Web site is the primary traveller information gateway for pre-trip travel information in Oregon. The Web site includes images from approximately 140 cameras installed on highways throughout the state, which allow travellers to see current traffic and weather conditions. It provides weather data collected by the state's network of road and weather information system (RWIS) stations, and information on incidents and roadway construction that may affect driver delay.	Since TripCheck went on-line in 1998, site usage numbers have continued to increase. In December 2000, there were approximately 900,000 visits, in December 2001, there were 1.5 million visits and in December 2002, there were approximately 1.6 million visits to TripCheck.com. A telephone-based survey of approximately 400 Oregonians by the University of Oregon in 2001 indicated that more than 60 percent of the commuters responding have used the Internet to access road and weather information. About 83% of respondents considered traffic and weather related information to be either somewhat or very important. This survey also concluded that 95% of respondents who had visited the TripCheck Web site found all the information they were looking for.

5.7.4 In-Vehicle and Handheld Devices

5.7.4.1 Description

As the capacity and capability of in-vehicle and handheld devices increase they are becoming effective tools for accessing a large range of traffic information sources. Combined communications and GPS devices can be programmed with a destination; they will then work out the quickest or shortest route to get you there. Some devices are also able to remotely connect to a server to get real time information on traffic flows, scheduled road works, incidents and other useful information. They can also store locations of petrol stations, shopping centres and other useful destinations.

5.7.4.2 Benefits

With real time information on traffic flows, the devices can help navigate traffic efficiently. This will reduce travel time and therefore congestion. There will be less time spent in traffic which will reduce time spent idling which will provide positive environmental benefits and lower car running costs. Drivers on nonessential trips will also choose to delay their trips to avoid congestion. This in itself will help reduce congestion.
Accurate and reliable traveller information provides proven benefits, particularly in areas of frequent and variable congestion, usually caused by incidents.

5.7.4.3 Potential Problems

Drivers may become distracted when driving their vehicles and may take their eyes off the road to look at the screen while driving. This could be overcome if the screen only worked while the car was stationary and the system used audio commands while the vehicle was in motion.

5.7.4.4 Applications

This system is likely to be best used in an area where traffic patterns are unpredictable. It will allow drivers to plan their trips before hand and change their plans en-route with the help of real time traffic information.

5.7.4.5 Relevance to NZTS / LTMA Objectives

Table 5.7.4.1 Contribution of In-Vehicle and Handheld Devices to NZTS/LTMA objectives (derived from Contribution Matrix Section 4).

NZTS / LTMA Objective	*Level of contribution*	*Comment*
A Economic Development	*Medium*	
Traffic Congestion	✓	Provide advance warning of incidents and congestion, allowing selection of alternative routes/modes and reducing further build up. Contribute through improved route selection and as part of a broader demand management strategy. Provide advance warning of incidents and congestion, allowing selection of alternative routes/modes and reducing further build up.
Traffic/Transport Demand	✓	
Travel time on key routes	➲	
Transportation Costs (travel time, VOC)	➲	
Travel time for car commuters to key employment centres	➲	
Maintain strategic route security / availability / information	✓	
Quality & efficiency of transport	✓	
Freight transport and mode transfer	✓	
Travel time reliability	✓	

Table 5.7.4.1 (continued)

NZTS / LTMA Objective	Level of contribution	Comment
B Safety and Personal Security	*Low*	
Number of traffic crashes	➲	Contribute through improved route selection and as part of a broader demand management strategy.
Level of conflict between vehicles / cyclists / pedestrians and other road users	➲	
Compliance (with traffic / transport regulations)	➲	
C Access & Mobility	*High*	
Traffic Congestion	✓	Provide advance warning of incidents and congestion, allowing selection of alternative routes/modes and reducing further build up. Contribute through improved route selection and as part of a broader demand management strategy. Contribute through improved route selection (can include advice on cycle suitable routes).
Traffic/Transport Demand	✓	
Sector to sector travel times by car	➲	
Frequency and reliability of key passenger transport services	➲	
Convenience (perceived and actual) of public transport services	➲	
Level (%) of commuting trips by passenger transport	➲	
Level (%) of commuting trips by Cycle	➲	
Level (%) of commuting trips by Pedestrians	➲	
Strategic route security / availability / information	✓	
Quality & efficiency of transport	✓	
Travel time reliability	✓	
D Public Health	*Medium*	
Traffic congestion in urban areas (impacts on local air quality)	➲	Provide advance warning of incidents and congestion, allowing selection of alternative routes/modes and reducing further build up. Contribute through improved route selection (can include advice on cycle suitable routes).
Numbers of short trips made by walking or cycling	➲	
Numbers of commuting trips made by walking or cycling	➲	
E Sustainability	*Medium*	
Traffic/Transport Demand	✓	Provide advance warning of incidents and congestion, allowing selection of alternative routes/modes and reducing further build up. Contribute through improved route selection and as part of a broader demand management strategy. Contribute through improved route selection (can include advice on cycle suitable routes).
Level(%) of trips that are not car based	➲	
Growth rate of total vehicle travel	➲	
Emission levels (particulates, nitrogen oxides, carbon monoxides, CO_2)	➲	
Levels of service on key routes	➲	
Extent to which the benefits will be sustainable over time	✓	
F Energy Efficiency	*High*	
Traffic Congestion	✓	Provide advance warning of incidents and congestion, allowing selection of alternative routes/modes and reducing further build up. Contribute through improved route selection and as part of a broader demand management strategy.
Traffic/Transport Demand	✓	
Efficiency of routes taken	✓	
Fuel use	➲	
level of travel in congested conditions	✓	
Use of energy efficient modes	➲	
Quality & efficiency of transport	✓	

Table 5.7.4.1 (continued)

NZTS / LTMA Objective	Level of contribution	Comment
G Integration	*Medium*	
Level of priority given to passenger transport	➲	Contribute through improved route selection and as part of a broader demand management strategy. Contribute through improved information to users.
Level of integration between road and rail	➲	
Improving rural community access & conditions	✓	
H Responsiveness	*High*	
Responding to diverse stake holder needs (particularly rural versus urban)	✓	Provide advance warning of incidents and congestion, allowing selection of alternative routes/modes and reducing further build up.
Contributions to national objectives	✓	
Maintain strategic route security / availability / information	✓	
Quality & efficiency of transport	✓	
Travel time reliability	✓	
I Affordability and Cost Effectiveness	*Medium*	
Relative benefit to cost ratio	➲	Cost effective when information collection and processing available.
Level of operating cost	➲	
J Implementation Risk	*Medium*	
Technical complexity	➲	Most technologies used are relatively low risk. Some risk in interoperability between systems.
Interoperability	➲	
Cost certainty	➲	
Public acceptance	✓	
Implementation constraints – resource consents, legal & others	➲	
✓ = Positive Contribution; ✗ = No Significant Contribution; ➲ = Partial Contribution		

5.7.4.6 Summary and Conclusions

In-vehicle and handheld devices are becoming effective tools for accessing a large range of traffic information sources. Combined communications and GPS devices can be programmed with a destination; they will then work out the quickest or shortest route to get you there.

With real time information on traffic flows the devices can help navigate traffic efficiently. This will reduce travel time and therefore congestion.

Accurate and reliable traveller information provides proven benefits, particularly in areas of frequent and variable congestion, usually caused by incidents.

In terms of the objectives set out by the NZTS and LTMA, these systems deliver benefits in several areas, including:

- Economic Development
- Access and Mobility

They also have the potential to provide a positive contribution towards the following New Zealand specific target areas:

- Congestion Relief
- Demand Management

- Incident Management
- Quality and Efficiency
- Travel Time Reliability

5.7.4.7 Example Applications

Table 5.7.4.2 Example applications of In-Vehicle and Handheld Devices.

Location	Description	Observed Benefits & Costs
Orlando, (USA)	The Orlando Test Network Study was designed to evaluate alternative TravTek visual and aural display configurations, and TravTek's route planning and route guidance functions with respect to: • Trip efficiency. • Navigation performance. • Driving performance. • Driver preference. • Driver perception. • Willingness-to-pay.	The TravTek system was found to improve the efficiency of trips over trips driven without the system. Tourists unfamiliar with the local area were able to plan trips to nearby unfamiliar destinations in about 75% less time using TravTek than using the method they would normally use. Participants in this study expressed a willingness to pay for a TravTek system. In a new car the median dollar amount the participants said they would pay for TravTek was about $1000. In a rental car, they judged that the TravTek system they drove would increase the weekly rental value by about $28.

5.8 Information Management

Data collected by ITS applications can be used in a range of applications to assist in planning, managing and maintaining the transport system. Data can be used to evaluate historical performance, supporting operational improvements, transportation-planning, research, and safety management activities. Key aspects of the use of ITS data are archiving, interoperability and analysis.

The systems included in this section are:

5.8.1 Data Archiving / Interoperability / Analysis

5.8.1 Data Archiving / Interoperability / Analysis

5.8.1.1 Description

Intelligent Transportation Systems provide and use information about transportation conditions to improve system performance in areas such as safety, mobility, efficiency and environmental impacts. Typically, ITS generate massive amounts of data about the state of travel that are used primarily by transportation authorities to effectively operate and manage their transportation systems, and by private individuals and industry to manage trips. These primary uses provide short-term, real-time information regarding the transportation systems' current conditions and driver and passenger choices.

The increasing deployment of ITS and the amount and variety of ITS-generated data offer great potential for longer-term transportation planning. Often, ITS-generated data and information might be similar or better than that traditionally used in transportation planning, operations, administration, and research. Some types of ITS-generated data may have no traditional counterparts but offer the potential for new and extended applications in these longer-term planning areas. Archived ITS-generated data can provide a valuable resource for such longer-term uses.

5.8.1.2 Benefits

In general, the benefits of using ITS-generated data are drawn from:

- More detailed short-interval data increases reliability of information.
- Alternative data sources to existing data, thereby reducing the costs of data collection.
- Greater geographic coverage.
- Provides data that may have been too costly to collect in the past, thereby meeting unmet data gaps.
- Providing data in electronic form, improving analysis opportunity.

5.8.1.3 Potential Problems

In order to obtain the best value from ITS data it is important that the best data is collected and retained, in a suitable format and analysed using appropriate methods. Problems encountered in this area include:

- Lack of interoperability between the data generated by different systems.
- Storage space and administration.
- Analysis methods not suited to the data available.

5.8.1.4 Applications

Wherever ITS facilities collect information on road and traffic/transport conditions there is value in gathering data for planning and management purposes. The most likely applications to produce clear benefits are those that are able to:

- Identify and address technical and institutional barriers to archiving so that ITS-generated data can be shared effectively.
- Achieve integration of existing data resources.
- Developing cost effective storage and analysis methods that deliver benefit.
- Maintaining ongoing evolution of data use.
- Sharing the developed procedures and software in an open-source environment.

Some examples of these procedures and software are:

- Those developed to convert raw ITS-generated data into formats acceptable to existing and/or off-the-shelf data management or analysis software.
- Those that check the quality of the data.
- Input missing data.
- Correct questionable data.
- Abstract information suitable for data analysis from 'text' files.
- Estimate potential recurring and non-recurring traffic delays, and other applications.

5.8.1.5 Relevance to NZTS / LTMA Objectives

Table 5.8.1.1 Contribution of Data Archiving / Interoperability / Analysis to NZTS/LTMA objectives (derived from Contribution Matrix Section 4).

NZTS / LTMA Objective	***Level of contribution***	***Comment***
A Economic Development	*Low*	
Travel time on key routes	➲	Contribute indirectly by assisting in other improvement initiatives.
Transportation Costs (travel time, VOC)	➲	
Transport users face the true costs of use	➲	
Travel time for car commuters to key employment centres	➲	
Maintain strategic route security / availability / information	➲	
Quality & efficiency of transport	➲	
Freight transport and mode transfer	➲	
Travel time reliability	➲	
B Safety and Personal Security	*Low*	
Number of traffic crashes	➲	By facilitating improvements in analysis for other measures.
Level & severity of personal injury	➲	
C Access & Mobility	*Low*	
Sector to sector travel times by car	➲	Contribute indirectly by assisting in other improvement initiatives.
Frequency and reliability of key passenger transport services	➲	
Convenience (perceived and actual) of public transport services	➲	
Level (%) of commuting trips by passenger transport	➲	
Level (%) of commuting trips by Cycle	➲	
Level (%) of commuting trips by Pedestrians	➲	
Compliance (with traffic / transport regulations)	➲	
Strategic route security / availability / information	➲	
Quality & efficiency of transport	➲	
Travel time reliability	➲	

Table 5.8.1.1 (continued)

NZTS / LTMA Objective	***Level of contribution***	***Comment***
D Public Health	*Low*	
Vehicle noise	➲	By facilitating improvements in analysis for other measures. Contribute indirectly by assisting in other improvement initiatives.
Numbers of short trips made by walking or cycling	➲	
Numbers of commuting trips made by walking or cycling	➲	
Compliance (with emissions regulations)	➲	
Level & severity of personal injury	➲	
E Sustainability	*Low*	
Level(%) of trips that are not car based	➲	Contribute indirectly by assisting in other improvement initiatives. Assist in the monitoring and management of freight.
Non road freight volumes as a percentage of total	➲	
Growth rate of total vehicle travel	➲	
Emission levels (particulates, nitrogen oxides, carbon monoxides, CO_2)	➲	
Extent to which users face full cost of their road use	➲	
Levels of service on key routes	➲	
Extent to which the benefits will be sustainable over time	✓	
G Integration	*Low*	
Provision for all modes on key transport corridors	➲	Contribute indirectly by assisting in other improvement initiatives. Assist in making provision for all modes.
Level of priority given to passenger transport	➲	
Efficiency and convenience of mode transfer points	➲	
Level of integration between road and rail	➲	
Improving rural community access & conditions	➲	
H Responsiveness	*Low*	
Responding to diverse stake holder needs (particularly rural versus urban)	➲	Assist in contributing to national planning initiatives.
Contributions to national objectives	✓	
Maintain strategic route security / availability / information	➲	
Quality & efficiency of transport	➲	
Travel time reliability	➲	
I Affordability and Cost Effectiveness	*High*	
Relative benefit to cost ratio	✓	Cost effectiveness is good, provided collection, interoperability and analysis processes are well planned.
Level of operating cost	✓	
Contribution direct from users	➲	

Table 5.8.1.1 (continued)

NZTS / LTMA Objective	***Level of contribution***	***Comment***
J Implementation Risk	*Low*	
Technical complexity	✓	Risks include poor interoperability, collection of high volumes of data without clear purpose. Potential for developing high cost database systems.
Interoperability	✓	
Cost certainty	✓	
Public acceptance	➲	
Implementation constraints – resource consents, legal & others	➲	
✓ = Positive Contribution; ✗ = No Significant Contribution; ➲ = Partial Contribution		

5.8.1.6 Summary and Conclusions

Data collected by ITS applications can be used in a range of applications to assist in planning, managing and maintaining the transport system. Data can be used to evaluate historical performance, supporting operational improvements, transportation planning, research, and safety management activities. Key aspects of the use of ITS data are archiving, interoperability and analysis.

In terms of the objectives set out by the NZTS and LTMA, these systems contribute indirectly to the benefits delivered by ITS facilities in all areas:

- Economic Development
- Safety and Personal Security
- Access and Mobility
- Public Health
- Environmental Sustainability

They also have the potential to provide a positive contribution towards all of the following New Zealand specific target areas:

- Congestion Relief
- Demand Management
- Incident Management
- Compliance
- Safety
- Route Security
- Quality and Efficiency
- Travel Time Reliability
- Environmental Mitigation

The use of these systems in New Zealand is relatively wide, but is increasing rapidly as the benefits of data interoperability are becoming more apparent.

5.8.1.7 Example Applications

Table 5.8.1.2 Example applications of Data Archiving / Interoperability / Analysis systems.

Location	Description	Observed Benefits & Costs
USA	U.S. Department of Transportation multi-agency, 5-year ITS Data Archiving Program Plan was developed based upon the vision of 'improving transportation decisions through the archiving and sharing of ITS generated data'.	Archived ITS-generated data provide unprecedented opportunities that traditional ways of compiling information can not offer. Making information accessible almost on a real-time basis allows transportation planners and operators to anticipate emerging issues, thereby allowing them to progress from a reactive mode to a proactive mode. Furthermore, more detailed and insightful understanding of the problems (safety, planning, operations, or maintenance) is now possible because of the expanded scope and increased frequency of data collection. The specific benefits of using ITS-generated data vary from one application to the next, and are difficult to enumerate. However, the general benefits of using archived ITS-generated data can be gauged in at least three ways. First, can ITS data replace traditional data? If so, this benefit can be measured in monetary terms. Second, can ITS-generated data supplement traditional data so that more reliable estimates can be developed? Third, can ITS-generated data meet data gaps that are expensive or impossible to meet with traditional data sources? Results from the research confirm that ITS-generated data can both replace and supplement data collected through traditional ways.

5.9 Crash Prevention and Safety

Information from crash prevention and safety applications can be used to implement roadway control strategies. A major goal of an ITS program is to improve safety and reduce risk for road users, including pedestrians, cyclists, operators, and occupants of all vehicles who must travel along a given roadway. Road geometry warning systems warn drivers, typically those in commercial trucks and other heavy vehicles, of potentially dangerous conditions which may cause rollovers or other crashes on ramps, curves, or downgrades. Highway-rail crossing systems can reduce the potential for catastrophic accidents involving buses or hazardous materials.

Intersection detection systems can reduce approach speeds at rural intersections by advising drivers of the presence and direction of approaching traffic. Pedestrian safety systems can help protect pedestrians by automatically activating in-pavement lighting to alert drivers as pedestrians enter crosswalks. Bicycle warning systems can notify drivers when a cyclist is in an upcoming stretch of roadway to improve safety on narrow bridges and tunnels. Animal warning systems have been deployed in Europe and are still being tested in the United States. These systems typically use radar to detect large animals approaching the roadway, and then alert drivers by activating flashers on warning signs located upstream of high-frequency crossing areas.

The three systems included in this section are:

5.9.1 Road Geometry Warning Systems : Ramp Rollover / Curve Speed / Downhill Speed

5.9.2 Highway Rail Crossing Systems

5.9.3 Intersection Collision Warnings

5.9.1 Road Geometry Warning Systems : Downhill Speed / Ramp Rollover / Curve Speed

5.9.1.1 Description

ITS facilities that warn drivers of particular hazards ahead related to their approach speed and type of vehicle. Common examples include systems that detect a heavy vehicle's approach speed, weight and/or length and warn the driver of a hazard ahead such as a steep grade or a sharp curve. This warning is usually through a variable message sign, but more recent developments have used in vehicle devices.

5.9.1.2 Benefits

The benefits of these targeted safety warnings are the higher success rate in alerting drivers to hazards, and in the case of systems targeted at trucks, a reduction in the numbers and effects of major incidents involving these vehicles.

5.9.1.3 Potential Problems

The VMS based systems use tried and tested technologies and as such are relatively cost effective and reliable. The main problems result form inappropriate location and use; eg. Implementing a system where there is not a recognised problem, or where the main problem is not approach speed but some other factor.

5.9.1.4 Applications

These systems are best used where there is a recognised problem of approach speed, that can not be simply addressed through engineering or other means.

5.9.1.5 Relevance to NZTS / LTMA Objectives

Table 5.9.1.1 Contribution of Road Geometry Warning Systems – Downhill Speed / Ramp Rollover / Curve Speed systems to NZTS/LTMA objectives (derived from Contribution Matrix Section 5).

NZTS / LTMA Objective	Level of contribution	Comment
A Economic Development	Low	
Maintain strategic route security / availability / information	➲	Contribute indirectly by reducing major incidents on key routes.
Quality & efficiency of transport	➲	
Freight transport and mode transfer	➲	
B Safety and Personal Security	High	
Number of traffic crashes	✓	Reduce crashes at problem sites through targeted enforcement and warning. Provide input to facilitate compliance systems.
Level of fatalities	✓	
Level & severity of personal injury	✓	
Level of conflict between vehicles / cyclists / pedestrians and other road users	✓	
Compliance (with traffic / transport regulations)	➲	

Table 5.9.1.1 (continued)

NZTS / LTMA Objective	Level of contribution	Comment
C Access & Mobility	*Low*	
Compliance (with traffic / transport regulations)	➲	Can assist by providing means of compliance monitoring and enforcement. Contribute indirectly by reducing major incidents on key routes.
Strategic route security / availability / information	➲	
Quality & efficiency of transport	➲	
D Public Health	*Medium*	
Level & severity of personal injury	✓	Safety; Reducing crashes at problem sites through targeted enforcement and warning.
E Sustainability	*Low*	
Extent to which the benefits will be sustainable over time	✓	Once installed the benefits are long term.
F Energy Efficiency	*Low*	
Quality & efficiency of transport	➲	Contribute indirectly by reducing major incidents on key routes.
H Responsiveness	*Medium*	
Responding to diverse stake holder needs (particularly rural versus urban)	✓	Contribute indirectly by reducing major incidents on key routes. Contribute by reducing major incidents on key routes.
Contributions to national objectives	✓	
Maintain strategic route security / availability / information	➲	
Quality & efficiency of transport	➲	
I Affordability and Cost Effectiveness	*Medium*	
Relative benefit to cost ratio	➲	When applied to a suitable site cost effectiveness is good.
Level of operating cost	✓	
J Implementation Risk	*Low*	
Technical complexity	✓	Technology used is well developed and reliable. Technology risks are low. Main risk is in inappropriate application.
Interoperability	✓	
Cost certainty	✓	
Public acceptance	✓	
Implementation constraints – resource consents, legal & others	✓	
✓ = Positive Contribution; × = No Significant Contribution; ➲ = Partial Contribution		

5.9.1.6 Summary and Conclusions

ITS facilities that warn drivers of particular hazards ahead related to their approach speed and type of vehicle. Common examples include systems that detect a heavy vehicle's approach speed, weight and/or length and warn the driver of a hazard ahead such as a steep grade or sharp curve. This warning is usually through a variable message sign, but more recent developments have used in vehicle devices.

These systems are best used where there is a recognised problem of approach speed that can not be simply addressed through engineering or other means.

In terms of the objectives set out by the NZTS and LTMA, these systems deliver benefits in several areas, including:

- Safety and Personal Security
- Access and Mobility
- Public Health

They also have the potential to provide a positive contribution towards the following New Zealand specific target areas:

- Incident Management
- Compliance
- Safety
- Route Security
- Travel Time Reliability

The use of these types of facilities in New Zealand is currently developing with trial systems being implemented at selected sites.

5.9.1.7 Example Applications

Table 5.9.1.2 Example applications of Road Geometry Warning Systems – Downhill Speed / Ramp Rollover / Curve Speed systems.

Location	Description	Observed Benefits & Costs
Capital Beltway — Washington DC, USA	The Capital Beltway circles the greater Washington DC area and has numerous entry and exit ramps. Over the past decade there have been several major incidents involving trucks rolling over while exiting the Beltway. In many cases, these crashes have resulted in fatalities and in one case, fire caused considerable damage to the Beltway ramp structure itself.	Three sites, with a prior history of truck rollover type crashes, were installed with in-road systems to advise drivers of the hazardous curves. The systems were installed in 1993 and evaluated independently over a three-year period. Findings from the evaluation revealed that activation of the sign resulted in greater speed reduction. The findings also showed that the overall speed reduction of trucks following activation of the sign was 21.7%. A more significant finding was that of the three sites chosen, not a single rollover crash has occurred at the three sites since they were installed.

5.9.2 Highway Rail Crossing Systems

5.9.2.1 Description

These systems are put in place to reduce the risk of accidents at rail crossings. They provide a warning to drivers that there is a train crossing ahead. They also provide an immediate warning if a train is approaching. Ideally they will also be able to warn train drivers if there is a vehicle on the tracks ahead so that the train driver may slow down and be prepared to stop should there be a vehicle on the tracks up ahead.

5.9.2.2 Benefits

- **Safety:** Accident, injury, fatality reduction and prevention; increased driver awareness.
- **Efficiency:** Exchange of real-time data between train and traffic controllers at Highway Rail Interchanges (HRI).
- **Productivity:** Cost reduction in transportation of goods and people.
- **Control:** More interoperable and coordinated transportation systems; ITS tracks and monitors train activity.
- **Communication:** Real-time communication between train operators, traffic control centres, and roadway vehicles.

5.9.2.3 Potential Problems

- The logistics of developing coordinated and interoperable nationwide system for ITS technologies at HRI.
- Human factors are largely responsible for accidents, injuries and fatalities at HRI. Such factors, including roadway driver confusion and train operator errors, are difficult to predict and control.

5.9.2.4 Applications

This is applicable in any situation where there is road/train crossing, particularly if there has been a history of near-misses or accidents.

5.9.2.5 Relevance to NZTS / LTMA Objectives

Table 5.9.2.1 Contribution of Highway Rail Crossing Systems to NZTS/LTMA objectives (derived from Contribution Matrix Section 5).

NZTS / LTMA Objective	*Level of contribution*	*Comment*
A Economic Development	*Low*	
Maintain strategic route security / availability / information	➲	Contribute indirectly by reducing major incidents on key routes.
Quality & efficiency of transport	➲	
B Safety and Personal Security	*High*	
Number of traffic crashes	✓	Reduce crashes at problem sites through targeted enforcement and warning. Provide input to facilitate compliance systems.
Level of fatalities	✓	
Level & severity of personal injury	✓	
Level of conflict between vehicles / cyclists / pedestrians and other road users	✓	
Compliance (with traffic / transport regulations)	➲	

Table 5.9.2.1 (continued)

NZTS / LTMA Objective	Level of contribution	Comment
C Access & Mobility	*Low*	
Compliance (with traffic / transport regulations)	➲	Can assist by providing means of compliance monitoring and enforcement. Contribute indirectly by reducing major incidents on key routes.
Strategic route security / availability / information	➲	
Quality & efficiency of transport	➲	
D Public Health	*Medium*	
Level & severity of personal injury	✓	Reduce crashes at problem sites through targeted enforcement and warning.
F Energy Efficiency	*Low*	
Quality & efficiency of transport	➲	Contribute indirectly by reducing major incidents on key routes.
G Integration	*Medium*	
Level of integration between road and rail	✓	Assist in providing improved efficiency and safety at interchanges.
Improving rural community access & conditions	✓	
H Responsiveness	*Medium*	
Responding to diverse stake holder needs (particularly rural versus urban)	✓	Contribute by reducing major incidents on key routes. Contribute indirectly by reducing major incidents on key routes.
Contributions to national objectives	✓	
Maintain strategic route security / availability / information	➲	
Quality & efficiency of transport	➲	
I Affordability and Cost Effectiveness	*Medium*	
Relative benefit to cost ratio	➲	Cost effective if installed at a problem site.
Level of operating cost	✓	
J Implementation Risk	*Low*	
Technical complexity	✓	Technologies range from simple low risk detection and warning systems to more complex tracking with higher risks.
Interoperability	✓	
Cost certainty	✓	
Public acceptance	✓	
Implementation constraints – resource consents, legal & others	➲	
✓ = Positive Contribution; ✗ = No Significant Contribution; ➲ = Partial Contribution		

5.9.2.6 Summary and Conclusions

These systems are put in place to reduce the risk of accidents at rail crossings. They provide a warning to drivers that there is a train crossing ahead. The main benefits are safety related, reduced accidents, injury, fatalities and increased driver awareness.

This is applicable in any situation where there is road/train crossing, particularly if there has been a history of near-misses or accidents.

In terms of the objectives set out by the NZTS and LTMA, these systems deliver benefits in several areas, including:

- Safety and Personal Security
- Public Health

They also have the potential to provide a positive contribution towards the following New Zealand specific target areas:

- Incident Management
- Compliance
- Safety
- Route Security

These systems are currently not operated in New Zealand

5.9.2.7 Example Applications

Table 5.9.2.2 Example applications of Highway Rail Crossing Systems.

Location	Description	Observed Benefits & Costs
Texas USA	A 36-inch **YIELD** sign with a supplemental message plate (36 inches by 24 inches) containing the phrase **TO TRAINS**. The second experimental enhanced sign system consists of a vehicle-activated strobe or flashing yellow beacon mounted above a standard railroad advance warning sign in combination with a new yellow warning sign that reads **LOOK FOR TRAIN AT CROSSING**. Researchers selected nine project sites from TxDOT's list of passive crossings that were scheduled to be upgraded to active control. TxDOT and the Texas Transportation Institute developed criteria to rank the potential sites, and researchers made field visits to determine the roadway alignment and to verify that each site satisfied the defined criteria. Researchers selected four sites for the **YIELD TO TRAINS** enhanced sign systems, two sites for the **LOOK FOR TRAIN AT CROSSING** enhanced sign systems with flashing strobe lights, and three sites for the **LOOK FOR TRAIN AT CROSSING** enhanced sign system with flashing beacons.	The analysis of the before and after speed studies did not find any across-the-board decreases in speeds at any of the locations using the three enhanced sign systems. On-site surveys indicated that the vehicle-activated systems were effective in gaining drivers' attention and that the devices did not alarm the drivers. For **the LOOK FOR TRAIN AT CROSSING** enhanced sign systems, 82% of survey respondents at the four sites surveyed noticed the flashing lights at the approaches to the railroad-highway grade crossings, and 73% noticed the sign placed below the flashing light or beacon. Additionally, 20 percent of the survey respondents remembered that the sign said to look or watch for trains, and another 36% noted that the signs said something about a railroad crossing. Thirty-eight percent of the survey participants stated that they believed **the LOOK FOR TRAIN AT CROSSING** enhanced sign system was a good idea. Also, 69 to 91% of the survey respondents at the four project sites where surveys were conducted were from the same county, verifying the researchers' belief that most drivers were familiar with the area.

5.9.3 Intersection Collision Warnings

5.9.3. Description

These systems alert drivers to the conditions at the intersection ahead. They can alert a driver to the proximity of other vehicles that are approaching the intersection. They may be in vehicle devices or signs on the side of the road. They may also be implemented at rail or pedestrian crossings.

5.9.3.2 Benefits

The main benefits are safety related, fewer accidents and fatalities and increased driver awareness, with the associated benefits to the economy.

5.9.3.3 Potential Problems

The main issues with these systems are the potential to distract drivers on the approach to a hazardous intersection, and the possibility that some drivers may come to rely on the systems too much, and so not take normal precautions.

5.9.3.4 Applications

This would be applicable in circumstances where there are intersections that have frequent accidents and traditional improvements are limited. The warnings are more likely to have increased benefits if focused on intersections on high speed roads as opposed to intercity intersections.

5.9.3.5 Relevance to NZTS / LTMA Objectives

Table 5.9.3.1 Contribution of Intersection Collision Warnings to NZTS/LTMA objectives (derived from Contribution Matrix Section 5).

NZTS / LTMA Objective	***Level of contribution***	***Comment***
A Economic Development	*Low*	
Maintain strategic route security / availability / information	➲	Contribute indirectly by reducing major incidents on key routes.
Quality & efficiency of transport	➲	
B Safety and Personal Security	*High*	
Number of traffic crashes	✓	Reduce crashes at problem sites through targeted enforcement and warning. Provide input to facilitate compliance systems.
Level of fatalities	✓	
Level & severity of personal injury	✓	
Level of conflict between vehicles / cyclists / pedestrians and other road users	✓	
Compliance (with traffic / transport regulations)	➲	
C Access & Mobility	*Low*	
Compliance (with traffic / transport regulations)	➲	Can assist by providing means of compliance monitoring and enforcement. Contribute indirectly by reducing major incidents on key routes.
Strategic route security / availability / information	➲	
Quality & efficiency of transport	➲	
D Public Health	*Medium*	
Level & severity of personal injury	✓	Reduce crashes at problem sites through targeted enforcement and warning.

Table 5.9.3.1 (continued)

NZTS / LTMA Objective	***Level of contribution***	***Comment***
F Energy Efficiency	*Low*	
Quality & efficiency of transport	➲	Contribute indirectly by reducing major incidents on key routes.
H Responsiveness	*Medium*	
Responding to diverse stake holder needs (particularly rural versus urban)	✓	Contribute by reducing major incidents on key routes. Contribute indirectly by reducing major incidents on key routes.
Contributions to national objectives	✓	
Maintain strategic route security / availability / information	➲	
Quality & efficiency of transport	➲	
I Affordability and Cost Effectiveness	*Medium*	
Relative benefit to cost ratio	➲	At this stage such systems are relatively expensive and would only be cost effective at locations where all other options had been tried.
Level of operating cost	✓	
J Implementation Risk	*Medium*	
Technical complexity	➲	Key risks are ensuring technology is highly reliable to avoid false information.
Interoperability	➲	
Cost certainty	➲	
Public acceptance	➲	
Implementation constraints – resource consents, legal & others	➲	
✓ = Positive Contribution; ✗ = No Significant Contribution; ➲ = Partial Contribution		

5.9.3.6 Summary and Conclusions

These systems alert drivers to the conditions at the intersection ahead. They can alert a driver to the proximity of other vehicles that are approaching the intersection. They may be in vehicle devices or signs on the side of the road. They may also be implemented at rail or pedestrian crossings.

The main benefits are safety related, fewer accidents and fatalities and increase driver awareness, with the associated benefits to the economy.
Key risks are ensuring technology is highly reliable to avoid false information.

In terms of the objectives set out by the NZTS and LTMA, these systems deliver benefits in several areas, including:

- Safety and Personal Security
- Public Health

They also have the potential to provide a positive contribution towards the following New Zealand specific target areas:

- Incident Management
- Compliance
- Safety
- Route Security

These systems are currently not operated in New Zealand

5.9.3.7 Example Applications

Table 5.9.3.2 Example applications of Intersection Collision Warnings.

Location	Description	Observed Benefits & Costs
Aden, Virginia, USA	An automated warning system installed at a rural intersection improved traveller safety by slowing traffic and providing those in greatest danger of colliding with an average of 38% more time to take corrective action. The system provided warnings to drivers on a major highway approaching a rural intersection with a minor road. While stop signs controlled the minor road, animated signs flashed warnings to those on the major road that traffic was present on the intersecting minor road. Animated signs were also posted on the minor road alerting drivers to the direction of approaching vehicles on the major road.	A before-after analysis of 1,623 instances when vehicles were approaching on both roads measured changes in vehicle speeds and the projected time-to-collision. The study revealed that average speed was reduced from 80 km/h to 76 km/h. Among the 10% of vehicles with the shortest, and most dangerous, projected times-to-collision, the study found an increase from 2.54 to 3.5 seconds. This represents 38% more time for drivers in greatest danger of colliding to react and avoid a crash. For high-speed vehicles, the average speed was reduced from 89 km/h to 88 km/h, and the average projected time-to-collision was greater than the critical 4.6-second accident-avoidance time requirement for vehicles at 88 km/h.
Los Angeles Rochester-State Phoenix-Central USA	Four intersections were monitored in three cities (Los Angeles, Rochester NY, and Phoenix) using video cameras to record pedestrian and motorist behaviour before and after automated pedestrian detection systems were installed at busy crosswalks. Pre-existing manual push buttons were available at each intersection before and after the automated systems were activated. In Los Angeles, both microwave and infrared detection systems were installed. Infrared detectors monitored pedestrians moving in the crosswalk, and microwave detectors monitored pedestrians waiting at roadside queuing areas. This system automatically called for a pedestrian crossing signal if a person was detected in the queuing area for a specified amount of time. In addition, the system delayed the green light for opposing traffic if a person was detected in the crosswalk during the DON'T WALK signal. If a pedestrian was moving in the crosswalk at the end of a crosswalk clearance interval, the system automatically extended the crossing time by 0.2-second increments to a maximum of 6 additional seconds. The Rochester and Phoenix sites were of different design. They deployed microwave type systems and restricted coverage to roadside queuing areas. Data were collected using video cameras before and after the deployment to monitor pedestrians, vehicles, crossing signals, traffic signals, and push buttons.	Overall, after pedestrian detection systems were activated at each crosswalk, there was a 24% increase in the number of pedestrians who began crossing during the WALK signal, and an 81% decrease in the number of pedestrians who began crossing during the steady DON'T WALK signal. An analysis indicated the addition of automated pedestrian detection to sites with existing pedestrian push-buttons will decreased the likelihood that pedestrians will encounter opposing traffic at crosswalks. It should be noted, however, that the number of sites upon which these results are based is small and, as the data in the report indicated, pedestrian performance can vary widely across sites. The report indicated that in the future, additional data should be collected at a larger number of sites to help traffic engineers analyze site selection, and determine the types of locations where automated detectors are most effective.

5.10 Roadway Operations and Maintenance

A range of ITS facilities are used to improve the management of roadway operations and maintenance, and to enhance safety on the transportation system. ITS applications in operations and maintenance focus on integrated management of maintenance, specialised service vehicles, hazardous road conditions remediation, and work zone mobility and safety.

Several applications help with asset management, including automated data collection applications for monitoring the condition of highway infrastructure. Applications in work zones include the temporary implementation of traffic management or incident management capabilities. These temporary systems can be stand-alone implementations, or they may supplement existing systems in the area during construction. Other applications for managing work zones include measures to control vehicle speeds and notify drivers of changes in lane configurations or travel times and delays through the work zones.

The systems that are included in this section are:

5.10.1 Asset Management

5.10.2 Work Zone Management

5.10.1 Asset Management

5.10.1.1 Description

ITS can assist in providing relevant information to asset managers on aspects such as freight demand, freight movement and network conditions. In addition, ITS can provide managers and transport regulators with the ability to better monitor and manage freight operations and freight vehicle access to the road network as well as establishing appropriate heavy vehicle charging and licensing options.

The components of these systems include networks of traffic counting devices; weigh-in-motion sites (WIM) and road condition monitors. Generally this information services a detailed asset management model and the extended ITS information gathering systems are in part designed to serve the needs of this model.

5.10.1.2 Benefits

The main benefits of these systems are the improvements that can be made in maintaining the road asset. The annual cost of maintaining road pavements in particular is a significant part of any roading authorities' costs and by using improved information to track and model the performance of this asset, significant savings can be made.

5.10.1.3 Potential Problems

The reliability of information from remote collection sites can be a problem if not maintained. Another issue is the cost of WIM sites which are expensive and cannot always be deployed in the numbers and locations that might be desirable for the best information to be gathered.

5.10.1.4 Applications

These facilities can be used to support the information needs of any road asset management system. But the most benefit is gained when used in conjunction with a robust model.

5.10.1.5 Relevance to NZTS / LTMA Objectives

Table 5.10.1.1 Contribution of Asset Management systems to NZTS/LTMA objectives (derived from Contribution Matrix Section 5).

NZTS / LTMA Objective	***Level of contribution***	***Comment***
A Economic Development	*Low*	
Maintain strategic route security / availability / information	✓	Assist in monitoring and maintaining transport infrastructure.
Quality & efficiency of transport	✓	
B Safety and Personal Security	*Medium*	
Number of traffic crashes	➲	By supporting better maintenance of safety related assets.
Level & severity of personal injury	➲	
C Access & Mobility	*Low*	
Strategic route security / availability / information	✓	Assist in monitoring and maintaining transport infrastructure.
Quality & efficiency of transport	✓	

Table 5.10.1.1 (continued)

NZTS / LTMA Objective	***Level of contribution***	***Comment***
D Public Health	*Low*	
Vehicle noise	➲	By supporting better maintenance of safety related assets. Reduce noise due to improved asset (better surface etc).
Level & severity of personal injury	➲	
E Sustainability	*Low*	
Extent to which the benefits will be sustainable over time	✓	
F Energy Efficiency	*Low*	
Quality & efficiency of transport	✓	Assist in monitoring and maintaining transport infrastructure.
H Responsiveness	*High*	
Contributions to national objectives	✓	Assist in monitoring and maintaining transport infrastructure.
Maintain strategic route security / availability / information	✓	
Quality & efficiency of transport	✓	
I Affordability and Cost Effectiveness	*High*	
Relative benefit to cost ratio	✓	Cost effectiveness is good but can be high cost to achieve desired coverage.
Level of operating cost	✓	
J Implementation Risk	*Low*	
Technical complexity	✓	Systems are well developed and risks are low provided they are well maintained.
Interoperability	✓	
Cost certainty	✓	
Public acceptance	✓	
Implementation constraints – resource consents, legal & others	✓	
✓ = Positive Contribution; ✗ = No Significant Contribution; ➲ = Partial Contribution		

5.10.1.6 Summary and Conclusions

ITS in Asset Management is used to provide better information on a range of variables.

The main benefits of these systems are the improvements that can be made in maintaining the road asset. The annual cost of maintaining road pavements in particular is a significant part of any roading authorities' costs and by using improved information to track and model the performance of this asset significant savings can be made.

These facilities can be used to support the information needs of any road asset management system. But the most benefit is gained when used in conjunction with a robust model.

In terms of the objectives set out by the NZTS and LTMA, these systems deliver benefits in several areas, including:

- Economic Development
- Safety and Personal Security
- Public Health
- Environmental Sustainability

They also have the potential to provide a positive contribution towards the following New Zealand specific target areas:

- Compliance
- Safety
- Route Security
- Quality and Efficiency
- Environmental Mitigation

These facilities have been used in New Zealand for a number of years and provide a valuable input to road asset management.

5.10.1.7 Example Applications

Table 5.10.1.2 Example applications of Asset Management systems.

Location	Description	Observed Benefits & Costs
Virginia, USA	Virginia became the first state to use a private company, entering into an asset-management contract with VMS, Inc., a Richmond, Virginia-based company that specializes in highway asset management. Under the 1996, five-and-one-half-year contract with VMS, Inc., all aspects of the highway system were guaranteed to be maintained at specified standards throughout the duration of the fixed-price, lump-sum agreement. A total of 20% of Virginia's interstate highways are covered under this contract.	The results of the first privatized asset management project have been positive for Virginia's Department of Transportation. The Virginia DOT estimates its contract will save $22 million over five-and-one-half years — or 17% of what it projected expenditures to be over the same period. In the Texas solicitations, the low bids, submitted by VMS, were in the neighbourhood of 20% below the government's estimates. States can use the funds saved to address other critical needs.

5.10.2 Work Zone Management

5.10.2.1 Description

The use of ITS in work zone management falls mainly into three categories.

- The use of VMS and other traveller information means to warn drivers of work zones and restrictions (in order to avoid or drive appropriately).
- The use of enforcement technologies to help manage speed and lane use restrictions.
- Surveillance and incident response to help clear incidents and breakdowns more quickly.

5.10.2.2 Benefits

The benefits of these systems include:

- Reduced accidents and better traffic management while work is occurring.
- Improved protection of the work site.
- Reduced traffic demand due to drivers avoiding road works.
- Improved response to incidents and breakdowns in order to keep work zone traffic flowing.

5.10.2.3 Potential Problems

The use of mobile VMS and other ITS technologies to manage work zones is fairly well developed and the reliability and access to mobile communications is high. The main problem areas remain reliability of portable power supplies, integration and interoperability with permanent traffic control facilities and centres, and the challenges of set up and relocation in work zones with high levels of changes. (e.g. where lane closures vary across peak periods).

5.10.2.4 Applications

The use ITS in work zone management is now relatively common and is increasing. As mobile technologies improve and become more cost effective the use of these systems to monitor enforce and inform will be applicable in most major urban work zones where volumes are high and the impact of incidents significant.

5.10.2.5 Relevance to NZTS / LTMA Objectives

Table 5.10.2.1 Contribution of Work Zone Management systems to NZTS/LTMA objectives (derived from Contribution Matrix Section 5).

NZTS / LTMA Objective	*Level of contribution*	*Comment*
A Economic Development	*Medium*	
Traffic Congestion	✓	Warning of hazards; traffic control; speed control etc. Contribute infrequently by assisting in managing demand during incidents and special events. Assist in reducing congestion and efficient route/mode selection by providing advance warning of works and congestion.
Travel time on key routes	➲	
Transportation Costs (travel time, VOC)	➲	
Travel time for car commuters to key employment centres	➲	
Maintain strategic route security / availability / information	✓	
Quality & efficiency of transport	✓	
Freight transport and mode transfer	➲	
Travel time reliability	✓	

Table 5.10.2.1 (continued)

NZTS / LTMA Objective	***Level of contribution***	***Comment***
B Safety and Personal Security	*High*	
Number of traffic crashes	➲	By reducing secondary crashes due to congestion, hazards and incident delays. Reduce risk of crashes at work sites through enhanced traffic management. Improve compliance with work site traffic restrictions etc.
Level & severity of personal injury	➲	
Level of conflict between vehicles / cyclists / pedestrians and other road users	✓	
Compliance (with traffic / transport regulations)	✓	
C Access & Mobility	*Medium*	
Traffic Congestion	✓	Warning of hazards; traffic control; speed control etc. Contribute infrequently by assisting in managing demand during incidents and special events. Assist by improving experience and reliability of public transport services. Improve compliance with work site traffic restrictions etc. Assist in reducing congestion and efficient route/mode selection by providing advance warning of works and congestion.
Sector to sector travel times by car	➲	
Frequency and reliability of key passenger transport services	➲	
Convenience (perceived and actual) of public transport services	➲	
Level (%) of commuting trips by passenger transport	➲	
Compliance (with traffic / transport regulations)	✓	
Strategic route security / availability / information	✓	
Quality & efficiency of transport	✓	
Travel time reliability	✓	
D Public Health	*Low*	
Traffic congestion in urban areas (impacts on local air quality)	➲	Warn of hazards; traffic control; speed control etc. Manage hazards; traffic control; speed control etc. By reducing secondary crashes due to congestion, hazards and incident delays.
Vehicle noise	➲	
Level & severity of personal injury	➲	
E Sustainability	*Medium*	
Level(%) of trips that are not car based	➲	Assist by improving experience and reliability of public transport services. Contribute infrequently by assisting in managing demand during incidents and special events.
Emission levels (particulates, nitrogen oxides, carbon monoxides, CO_2)	➲	
Levels of service on key routes	➲	
Extent to which the benefits will be sustainable over time	➲	
F Energy Efficiency	*Medium*	
Traffic Congestion	✓	Warn of hazards; traffic control; speed control etc. Contribute infrequently by assisting in managing demand during incidents and special events. Assist by improving experience and reliability of public transport services. Assist in reducing congestion and efficient route/mode selection by providing advance warning of works and congestion.
Fuel use	➲	
Level of travel in congested conditions	✓	
Use of energy efficient modes	➲	
Quality & efficiency of transport	✓	

Table 5.10.2.1 (continued)

NZTS / LTMA Objective	***Level of contribution***	***Comment***
G Integration	*Low*	
Level of priority given to passenger transport	➲	Assist by improving experience and reliability of public transport services.
H Responsiveness	*High*	
Responding to diverse stake holder needs (particularly rural vs urban)	✓	Assist in reducing congestion and efficient route/mode selection by providing advance warning of works and congestion.
Contributions to national objectives	✓	
Maintain strategic route security / availability / information	✓	
Quality & efficiency of transport	✓	
Travel time reliability	✓	
I Affordability and Cost Effectiveness	*High*	
Relative benefit to cost ratio	✓	When implemented appropriately these systems are cost effective.
Level of operating cost	✓	
J Implementation Risk	*Low*	
Technical complexity	✓	Technology risks include ability to move easily with changing work zones; ensuring adequate power and communications supply and interoperability with permanent facilities.
Interoperability	✓	
Cost certainty	✓	
Public acceptance	✓	
Implementation constraints – resource consents, legal & others	➲	
✓ = Positive Contribution; ✗ = No Significant Contribution; ➲ = Partial Contribution		

5.10.2.6 Summary and Conclusions

ITS in work zones assist in warning drivers, enforcing restrictions and monitoring incidents and breakdowns. Benefits include reduced accidents and improved traffic management.

Problem areas are reliability of portable power supplies, integration and interoperability with permanent traffic control facilities and centres, and dealing with high levels of change.

The use ITS in work zone management is now relatively common and is increasing. As mobile technologies improve and become more cost effective the use of these systems to monitor enforce and inform will be applicable in most major urban work zones where volumes are high and the impact of incidents significant.

In terms of the objectives set out by the NZTS and LTMA, these systems deliver benefits in several areas, including:

- Economic Development
- Safety and Personal security
- Access and Mobility
- Sustainability

They also have the potential to provide a positive contribution towards the following New Zealand specific target areas:

- Congestion Relief

- Demand Management
- Incident Management
- Compliance
- Safety
- Quality and Efficiency
- Travel Time Reliability

The use of these types of systems in New Zealand is increasing, particularly the use of mobile VMS as they become more widely available.

5.10.2.7 Example Applications

Table 5.10.2.2 Example applications of Work Zone Management systems.

Location	Description	Observed Benefits & Costs
A work zone in Arkansas was equipped with an Automated Work Zone Information System (AWIS). This study evaluated performance of the system to assess the impacts of AWIS on safety.	The site was a 6.3 mile segment Interstate 40 located in Lonoke County. This segment of roadway is considered rural and has an average daily traffic volume of 36,350 vehicles, with 43% of traffic being trucks. The AWIS deployed at this work zone site included: a Central System Controller, two highway advisory radios, five traffic sensors, five changeable message signs (CMS), and two supplemental speed stations per lane closure. This system was primarily a queue detection system designed to calculate and report delay times to travellers via changeable message signs at the roadside. To determine delay, traffic sensors were installed upstream of the lane closure or taper. If the difference in vehicle speeds between sensors was greater than 10 m/h, a variable message sign located upstream would display the message "REDUCE SPEED TO XX M/H", followed by the message "YY MINUTE DELAY". If the difference in speed was less than 10 m/h, only the delay message was displayed. In addition, The HAR system at the site provided the public with general work zone information, and informed travellers of expected delays.	The objective was to reduce the number of rear-end and fatal crashes at the site. The effectiveness of the system was determined by an evaluation between the Lonoke County site and two comparable construction sites not using AWIS (Brinkley-Goodwin and Goodwin-East). The analysis found that the fatal crash rate in Lonoke County was lower than both comparison sites. Lonoke County had a lower rear-end crash rate than Brinkley-Goodwin but higher rear-end crash rate than Goodwin-East. These results are summarized in the following table.

Description	Fatal Crash Rate Per 100 Million Vehicle Miles Travelled	Rear-End Crash Rate Per 100 Million Vehicle Miles Travelled
Lonoke County Site (with AWIS)	2.2	33.7
Brinkley – Goodwin (without AWIS)	3.4	43.2
Goodwin – East (without AWIS)	3.2	29.5

5.11 Road Weather Conditions Management

5.11.1 Road Weather Conditions Management

5.11.1.1 Description

Adverse weather conditions pose a threat to the infrastructure and operation of the transport system. There are many economic and social impacts that result from the closure of roads or other transport infrastructure, and from the accidents that adverse weather hazards contribute to. ITS facilities can assist in predicting managing and mitigating these effects.

Essentially ITS facilities can assist in four main areas;

- Surveillance, Monitoring and Prediction of adverse weather
- Information Dissemination
- Traffic Control
- Response and Treatment

ITS can assist in predicting weather changes, identify threats to the highway system, and proactively respond. Transportation system operators can warn people of changing weather, manage the infrastructure, and respond to conditions in real time through the following three types of road weather management strategies that can be used to mitigate the impacts of rain, snow, ice, fog, high winds, flooding, tornadoes, hurricanes, and avalanches:

- Advisory strategies provide information on prevailing and predicted conditions to both transportation managers and motorists. Posting fog/ice warnings on Dynamic Message Signs and listing flooded routes on web sites are examples of advisory strategies.
- Control strategies alter the state of roadway devices to permit or restrict traffic flow and regulate roadway capacity. Reducing speed limits with Variable Speed Limit signs and modifying traffic signal timing are examples of control strategies.
- Treatment strategies supply resources to roads to minimize or eliminate weather impacts. The most common treatment strategies are application of sand, salt, and anti-icing chemicals to pavements to improve traction and prevent ice bonding.

5.11.1.2 Benefits

The benefits of these systems include:

- Improved safety through prediction, warning and treatment.
- Improved availability and efficiency of the transport network.
- Improved route and mode planning as travellers can plan their trips taking account of the conditions.

5.11.1.3 Potential Problems

Problems with the deployment and operation of weather management systems include:

- Providing an effective contribution to weather prediction through selective monitoring requires the careful selection of locations and measures.
- Providing reliable information to road operators and users can be difficult and may impact on the trust put in these systems leading to reduced effect.

5.11.1.4 Applications

These systems are best deployed in areas where there is a defined weather related problem, either presenting a risk of road closure or a risk of accidents. Examples include snow, ice, fog, high winds, flooding, and avalanches.

The higher priority facilities should be targeted at strategic section of the network where there is an opportunity to respond and inform travellers such that they can make alternative choices.

5.11.1.5 Relevance to NZTS / LTMA Objectives

Table 5.11.1.1 Contribution of Road Weather Conditions Management systems to NZTS/LTMA objectives (derived from Contribution Matrix Section 5).

NZTS / LTMA Objective	*Level of contribution*	*Comment*
A Economic Development	*High*	
Traffic Congestion	✓	Assist in early detection of hazards and incidents, and managing traffic, so reducing congestion from closures and incident related delays.
Traffic/Transport Demand	➲	
Travel time on key routes	➲	
Transportation Costs (travel time, VOC)	➲	
Travel time for car commuters to key employment centres	➲	
Maintain strategic route security / availability / information	✓	
Quality & efficiency of transport	✓	
Freight transport and mode transfer	✓	
Travel time reliability	✓	
B Safety and Personal Security	*High*	
Number of traffic crashes	✓	Assist in early detection of hazards and managing response, so reducing risk of crashes due to weather hazards. Where road based public transport services operate.
Level of fatalities	✓	
Level & severity of personal injury	✓	
Perceived personal safety/security for non car mode trips	➲	
C Access & Mobility	*High*	
Traffic Congestion	✓	Assist in early detection of hazards and incidents, and managing traffic, so reducing congestion from closures and incident related delays. Contribute only during times of adverse conditions and incidents.
Traffic/Transport Demand	➲	
Sector to sector travel times by car	➲	
Frequency and reliability of key passenger transport services	➲	
Convenience (perceived and actual) of public transport services	➲	
Level (%) of commuting trips by passenger transport	➲	
Level (%) of commuting trips by Cycle	➲	
Level (%) of commuting trips by Pedestrians	➲	
Strategic route security / availability / information	✓	
Quality & efficiency of transport	✓	
Travel time reliability	✓	

Table 5.11.1.1 (continued)

NZTS / LTMA Objective	Level of contribution	Comment
D Public Health	*Medium*	
Traffic congestion in urban areas (impacts on local air quality)	✓	Assist in early detection of hazards and incidents, and managing traffic, so reducing congestion from closures and incident related delays. Contributes only during times of adverse conditions and incidents. Can provide input to other systems.
Numbers of short trips made by walking or cycling	➲	
Numbers of commuting trips made by walking or cycling	➲	
Compliance (with emissions regulations)	➲	
Level & severity of personal injury	✓	
E Sustainability	*High*	
Traffic/Transport Demand	➲	Assist in early detection of hazards and incidents, and managing traffic, so reducing congestion from closures and incident related delays. Contribute only during times of adverse conditions and incidents.
Level(%) of trips that are not car based	➲	
Emission levels (particulates, nitrogen oxides, carbon monoxides, CO_2)	➲	
Levels of service on key routes	➲	
Extent to which the benefits will be sustainable over time	✓	
F Energy Efficiency	*High*	
Traffic Congestion	✓	Assist in early detection of hazards and incidents, and managing traffic, so reducing congestion from closures and incident related delays. Contribute only during times of adverse conditions and incidents.
Traffic/Transport Demand	➲	
Efficiency of routes taken	➲	
Fuel use	➲	
level of travel in congested conditions	✓	
Use of energy efficient modes	➲	
Quality & efficiency of transport	✓	
G Integration	*High*	
Efficiency and convenience of mode transfer points	➲	Assist operators in maintaining reliable schedules and information to users. Provide warning of adverse conditions.
Level of integration between road and rail	➲	
Improving rural community access & conditions	✓	
H Responsiveness	*High*	
Responding to diverse stake holder needs (particularly rural versus urban)	✓	Assist operators in maintaining reliable schedules and information to users. Provide warning of adverse conditions. Assist in early detection of hazards and incidents, and managing traffic, so reducing congestion from closures and incident related delays.
Contributions to national objectives	✓	
Maintain strategic route security / availability / information	✓	
Quality & efficiency of transport	✓	
Travel time reliability	✓	
I Affordability and Cost Effectiveness	*High*	
Relative benefit to cost ratio	✓	When implemented appropriately these facilities are cost effective and provide significant value.
Level of operating cost	✓	

Table 5.11.1.1 (continued)

NZTS / LTMA Objective	Level of contribution	Comment
J Implementation Risk	*Low*	
Technical complexity	✓	The technologies used are well developed and low risk. However, there is a risk of inappropriate deployment and a need to implement as part of a coordinated strategy including communications and response planning.
Interoperability	✓	
Cost certainty	✓	
Public acceptance	✓	
Implementation constraints – resource consents, legal & others	✓	
✓ = Positive Contribution; ✗ = No Significant Contribution; ➲ = Partial Contribution		

5.11.1.6 Summary and Conclusions

Adverse weather conditions pose a threat to the infrastructure and operation of the transport system. ITS facilities can assist in predicting managing and mitigating these effects.

Benefits of these systems include improved safety, availability and efficiency of the transport network.

These systems are best deployed in areas where there is a defined weather related problem, either presenting a risk of road closure or a risk of accidents. Examples include heavy, snow, ice, fog, high winds, flooding, and avalanches.

In terms of the objectives set out by the NZTS and LTMA, these systems deliver benefits in several areas, including:

- Economic Development
- Safety and Personal Security
- Access and Mobility
- Environmental Sustainability

They also have the potential to provide a positive contribution towards the following New Zealand specific target areas:

- Congestion Relief
- Demand Management
- Incident Management
- Safety
- Route Security
- Quality and Efficiency
- Travel Time Reliability
- Environmental Mitigation

There are a range of New Zealand applications in use, focused on dealing with problems related to snow, ice, avalanches and fog. Transit New Zealand is also currently working on systems to assist in early flood warnings.

5.11.1.7 Example Applications

Table 5.11.1.2 Example applications of Road Weather Conditions Management systems.

Location	Description	Observed Benefits & Costs
Idaho, USA	The use of road weather sensors to manage the application of anti-icing treatments.	Crashes reduced by 83 percent, labour hours by 62 percent, and material costs by 83 percent.
Tennessee, USA	A fog detection and warning system is installed on I-75.	There has been a decline in fog-related crashes from more than 200 between 1973 and 1993, to just one between 1994 and 2002.
Desert Road, New Zealand	Ice and snow are regular hazards on the section of State Highway 1 across the central plateau. To assist in managing this problem a series of sophisticated ice monitoring devices have been installed.	These devices use a combination of temperature and humidity sensors to predict when ice is likely to occur. This information is then used to initiate treatment and potential closures. Since installed these devices have significantly improved treatment efficiencies leading to reduced costs.

5.12 Electronic Road User Charges

Electronic Toll Collection (ETC) services provide several functions for a variety of tolling and road pricing facilities. They reduce the administrative and labour costs associated with toll transactions on existing toll facilities, provide the means to implement congestion charging and wide area road user charging systems, and significantly reduce vehicle delays at toll points.

These systems combine technologies such as GPS, wireless transponders and other local communications systems that allow vehicles to communicate with road side devices.
The most common technology used for toll systems is Dedicated-Short-Range-Communications (DSRC), of which several standards have been implemented across the world.

ETC has been instrumental in the increasing popularity and efficiency of toll roads and roadway pricing as a mechanism to construct new facilities, and manage demand.

The systems that are included in this section are:

5.12.1 Wide Area RUC
5.12.2 Project Specific E-Toll Collection Systems
5.12.3 Electronic Road / Congestion Pricing

5.12.1 Wide Area RUC

5.12.1.1 Description

Wide area Road User Charging (RUC) systems are designed to charge vehicles by distance travelled, and potentially other parameters, providing a more transparent charging regime. The electronic systems developed to facilitate this are mainly GPS based devices that track vehicle movement and communicate distance and other criteria using a local communications system such as DSRC or GPRS.

5.12.1.2 Benefits

With a fully electronic RUC system it is possible to charge variable rates by a combination of time of day, route used, weight, emissions class and size of vehicle.

The principal benefit of a fully electronic road user charging system is the ability to charge more directly for use, and therefore to effectively influence road user behaviour to address issues such as peak period congestion, environmental impact, better manage road infrastructure and transport demand.

5.12.1.3 Potential Problems

Although the technologies involved in these systems such as GPS and DSRC are well developed and in wide use; the combination of these technologies into a reliable electronic RUC system is less common. The key problem areas lie in the ability to fully monitor and enforce such a system as a primary charging mechanism. However, several examples have been implemented in Europe in recent years, and as such the combined technologies and back office systems required to deliver a reliable system are now being deployed.

5.12.1.4 Applications

A fully electronic RUC system would generally be applicable only at national or state level, and may apply to the entire vehicle fleet or a section of the fleet (such as heavy vehicles or specialist vehicles). Such a system would be best applied where there was a desire to influence travel through access control or variable rates, or to charge more directly for use.

5.12.1.5 Relevance to NZTS / LTMA Objectives

Table 5.12.1.1 Contribution of Wide Area RUC systems to NZTS/LTMA objectives (derived from Contribution Matrix Section 6).

NZTS / LTMA Objective	***Level of contribution***	***Comment***
A Economic Development	*High*	
Traffic Congestion	➲	Contribute as part of a broader demand management strategy. Provide a means of directly influencing traffic demand. Provide a means of directly charging for road use and so influencing traffic demand.
Traffic/Transport Demand	✓	
Travel time on key routes	➲	
Transportation Costs (travel time, VOC)	➲	
Transport users face the true costs of use	✓	
Travel time for car commuters to key employment centres	➲	
Maintain strategic route security / availability / information	➲	
Quality & efficiency of transport	✓	
Freight transport and mode transfer	✓	
Quality & efficiency of transport	➲	
B Safety and Personal Security	*Low*	
Level of conflict between vehicles / cyclists / pedestrians and other road users	➲	Contribute as part of a broader strategic route demand management strategy. Improve ability to monitor compliance with a range of traffic regulations.
Perceived personal safety/security for non car mode trips	➲	
Compliance (with traffic / transport regulations)	✓	
C Access & Mobility	*Medium*	
Traffic Congestion	➲	Contribute as part of a broader demand management strategy. Provide a means of directly influencing traffic demand. Improve ability to monitor compliance with a range of traffic regulations.
Traffic/Transport Demand	✓	
Sector to sector travel times by car	➲	
Compliance (with traffic / transport regulations)	✓	
Strategic route security / availability / information	➲	
Quality & efficiency of transport	✓	
Travel time reliability	➲	
D Public Health	*Low*	
Traffic congestion in urban areas (impacts on local air quality)	➲	Contribute as part of a broader demand management strategy. Improve ability to monitor compliance with a range of traffic regulations.
Vehicle noise	➲	
Compliance (with emissions regulations)	✓	

Table 5.12.1.1 (continued)

NZTS / LTMA Objective	***Level of contribution***	***Comment***
E Sustainability	*High*	
Traffic/Transport Demand	✓	Provide a means of directly influencing traffic demand. Assist in the monitoring and management of freight.
Non road freight volumes as a percentage of total	✓	
Growth rate of total vehicle travel	✓	
Extent to which users face full cost of their road use	✓	
Levels of service on key routes	➲	
Extent to which the benefits will be sustainable over time	✓	
F Energy Efficiency	*High*	
Traffic Congestion	➲	Contribute as part of a broader demand management strategy. Provide a means of directly influencing traffic demand.
Traffic/Transport Demand	✓	
Efficiency of routes taken	✓	
level of travel in congested conditions	➲	
Quality & efficiency of transport	✓	
G Integration	*Medium*	
Provision for all modes on key transport corridors	✓	Assist in making provision for all modes. Can assist in providing priority to public transport vehicles. Can provide input to broader management systems. Can assist in limiting impact of heavy traffic on local communities.
Level of priority given to passenger transport	✓	
Level of integration between road and rail	➲	
Improving rural community access & conditions	✓	
H Responsiveness	*High*	
Responding to diverse stake holder needs (particularly rural versus urban)	✓	Provide a means of directly influencing traffic demand. Contribute as part of a broader demand management strategy.
Contributions to national objectives	✓	
Maintain strategic route security / availability / information	➲	
Quality & efficiency of transport	✓	
Travel time reliability	➲	
I Affordability and Cost Effectiveness	*Medium*	
Relative benefit to cost ratio	➲	Technically complex systems with only limited deployment internationally.
Level of operating cost	➲	
Contribution direct from users	✓	
J Implementation Risk	*Medium*	
Technical complexity	➲	Risks of technology selection, operation and systems.
Interoperability	➲	

✓ = Positive Contribution; ✗ = No Significant Contribution; ➲ = Partial Contribution

5.12.1.6 Summary and Conclusions

Wide area road user charging (RUC) systems are designed to charge vehicles by distance travelled, and potentially other parameters.

With a fully electronic RUC system it is possible to charge variable rates by combination of time of day, route used, weight, emissions class and size of vehicle. The principal benefits being to influence road user behaviour to address issues of congestion, environmental impact, and better manage road infrastructure and transport demand.

Although the individual technologies involved are well developed, only recently have these been combined and applied to deliver this type of facility.

In terms of the objectives set out by the NZTS and LTMA, these systems deliver benefits in several areas, including:

- Economic Development
- Safety and Personal Security
- Access and Mobility
- Environmental Sustainability

They also have the potential to provide a positive contribution towards the following New Zealand specific target areas:

- Congestion Relief
- Demand Management
- Incident Management
- Compliance
- Safety
- Route Security
- Quality and Efficiency
- Travel Time Reliability
- Environmental Mitigation

There are currently no wide area electronic road user charging systems operating in New Zealand; however the Ministry of Transport has been examining this type of system for potential future use.

5.12.1.7 Example Applications

Table 5.12.1.2 Example applications of Wide Area RUC systems.

Location	Description	Observed Benefits & Costs
Switzerland	Switzerland introduced a distance based road user charge for trucks on 1 January 2001. The charge level depends on the distance travelled, the maximum permitted weight of the vehicle (according to the vehicle documents) and the emission standards. Technology used is a combination of microwave (DSRC) and GPS. Trucks are fitted with an On Board Unit (OBU). Vehicles covered are all trucks over 3.5t Roads covered are all roads in Switzerland.	The Swiss system was implemented to cover the high costs of heavy goods vehicles on the roads. With the charging system in place there has been an increase of 45% in sales of new HGVs in the first year as the new vehicles belonged to the lowest and cheapest emission classes. There was also a fall of 5.6% in motorway traffic in the first year.

5.12.2 Project Specific E-Toll Collection Systems

5.12.2.1 Description

A project specific E-Toll is a toll that is levied on a particular section of infrastructure for the purpose of generating revenue to assist with the funding for that particular section of infrastructure. The revenue that is created from the toll may be used on the road that is being tolled or it may go towards another project. The toll in this case is not being used specifically to influence demand, although may do so, and the toll is applied specifically to vehicles using this infrastructure.

A key difference with this type of facility is the ability to monitor access to a specific section and to charge for use. Unlike a wider road user charge which must monitor vehicles across a network and charge by distance, these systems usually charge by access to sections and do so using more localised and specific technologies.

The vast majority of electronic toll systems in use today use DSRC technology to provide the vehicle to roadside communications between a transponder in the vehicle and tightly focused road side devices.

Older system still exist which simply automate the existing toll gates, however there is an increasing move to full multi-lane free flow tolling, providing significant reductions in toll gate delays and operational costs. Free Flow tolling uses a combination of DSRC vehicle to roadside facilities, and enforcement systems based on video number plate recognition (ANPR).

5.12.2.2 Benefits

The main benefits of electronic tolling in this context are the significant improvements in toll gate delays. However, there are also benefits in terms of reduced costs for the toll road operators.

5.12.2.3 Potential Problems

Electronic toll systems have been in operation for several years and many of the initial problems with applying this type of technology have now been overcome. The key areas of risk include:

- Inappropriate application of technologies and design of support systems leading to increased operating costs.
- Systems in place for dealing with casual users on free flow facilities can lead to increase costs.
- Legislative constraints.

5.12.2.4 Applications

These types of systems are generally used to automate the toll collection task for specific toll funded projects. Depending on the legislative framework in place, level of traffic demand and casual users, either a simple toll gate e-toll may be used, or a full free flow facility.

5.12.2.5 Relevance to NZTS / LTMA Objectives

Table 5.12.2.1 Contribution of Project Specific E-Toll Collection Systems to NZTS/LTMA objectives (derived from Contribution Matrix Section 6).

NZTS / LTMA Objective	Level of contribution	Comment
A Economic Development	*High*	
Traffic Congestion	✓	Provide a means of directly influencing traffic demand. Contribute to reduced delays at toll collection points. Contribute as part of a broader strategic route demand management strategy.
Traffic/Transport Demand	✓	
Travel time on key routes	✓	
Transportation Costs (travel time, VOC)	✓	
Transport users face the true costs of use	✓	
Travel time for car commuters to key employment centres	✓	
Maintain strategic route security / availability / information	➲	
Quality & efficiency of transport	✓	
Freight transport and mode transfer	✓	
Travel time reliability	✓	
B Safety and Personal Security	*Medium*	
Number of traffic crashes	✓	Contribute to reduced conflicts to toll collection points Contribute through reduced overall crash rate. Contribute through reduced congestion at toll points. Improved ability to monitor compliance with a range of traffic regulations.
Level & severity of personal injury	➲	
Level of conflict between vehicles / cyclists / pedestrians and other road users	➲	
Compliance (with traffic / transport regulations)	✓	
C Access & Mobility	*High*	
Traffic Congestion	✓	Provide a means of directly influencing traffic demand. Contribute to reduced delays at toll collection points. Improve ability to monitor compliance with a range of traffic regulations. Contribute as part of a broader strategic route demand management strategy.
Traffic/Transport Demand	✓	
Sector to sector travel times by car	✓	
Frequency and reliability of key passenger transport services	✓	
Convenience (perceived and actual) of public transport services	➲	
Level (%) of commuting trips by passenger transport	➲	
Compliance (with traffic / transport regulations)	✓	
Strategic route security / availability / information	➲	
Quality & efficiency of transport	✓	
Travel time reliability	✓	

Table 5.12.2.1 (continued)

NZTS / LTMA Objective	***Level of contribution***	***Comment***
D Public Health	*Low*	
Traffic congestion in urban areas (impacts on local air quality)	✓	Provide a means of directly influencing traffic demand. Improved ability to monitor compliance with a range of traffic regulations. Contribute through reduced overall crash rate.
Vehicle noise	✓	
Compliance (with emissions regulations)	✓	
Level & severity of personal injury	➲	
E Sustainability	*High*	
Traffic/Transport Demand	✓	Provide a means of directly influencing traffic demand. Contribute to reduced delays at toll collection points. Assist in the monitoring and management of freight.
Level(%) of trips that are not car based	➲	
Non road freight volumes as a percentage of total	➲	
Growth rate of total vehicle travel	✓	
Emission levels (particulates, nitrogen oxides, carbon monoxides, CO_2)	➲	
Extent to which users face full cost of their road use	✓	
Levels of service on key routes	✓	
Extent to which the benefits will be sustainable over time	✓	
F Energy Efficiency	*High*	
Traffic Congestion	✓	Provide a means of directly influencing traffic demand. Contribute to reduced delays at toll collection points.
Traffic/Transport Demand	✓	
Efficiency of routes taken	✓	
Fuel use	➲	
level of travel in congested conditions	✓	
Use of energy efficient modes	➲	
Quality & efficiency of transport	✓	
G Integration	*Low*	
Provision for all modes on key transport corridors	✓	Assist in making provision for all modes. Can assist in providing priority to public transport vehicles.
Level of priority given to passenger transport	✓	
H Responsiveness	*High*	
Responding to diverse stake holder needs (particularly rural versus urban)	✓	Contribute to reduced delays at toll collection points. Contributes as part of a broader strategic route demand management strategy.
Contributions to national objectives	✓	
Maintain strategic route security / availability / information	➲	
Quality & efficiency of transport	✓	
Travel time reliability	✓	
I Affordability and Cost Effectiveness	*Medium*	
Relative benefit to cost ratio	➲	Cost effectiveness is closely linked to the size of project and level of traffic demand.
Level of operating cost	➲	
Contribution direct from users	✓	

Table 5.12.2.1 (continued)

NZTS / LTMA Objective	***Level of contribution***	***Comment***
J Implementation Risk	*Medium*	
Technical complexity	➲	Although the technologies used in these systems are now well established there are major risks in applying the right mix of systems and technology to suit the particular facility.
Interoperability	➲	
Cost certainty	➲	
Public acceptance	➲	
Implementation constraints – resource consents, legal & others	➲	
✓ = Positive Contribution; ✗ = No Significant Contribution; ➲ = Partial Contribution		

5.12.2.6 Summary and Conclusions

A project specific E-Toll is a toll that is levied on a particular section of infrastructure for the purpose of creating revenue that is put into the funding for a particular section of infrastructure.

The main benefits of electronic tolling in this context are the significant improvements in toll gate delays. However, there are also benefits in terms of reduced costs for the toll road operators.

These types of systems are generally used to automate the toll collection task for specific toll funded projects. Depending on the legislative framework in place, level of traffic demand and casual users, either a simple toll gate e-toll may be used, or a full free flow facility.

Although the technologies used in these systems are now well established there are major risks in applying the right mix of systems.

In terms of the objectives set out by the NZTS and LTMA, these systems deliver benefits in several areas, including:

- Economic Development
- Safety and Personal Security
- Access and Mobility
- Environmental Sustainability

They also have the potential to provide a positive contribution towards the following New Zealand specific target areas:

- Congestion Relief
- Demand Management
- Compliance
- Safety
- Route Security
- Quality and Efficiency
- Travel Time Reliability
- Environmental Mitigation

Currently in New Zealand there is only one toll road in operation with a limited electronic payment facility. However, the development of a standardised national electronic toll system is currently being progressed.

5.12.2.7 Example Applications

Table 5.12.2.2 Example applications of Project Specific E-Toll Collection Systems.

Location	Description	Observed Benefits & Costs
Orlando-Orange County Expressway Authority, USA	E-PASS is a DSRC transponder based electronic toll system used by the expressway authority.	While manual and automatic coin lanes can process approximately 380 to 680 vehicles per hour, one dedicated E-PASS lane at the Holland East plaza has recorded an hourly throughput rate in excess of 1,800 vehicles per hour. As long as E-PASS usage increases at a greater rate than peak hour traffic growth, the need to expand or reconstruct a toll plaza can be avoided.
Austria Motorway Truck System	Austria has recently implemented a DSRC based system on the motorways.	In evaluating suitable technology options the following rates of flow were calculated. Manual toll gates with barriers – 200-300 v/hr ETC, with barriers – 500-650 v/hr ETC stop and Go – 1000 v/hr Multi Lane Free-Flow – 3000 v/hr
City Link, Melbourne, Australia	A multi lane free flow electronic toll system has been installed to collect tolls for this project. A combination of electronic tags, read by overhead gantry equipment, and number plate recognition systems are used to assign toll charges to passing vehicles.	The main benefits of this system have been the significant saving in delays to vehicles by removing the need for toll booth. This has lead to improved use levels as the overall time saving and inconvenience for drivers is reduced.

5.12.3 Electronic Road / Congestion Pricing

5.12.3.1 Description

Congestion pricing is used as a means to charge for access to particular congested areas at peak times. Several variations of this concept exist including, cordon charges, area charges and charges on congested routes.

The system chosen will be governed by the characteristics of the congested area, local geography and travel patterns, and the technology used developed to suit these circumstances. There are a variety of options available, but two of the most successful have been the DSRC based Singapore system and the more basic video (ANPR) London system.

5.12.3.2 Benefits

The main aim and benefit of congestion charging is to control traffic demand in a particular section of the road network at a particular time of day. This leads to reduced congestion, improved environment, and improved public transport reliability.

5.12.3.3 Potential Problems

Challenges associated with these types of systems include:

- Legislative constraints.
- Dealing with complex exemptions and related enforcement.
- Developing appropriate technologies to suit specific system needs.
- Providing flexibility for future modification of boundaries and charges.

5.12.3.4 Applications

The application of congestion pricing requires detailed analysis of a range of issues, including:

- Availability and use of the existing road transport network in the area.
- Transport demand patterns.
- Social and economic impacts.
- Availability and capacity of existing public transport facilities.

The system chosen will be governed by the characteristics of the congested area, local geography and the technology used developed to suit these circumstances.

5.12.3.5 Relevance to NZTS / LTMA Objectives

Table 5.12.3.1 Contribution of Electronic Road / Congestion Pricing systems to NZTS/LTMA objectives (derived from Contribution Matrix Section 6).

NZTS / LTMA Objective	*Level of contribution*	*Comment*
A Economic Development	*High*	
Traffic Congestion	✓	Provide a means of directly influencing traffic demand. Contribute as part of a broader demand management strategy.
Traffic/Transport Demand	✓	
Travel time on key routes	➲	
Transportation Costs (travel time, VOC)	➲	
Transport users face the true costs of use	✓	
Travel time for car commuters to key employment centres	➲	
Maintain strategic route security / availability / information	➲	
Quality & efficiency of transport	✓	
Freight transport and mode transfer	✓	
Travel time reliability	➲	
B Safety and Personal Security	*Medium*	
Number of traffic crashes	✓	Contribute to reduced conflicts due to congestion within area. Contribute through reduced overall crash rate. Contribute through reduced congestion related conflicts. Improve ability to monitor compliance with a range of traffic regulations.
Level & severity of personal injury	➲	
Level of conflict between vehicles / cyclists / pedestrians and other road users	➲	
Perceived personal safety/security for non car mode trips	✓	
Compliance (with traffic / transport regulations)	✓	
C Access & Mobility	*High*	
Traffic Congestion	✓	Provide a means of directly influencing traffic demand. Contribute as part of a broader demand management strategy. Improve access and traffic flow by controlling access to congested areas.
Traffic/Transport Demand	✓	
Sector to sector travel times by car	➲	
Frequency and reliability of key passenger transport services	✓	
Convenience (perceived and actual) of public transport services	✓	
Level (%) of commuting trips by passenger transport	✓	
Level (%) of commuting trips by Cycle	✓	
Level (%) of commuting trips by Pedestrians	✓	
Compliance (with traffic / transport regulations)	✓	
Strategic route security / availability / information	➲	
Quality & efficiency of transport	✓	
Travel time reliability	➲	

Table 5.12.3.1 (continued)

NZTS / LTMA Objective	Level of contribution	Comment
D Public Health	*High*	
Traffic congestion in urban areas (impacts on local air quality)	✓	Provide a means of directly influencing traffic demand. Improve environment by controlling access to congested areas. Improve ability to monitor compliance with a range of traffic regulations. Contribute through reduced overall crash rate.
Vehicle noise	✓	
Numbers of short trips made by walking or cycling	✓	
Numbers of commuting trips made by walking or cycling	✓	
Compliance (with emissions regulations)	✓	
Level & severity of personal injury	➲	
E Sustainability	*High*	
Traffic/Transport Demand	✓	Improve access and traffic flow by controlling access to congested areas. Assist in the monitoring and management of freight. Provide a means of directly charging for road use and so influencing traffic demand. Contribute as part of a broader demand management strategy.
Level(%) of trips that are not car based	✓	
Non road freight volumes as a percentage of total	➲	
Growth rate of total vehicle travel	✓	
Emission levels (particulates, nitrogen oxides, carbon monoxides, CO_2)	✓	
Extent to which users face full cost of their road use	✓	
Levels of service on key routes	➲	
Extent to which the benefits will be sustainable over time	✓	
F Energy Efficiency	*High*	
Traffic Congestion	✓	Provide a means of directly influencing traffic demand. Improve access and traffic flow by controlling access to congested areas.
Traffic/Transport Demand	✓	
Efficiency of routes taken	✓	
Fuel use	✓	
level of travel in congested conditions	✓	
Use of energy efficient modes	✓	
Quality & efficiency of transport	✓	
G Integration	*High*	
Provision for all modes on key transport corridors	✓	Assist in making provision for all modes. Can assist in providing priority to public transport vehicles. Improve access and traffic flow by controlling access to congested areas.
Level of priority given to passenger transport	✓	
Efficiency and convenience of mode transfer points	✓	
H Responsiveness	*High*	
Responding to diverse stake holder needs (particularly rural versus urban)	✓	Provide a means of directly influencing traffic demand. Contribute as part of a broader strategic route demand management strategy. Contribute as part of a broader demand management strategy.
Contributions to national objectives	✓	
Maintain strategic route security / availability / information	➲	
Quality & efficiency of transport	✓	
Travel time reliability	➲	

Table 5.12.3.1 (continued)

NZTS / LTMA Objective	***Level of contribution***	***Comment***
I Affordability and Cost Effectiveness	*Medium*	
Relative benefit to cost ratio	➲	Cost effectiveness is closely linked to the size of support systems and level of traffic demand.
Level of operating cost	➲	
Contribution direct from users	✓	
J Implementation Risk	*Medium*	
Technical complexity	➲	Although the technologies used in these systems are individually well established there are major risks in applying the right mix of systems and technology to suit the particular facility.
Interoperability	➲	
Cost certainty	➲	
Public acceptance	➲	
Implementation constraints – resource consents, legal & others	➲	
✓ = Positive Contribution; ✗ = No Significant Contribution; ➲ = Partial Contribution		

5.12.3.6 Summary and Conclusions

Congestion pricing is used as a means to charge for access to particular congested areas at peak times. Several variations of this concept exist including cordon charges, area charges and charges on congested routes.

The main aim and benefit of congestion charging is to control traffic demand in a particular section leading to reduced congestion, improved environment, and improved public transport reliability.

The application of congestion pricing requires detailed analysis of a range of issues. The system chosen will be governed by the characteristics of the congested area, local geography and the technology used developed to suit these circumstances.

In terms of the objectives set out by the NZTS and LTMA, these systems deliver benefits in several areas, including:

- Economic Development
- Safety and Personal Security
- Access and Mobility
- Public Health
- Environmental Sustainability

They also have the potential to provide a positive contribution towards the following New Zealand specific target areas:

- Congestion Relief
- Demand Management
- Compliance
- Safety
- Route Security
- Quality and Efficiency
- Travel Time Reliability
- Environmental Mitigation

There are currently no such systems operating in New Zealand.

5.12.3.7 Example Applications

Table 5.12.3.2 Example applications of Electronic Road / Congestion Pricing systems.

Location	Description	Observed Benefits & Costs
Singapore	Singapore has operated a charge for the right to enter a 2.3-mile restricted zone within the central area since 1975 during morning peak.	Singapore's pricing approach successfully reduced traffic by 45% and the number of cars travelling into the city centre by 70%.
London, UK	London congestion charging was introduced in February 2003. The scheme charges GBP5.00 per vehicle entering the central area.	Reported benefits since the scheme was introduced include: 30% fewer traffic delays inside the charging zone. A reduction of 18% in traffic entering the zone during charging hours.

5.13 Fleet Management Systems

5.13.1 Fleet Management Systems

5.13.1.1 Description

ITS applications for commercial vehicle operations are designed to enhance communication between motor operators and their vehicles, and between carriers and regulatory agencies. These systems are generally GPS based with some form of short range communication such as GPRS linking the units back to their base. Using associated software they help both carriers and agencies in reducing operating expenses through increased efficiency, and assist in improving safety.

5.13.1.2 Benefits

These systems allow transport operators to monitor their fleet and provide them with information on location, schedule, vehicle performance and conditions. This information assists in planning deliveries to optimise efficiency, and assists in vehicle servicing and safe operation.

Using these facilities companies are able to make accurate predictions of when stock will be arriving at its destination; scheduling of other services and routes.

Other variations can provide the means of monitoring and controlling access to parts of the road network for specialist vehicles and providing regulators with more efficient means of checking aspects of the vehicles loading and safety.

From a broader perspective, the benefits that these systems provide to transport operators and regulators translate into improved efficiency and productivity across the commercial transport sector.

5.13.1.3 Potential Problems

The more basic vehicle tracking and systems monitoring technologies have been in operation for some time and are fairly well established, and in this sector of vehicle tracking and monitoring the systems have few problems. However, in the area of interface with regulating authorities, the legislative and administrative issues present some problems and are not so well developed.

5.13.1.4 Applications

Most large truck operators now utilise these systems to assist in managing their vehicles and broader operations. There are several companies offering these systems with a range of services available.

Their use in a regulatory role is less well established but several applications have been successfully implemented, particularly for specialist vehicles and access conditions.

5.13.1.5 Relevance to NZTS / LTMA Objectives

Table 5.13.1.1 Contribution of Fleet Management Systems to NZTS/LTMA objectives (derived from Contribution Matrix Section 6).

NZTS / LTMA Objective	Level of contribution	Comment
A Economic Development	*Medium*	
Transportation Costs (travel time, VOC)	➲	Contribute indirectly to commercial vehicle operating costs. Can be used as an input to strategic route monitoring (early warning of problems). Can be used as an element of more direct charging system. Provide assistance in the management of freight commercial vehicles.
Transport users face the true costs of use	➲	
Maintain strategic route security / availability / information	➲	
Quality & efficiency of transport	➲	
Freight transport and mode transfer	✓	
Travel time reliability	➲	
B Safety and Personal Security	*Medium*	
Number of traffic crashes	➲	Contribute as part of other systems Improved ability to monitor compliance with a range of traffic regulations.
Level & severity of personal injury	➲	
Level of conflict between vehicles / cyclists / pedestrians and other road users	➲	
Compliance (with traffic / transport regulations)	✓	
C Access & Mobility	*Low*	
Compliance (with traffic / transport regulations)	➲	Improved ability to monitor compliance with a range of traffic regulations. Can be used as an input to strategic route monitoring (early warning of problems).
Strategic route security / availability / information	➲	
Quality & efficiency of transport	➲	
Travel time reliability	➲	
D Public Health	*Medium*	
Vehicle noise	➲	Can assist in improving vehicle standards and use related to noise. Can assist in improving vehicle standards and use related to emissions. Contribute as part of other systems.
Compliance (with emissions regulations)	➲	
Level & severity of personal injury	➲	
E Sustainability	*Medium*	
Non road freight volumes as a percentage of total	✓	Assist in the monitoring and management of freight. Can provide input to other systems. Can be used as an element of more. direct charging system.
Growth rate of total vehicle travel	➲	
Extent to which users face full cost of their road use	➲	
Extent to which the benefits will be sustainable over time	✓	
F Energy Efficiency	*High*	
Quality & efficiency of transport	➲	Can be used as an input to strategic route monitoring (early warning of problems).
G Integration	*High*	
Efficiency and convenience of mode transfer points	✓	Improve efficiency of freight transfer. Can provide input to broader management systems. Can assist in limiting impact of heavy traffic on local communities.
Level of integration between road and rail	➲	
Improving rural community access & conditions	✓	

Table 5.13.1.1 (continued)

NZTS / LTMA Objective	***Level of contribution***	***Comment***
H Responsiveness	*Medium*	
Contributions to national objectives	✓	Can be used as an input to strategic route monitoring (early warning of problems).
Maintain strategic route security / availability / information	➲	
Quality & efficiency of transport	➲	
Travel time reliability	➲	
I Affordability and Cost Effectiveness	*High*	
Relative benefit to cost ratio	➲	Well established and cost effective for operator focused systems.
Level of operating cost	✓	
Contribution direct from users	➲	
J Implementation Risk	*Medium*	
Technical complexity	➲	Low risk as well established technologies. But relatively limited application as a regulatory support service.
Interoperability	➲	
Cost certainty	➲	
Public acceptance	✓	
Implementation constraints – resource consents, legal & others	➲	
✓ = Positive Contribution; ✗ = No Significant Contribution; ➲ = Partial Contribution		

5.13.1.6 Summary and Conclusions

ITS applications for commercial vehicle operations are designed to enhance communication between motor operators and their vehicles, and between carriers and regulatory agencies. They help both carriers and agencies in reducing operating expenses through increased efficiency, and assist in improving safety.

Most large truck operators now utilise these systems to assist in managing their vehicles and broader operations. There are several companies offering these systems with a range of services available. Their use in a regulatory role is less well established but several applications have been successfully implemented, particularly for specialist vehicles and access conditions.

In terms of the objectives set out by the NZTS and LTMA, these systems deliver benefits in several areas, including:

- Economic Development
- Safety and Personal Security
- Public Health
- Sustainability

They also have the potential to provide a positive contribution towards the following New Zealand specific target areas:

- Incident Management
- Compliance
- Safety
- Quality and Efficiency
- Travel Time Reliability

There are several GPS based fleet management systems operating in New Zealand.

5.13.1.7 Example Applications

Table 5.13.1.2 Example applications of Fleet Management Systems.

Location	Description	Observed Benefits & Costs
UK	Freightmaster (UK) implemented GPS based fleet management to 22 vehicles.	The system is reported to improve driver adherence to route. Live tracking features assist in redirecting vehicles at short notice, resulting in a substantial saving on fuel. Following installation overtime costs have reduced. Customer enquiries on deliveries can be resolved, quickly and with certainty. Overall Increased profits and savings on wages and fuel haulage and distribution service and maintenance.

5.14 Tunnel Management Systems

5.14.1 Tunnel Management Systems

5.14.1.1 Description

The use of ITS in tunnel management is mainly focused in three areas; surveillance of conditions with the tunnel; fire systems to detect fire early and control any outbreak; and the coordination of response to any incident.

As the consequences of any incident within a tunnel have the potential to be more significant than for open road incident, the systems targeted at these three areas are usually more extensive.

The level of protection generally governed by several factors:

- Traffic volume
- Risk of congestion
- Emergency services access time
- Percentage heavy goods vehicles
- Level of dangerous goods
- Accessibility (generally via adjacent tunnel)
- Lane width
- Speed limit

5.14.1.2 Benefits

If there is an emergency within a road tunnel the risk and consequences of a fire are high. ITS facilities help to detect and respond to any incident more quickly and so reduce the risk of serious loss of life and long term closure of the tunnel.

The ability of a tunnel control centre to deploy first response tools like fire sprinklers, first aid teams or air ventilation mean that the problem will not continue to grow while emergency services make their way to the scene. It also means that minor problems can be dealt with before they become worse.

5.14.1.3 Potential Problems

The main problems associated with traffic surveillance and monitoring systems are:

- Public concern regarding privacy and civil liberties.
- Recognition of the cost of maintenance and commitment to ongoing operations.

Fire systems and response coordination are closely linked, and one other are where these systems have problems is in the coordination of these 2 facilities.

5.14.1.4 Applications

These systems are applicable to any traffic tunnel; however the level of the systems used needs to be designed to suit the particular risks involved. This is generally determined by factors such as traffic level; speed and the other considerations listed above.

5.14.1.5 Relevance to NZTS / LTMA Objectives

Table 5.14.1.1 Contribution of Tunnel Management Systems to NZTS/LTMA objectives (derived from Contribution Matrix Section 6).

NZTS / LTMA Objective	Level of contribution	Comment
A Economic Development	Medium	
Maintain strategic route security / availability / information	✓	Assist in early detection of incidents and managing traffic, so improving critical response time.
B Safety and Personal Security	High	
Number of traffic crashes	✓	Assist in early detection of incidents and managing traffic, so improving critical response time. Improve ability to monitor compliance with a range of traffic regulations.
Level of fatalities	✓	
Level & severity of personal injury	✓	
Perceived personal safety/security for non car mode trips	✓	
Compliance (with traffic / transport regulations)	✓	
C Access & Mobility	Medium	
Compliance (with traffic / transport regulations)	✓	Improve ability to monitor compliance with a range of traffic regulations. Assist in early detection of incidents and managing traffic; so improving critical response time.
Strategic route security / availability / information	✓	
D Public Health	Medium	
Vehicle noise	➲	Can assist in improving vehicle standards and use related to noise. Can assist in improving vehicle standards and use related to emissions. Assist in early detection of incidents and managing traffic; so improving critical response time.
Compliance (with emissions regulations)	➲	
Level & severity of personal injury	✓	
E Sustainability	Low	
Extent to which the benefits will be sustainable over time	✓	Once systems in place the benefits are long term and do not diminish.
H Responsiveness	High	
Contributions to national objectives	✓	Assist in early detection of incidents and managing traffic, so improving critical response time.
Maintain strategic route security / availability / information	✓	
I Affordability and Cost Effectiveness	High	
Relative benefit to cost ratio	✓	Systems can be high cost but are effective when properly targeted.
Level of operating cost	➲	
J Implementation Risk	Low	
Technical complexity	✓	Majority of systems are reliable technologies. Some risk in operational cost and maintenance.
Interoperability	✓	
Cost certainty	✓	
Public acceptance	➲	
Implementation constraints – resource consents, legal & others	➲	
✓ = Positive Contribution; ✗ = No Significant Contribution; ➲ = Partial Contribution		

5.14.1.6 Summary and Conclusions

The use of ITS in Tunnel management is mainly focused in three areas; surveillance of conditions with the tunnel; fire systems to detect fire early and control any outbreak; and the coordination of response to any incident. These systems are applicable to any traffic tunnel, however the level of the system used needs to be designed to suit the particular risks involved.

In terms of the objectives set out by the NZTS and LTMA, these systems deliver benefits in several areas, including:

- Economic Development
- Safety and Personal Security
- Access and Mobility
- Public Health

They also have the potential to provide a positive contribution towards the following New Zealand specific target areas:

- Incident Management
- Compliance
- Safety
- Route Security

There are a range of tunnel management systems currently operated in New Zealand including 24hr monitoring facilities at Lyttleton Tunnel and fire and surveillance systems in the Wellington Mt Victoria and Terrace Tunnels.

5.14.1.7 Example Applications

Table 5.14.1.2 Example applications of Tunnel Management Systems.

Location	Description	Observed Benefits & Costs
Mt Blanc Tunnel France	Following a major incident in 1999 Mt Blanc Tunnel has been refitted with a range of safety systems and opened again to traffic in March 2002. Systems include: • Vehicle heat screening on entry. • Air flow management to control smoke in event of fire. • A range of surveillance systems including video, heat and smoke sensors. • An upgraded tunnel control centre. • Escape tunnels and guidance systems.	The system described, have been developed using a detailed risk assessment process and are recognised as some of the most advanced in Europe; setting the new European standard adopted in 2003.

6. Ranking Comparison with NZTS and LTMA Objectives

Using the evaluation process detailed above (and in the detailed Contribution Matrix, section 4), the following priority list has been developed. This list sets out which systems or groups of systems have the greatest potential to provide benefits in the context of the NZTS and LTMA objectives.

Drawn from the Contribution Matrix, the High, Medium and Low ratings under each category have been converted to scores of 5 (High), 3 (Medium) and 1 (Low). These have then been summed to give an overall score for each system/facility across all of the criteria. The total score for each under 'Rating' has then been used to list the systems from highest to lowest. In the case of 'implementation risk' this is reversed, with low risks scoring 5 and high risks 1.

The balance and proportions of the contributions provided by each of the facilities considered are illustrated by the charts contained in the Appendix.
The table below also provides brief comment on the main benefits of each in a New Zealand context.

Table 6.1 Priority list of Intelligent Transport Systems.

System	System Category	Rating against objectives	Main Benefit Areas in NZ context
Monitoring, Prediction, Informing, Response and Treatment	ROAD WEATHER CONDITION MANAGEMENT	48	Potential to contribute to improved safety and route security/availability.
Adaptive Signal Control	ARTERIAL MANAGEMENT SYSTEMS	44	Many existing systems in place. Improvements and new facilities have good potential to contribute to congestion relief, improve quality and efficiency of transport and facilitate demand management and incident management.
Electronic Road / Congestion Pricing	ELECTRONIC ROAD USER CHARGING	44	Potential to contribute to congestion relief, improved quality and efficiency of transport and provide demand management facilities.
Incident Detection	MOTORWAY MANAGEMENT SYSTEMS	42	Many existing systems in place. Improved and new facilities have potential to contribute to congestion relief, improve quality and efficiency of transport and support incident management.
Traffic Surveillance	ARTERIAL MANAGEMENT SYSTEMS	42	
Incident Detection	ARTERIAL MANAGEMENT SYSTEMS	42	
Parking Management	ARTERIAL MANAGEMENT SYSTEMS	42	Potential to contribute to congestion relief, improve quality and efficiency of transport and facilitates demand management.
Parking Management & Availability	INTEGRATED URBAN TRAFFIC CONTROL SYSTEMS	42	

Table 6.1 (continued)

System	System Category	Rating against objectives	Main Benefit Areas in NZ context
Pre-trip and En-Route Information	ADVANCED TRAVELLER INFORMATION SYSTEMS	42	Some systems in place. These facilities have potential to reduce congestion and improve the quality and efficiency of transport.
Traffic Surveillance	MOTORWAY MANAGEMENT SYSTEMS	40	Many existing systems in place. Improved and new facilities have potential to contribute to congestion relief, improve quality and efficiency of transport and support incident management.
VMS & Information Dissemination	RURAL HIGHWAY SYSTEMS	40	The main benefits of VMS in rural situations are: providing drivers with real time information on incidents; allowing improved selection of alternative routes; and reducing the risk of secondary accidents.
Ride Share Information	ADVANCED TRAVELLER INFORMATION SYSTEMS	40	Contribute to improve ride share use and associated benefits of reduced congestion and emissions.
Real-Time Public Transport Passenger Information Systems	INTEGRATED URBAN TRAFFIC CONTROL SYSTEMS	38	Some existing systems in place. These systems have potential to contribute to congestion relief through improved public transport use, and enhance the quality and efficiency of transport.
Access Control Systems	INTEGRATED URBAN TRAFFIC CONTROL SYSTEMS	38	Potential to contribute to congestion relief, improved quality and efficiency of transport and provide demand management facilities.
Priority Signal Pre-emption & Advance Stop Line Intersections	BUS MANAGEMENT SYSTEMS	38	Some existing systems in place. These systems have potential to contribute to congestion relief for public transport and improve public transport use.
Detection, Information Collection & Processing	ADVANCED TRAVELLER INFORMATION SYSTEMS	38	Provide basic ATIS. These facilities have potential to reduce congestion and improve the quality and efficiency of transport.
Variable Message Signs	MOTORWAY MANAGEMENT SYSTEMS	36	The main benefits of VMS in a motorway and arterial environment are: providing drivers with real time information on congestion and incidents; allowing improved selection of alternative routes; and reducing the risk of secondary accidents. Also potential to improve traffic efficiency by reducing demand in congested areas and diverting traffic away from incidents.
Variable Message Signs	ARTERIAL MANAGEMENT SYSTEMS	36	
Ramp Control: Ramp Metering	MOTORWAY MANAGEMENT SYSTEMS	36	Potential to assist motorway demand management and congestion relief. Improved motorway capacity, reduced accident rates.
Response / Recovery / Hazardous Materials / Emergency Medical Services	EMERGENCY & INCIDENT MANAGEMENT SYSTEMS	36	Potential to reduce fatalities, delays and other adverse impacts of incidents.
Project Specific E-Toll Collection Systems	ELECTRONIC ROAD USER CHARGING	36	Potential to contribute to demand management on specific routes and assist in broader demand management/congestion relief initiatives.

Table 6.1 (continued)

System	System Category	Rating against objectives	Main Benefit Areas in NZ context
Ramp Control: Priority	MOTORWAY MANAGEMENT SYSTEMS	34	Provide improved ability to support access control restrictions contributing to demand management and improved public transport efficiency.
Dynamic Routing/Scheduling	BUS MANAGEMENT SYSTEMS	34	Improved efficiency of service, leading to higher levels of public transport convenience and use.
Incident Detection	RURAL HIGHWAY SYSTEMS	34	Many existing systems in place. Improved and new facilities have potential to contribute to congestion relief, improve quality and efficiency of transport and support incident management.
In-Vehicle & Hand-Held Devices	ADVANCED TRAVELLER INFORMATION SYSTEMS	34	Provide drivers and travellers with real time information on congestion, incidents and services. Allowing improved selection of alternatives. Has potential to improve traffic efficiency by reducing demand in congested areas, diverting traffic away from incidents or heavily congested areas, providing up to date information to drivers on hazards and road conditions, and improving safety through reduced congestion related or secondary accidents.
Work Zone Management	ROADWAY OPERATIONS & MAINTENANCE	34	Improve safety and efficiency of work zones leading to reduced incidents and reduced congestion.
Wide area RUC	ELECTRONIC ROAD USER CHARGING	34	Potential to contribute to congestion relief, improve quality and efficiency of transport and provide demand management facilities.
Special Event Transportation Management	MOTORWAY MANAGEMENT SYSTEMS	32	Reduce congestion and improved quality and efficiency of transport.
Environmental Monitoring & Forecasting	INTEGRATED URBAN TRAFFIC CONTROL SYSTEMS	32	Improved ability to address environmental effects through wider transportation management systems; leading to reduced environmental impacts.
Surveillance, Fire Systems & Response Coordination	TUNNEL MANAGEMENT SYSTEMS	32	Improved safety, incident response and associated benefits.
Integrated Smart Cards / Multi Use Payment Systems	INTEGRATED URBAN TRAFFIC CONTROL SYSTEMS	28	Improved payment convenience and efficiency leading to higher levels of public transport use.
On-Vehicle Surveillance & Facility Surveillance	BUS MANAGEMENT SYSTEMS	28	Improved safety and security, leading to increased use of public transport and associated benefits.
Speed Enforcement	RURAL HIGHWAY SYSTEMS	28	Improved safety and reduced incidents.
Lane Management: Variable Speed Limits	MOTORWAY MANAGEMENT SYSTEMS	26	Improved safety and contributes to reducing incident related congestion.
Traffic Signal Enforcement	ARTERIAL MANAGEMENT SYSTEMS	26	Improved safety and reduced incidents.

Table 6.1 (continued)

System	System Category	Rating against objectives	Main Benefit Areas in NZ context
Electronic Safety Screening	RURAL HIGHWAY SYSTEMS	26	Improved safety and reduced incidents.
Electronic Safety Screening	MOTORWAY MANAGEMENT SYSTEMS	26	Improved safety and reduced incidents.
Highway Rail Crossing Systems	CRASH PREVENTION & SAFETY	26	Improved safety and reduced incidents.
Fleet Management Systems	FLEET MANAGEMENT SYSTEMS	26	Improved efficiency of transport.
Road Geometry Warning Systems: Ramp Rollover / Curve Speed Downhill Speed	CRASH PREVENTION & SAFETY	24	Improved safety and reduced incidents.
Asset Management	ROADWAY OPERATIONS & MAINTENANCE	24	Improved quality & efficiency of transport.
Speed Enforcement	MOTORWAY MANAGEMENT SYSTEMS	22	Improved safety and reduced incidents.
Intersection Enforcement	RURAL HIGHWAY SYSTEMS	22	Improved safety and reduced incidents.
Intersection Collision Warning	CRASH PREVENTION & SAFETY	22	Improved safety and reduced incidents.
Electronic Weight Screening	RURAL HIGHWAY SYSTEMS	22	Potential to improve safety and reduce asset damage.
Electronic Weight Screening	MOTORWAY MANAGEMENT SYSTEMS	22	Potential to improve safety and reduce asset damage.
Lane Management: Lane Control	MOTORWAY MANAGEMENT SYSTEMS	20	Improved safety and contributes to reducing incident related congestion.
Data Archiving / Interoperability / Analysis	INFORMATION MANAGEMENT	20	Provides basis for increased benefits from existing and developing systems in many areas.

7. Review and Summary

The evaluations of the ITS facilities considered results in a range of scores from the highest at 48 down to the lowest at 20. Within this range the ITS applications fall broadly into 4 sections:

Tier 1 – High Contribution (40 and over)
Tier 2 – Medium-High Contribution (34-38)
Tier 3 – Low-Medium Contribution (26-32)
Tier 4 – Low Contribution (Less than 25)

The balance and proportions of the contributions provided by each of the facilities considered are illustrated by the charts contained in the Appendices.

7.1 Tier 1 : High Contribution ITS Facilities

This list sets out the systems or groups of systems that have the **greatest potential** to provide benefits in the context of the NZTS and LTMA objectives, including consideration of their cost effectiveness and level of complexity. These include:

1. Systems aimed at monitoring road weather conditions, prediction of adverse conditions, informing drivers and assisting in more effective response and treatment.
2. Adaptive Signal Control used in urban arterial situations.
3. Electronic road user charging / congestion pricing.
4. Incident Detection and Traffic Surveillance in motorway and arterial situations.
5. Parking Management on arterial routes and Parking Management and Availability systems as part of integrated urban traffic control systems.
6. Pre-Trip and En-Route Information elements of advanced traveller information systems.
7. VMS and Information Dissemination on key rural highways.
8. Ride Share Information facilities as part of advanced traveller information systems.

The facilities in this list reflect a strong focus on travel demand monitoring, management and control, as well as the early detection and management of specific problems. This reflects the fact that, in urban situations, the benefits of improved demand management and real time management of traffic conditions can have a significant impact on a range of other areas important in the context of the NZTS.

The improved management of travel demand and traffic congestion in urban areas can lead to significant improvements in economic efficiency, safety, and environmental impacts.

The main elements here are systems that influence travel demand through better information, and through direct means such as congestion pricing. These are supplemented by the improved monitoring and management of traffic congestion and further improved information services.

7.2 Tier 2 : Medium-High Contribution ITS Facilities

The Tier 2 list sets out which systems or groups of systems have **significant potential** to provide benefits in the context of the NZTS and LTMA objectives, and including consideration of their cost effectiveness and level of complexity. These include:

1. Real-Time Public Transport Passenger Information Systems as part of an integrated urban traffic control system.
2. Access Control Systems used as part of an integrated urban traffic control system.
3. Priority Signal Pre-emption and Advance Stop Line Intersections for bus services.
4. Detection, Information Collection and Processing elements of advanced traveller information systems.
5. Variable Message Signs used as part of a motorway management and arterial management systems.
6. Ramp Metering and Priority Controls as part of wider motorway management systems.
7. Emergency and Incident Management Systems that assist in response, recovery, hazardous materials management and assisting emergency medical services .
8. Project Specific E-Toll Collection Systems.
9. Dynamic routing and scheduling elements of bus management systems.
10. Incident Detection on rural highway systems.
11. In-Vehicle and Hand-Held Devices for delivering traveller information.
12. Work Zone Management facilities.
13. Wide Area RUC systems.

The facilities in this Tier again have a strong focus on travel demand management, but are more related to management of demand at specific locations. For example the use of ramp metering as a demand management tool is more location specific than congestion charging and as such has less overall impact. Other facilities in this list are rated slightly lower due to their complexity and cost effectiveness, such as wide area RUC.

As with Tier 1, these systems reflect the fact that benefits of improved demand management and real-time management of traffic conditions can have a significant impact on a range of other areas important in the context of the NZTS.

The main elements here are systems that influence the efficiency of traffic flow and travel demand at a local level and more specific components used in information delivery.

7.3 Tier 3 : Low-Medium Contribution ITS Facilities

This tier sets out the systems or groups of systems that have **some potential** to provide benefits in the context of the NZTS and LTMA objectives, but are in the lower half of the overall list. Again, these assessments also include consideration of cost effectiveness and level of complexity. This 3rd Tier list includes:

1. Special Event Transportation Management elements of motorway management systems.

2. Environmental Monitoring and Forecasting elements of integrated urban traffic control systems.
3. Surveillance, Fire Systems and Response Coordination elements of tunnel management systems.
4. Integrated Smart Cards / Multi Use Payment Systems linked to integrated urban traffic control systems.
5. On-Vehicle Surveillance and Facility Surveillance of bus management systems.
6. Speed Enforcement on rural highway systems.
7. Lane Management and Variable Speed Limits as part of motorway management systems.
8. Traffic Signal Enforcement on arterial routes.
9. Electronic Safety Screening.
10. Highway Rail Crossing Systems.
11. Fleet Management Systems.

The facilities in this Tier mainly comprise ITS elements aimed at particular aspects and elements of transport management. For example, the use of ITS in managing special events, systems aimed specifically at environmental monitoring, tunnel safety, speed and signal enforcement etc.

The focus at this level is less on demand management, and more related to addressing a specific issue.

The rating of these systems reflect the fact that while these systems provide real benefits in the context of the NZTS, the level of overall benefit is reduced by specialisation. This does not mean that these systems are necessarily any less needed, as they may provide significant benefits in their particular area, or as a component of a wider system.

7.4 Tier 4 : Low Contribution ITS Facilities

This Tier 4 list sets out which systems or groups of systems have the **least potential** to provide benefits in the context of the NZTS and LTMA objectives, and including consideration of their cost effectiveness and level of complexity. These include:

1. Road Geometry Warning Systems: Ramp Rollover / Curve Speed Downhill Speed.
2. Asset Management.
3. Speed Enforcement elements of motorway management systems.
4. Intersection Enforcement and collision warning systems.
5. Electronic Weight Screening.
6. Lane Management and Lane Control elements of motorway management systems.
7. Data Archiving / Interoperability / Analysis.

As with Tier 3, the facilities in this list mainly comprise ITS elements aimed at a particular specialised tasks. For example, the use of ITS in asset management, and systems targeted at a specific local safety hazards, providing information and controls on local lane use and speed.

The focus at this level is again less on demand management, and more on addressing a specific local issue.

The rating of these systems reflect the fact that their benefits are mostly localised, in the context of the NZTS, the level of overall benefit reduced by specialisation. This does not mean that these systems are necessarily any less needed, as they may provide significant benefits in their particular area, or as a component of a wider system.

8. Conclusion and Recommendations

The systems or groups of systems that have the greatest potential to provide benefits in the context of the NZTS and LTMA objectives are those that have a strong focus on travel demand monitoring, management and control, as well as those aimed at early detection and management of specific problems in congested areas.

This reflects the fact that, in urban situations, the benefits of improved demand management and real time management of traffic conditions can have a significant impact on a range of other areas important in the context of the NZTS.

The improved management of travel demand and traffic congestion in urban areas can lead to significant improvements in economic efficiency, safety, and environmental impacts.

The most effective are systems that influence travel demand through better information, and through direct means such as congestion pricing. These are supplemented by those that improve detection and monitoring, manage traffic congestion and further improve information reliability and delivery.

The best aligned systems are those that address the four key elements of demand management;

1. Improving ability to make informed choices (ATIS).
2. Influencing travel choice through direct means (congestion charging).
3. Control and management of traffic flow (adaptive signal control / ramp metering / parking systems).
4. Early detection and management of incidents (detection and monitoring systems).

The development and deployment of these types of facilities is growing rapidly in New Zealand and in order to ensure that the best results are achieved, there is a need for good early planning, a focus on the significant benefits of integration and interoperability, driven by a clear understanding of the risks and issues that will influence the success of these systems.

Key factors in the future success of these facilities will be:

- The future development of adaptive signal controls.
- The deployment of road-user/congestion charging.
- The development of integrated traveller information systems.

Other systems rated highly that have particular relevance in the New Zealand context include

- Systems aimed at monitoring road weather conditions, prediction of adverse conditions, informing drivers and assisting in more effective response and treatment.
- VMS and Information Dissemination on key rural highways.

These systems have particular relevance in New Zealand given the relatively high proportion of rural highways subject to adverse weather conditions that provide important strategic connections. With the rapidly reducing costs of the technologies and communications options used in this area, the opportunities to improve the reliability and safety of these routes have increased.

As the deployment of systems in these areas increase there is an opportunity to benefit from the broadening of integration opportunities and increased interoperability.

Although not in the top rated group several other systems have the potential to make a significant contribution, particularly when combined as part of an integrated urban system. These include:

1. Real-Time Public Transport Passenger Information Systems as part of an integrated urban traffic control system.
2. Priority Signal Pre-emption and Advance Stop Line Intersections for bus services.
3. Variable Message Signs used as part of a motorway management and arterial management system.
4. Environmental Monitoring and Forecasting elements of integrated urban traffic control systems.
5. Tunnel systems for surveillance, fire, response and coordination.
6. Speed and signal enforcement.

To assist in supporting the effective development of ITS solutions in these areas, it is recommended that further work be undertaken in the following areas.

1. A review of existing adaptive signal control facilities and planning for future development of these systems.
2. Research into the potential use of road-user/congestion charging in a New Zealand environment.
3. The future development of integrated traveller information systems.
4. The development of integrated weather condition monitoring, prediction, mitigation and warning systems.
5. The development of integrated Real-Time Urban Transport Information Systems.
6. Development of environmental monitoring and forecasting elements of integrated urban traffic control systems.
7. Review and future planning of tunnel systems for surveillance, fire, response and coordination.

Appendices – Benefit / Contribution Charts

A	Motorway Management Systems
B	Arterial Management Systems
C	Integrated Urban Traffic Control Systems
D	Bus Management Systems
E	Rural Highway Systems
F	Emergency Management Systems
G	Advanced Traveller Information Systems
H	Information Management
I	Crash Prevention and Safety
J	Roadway Operation and Maintenance
K	Road Weather Conditions Management
L	Electronic Road User Charging
M	Fleet Management Systems
N	Tunnel Management Systems

Appendix A

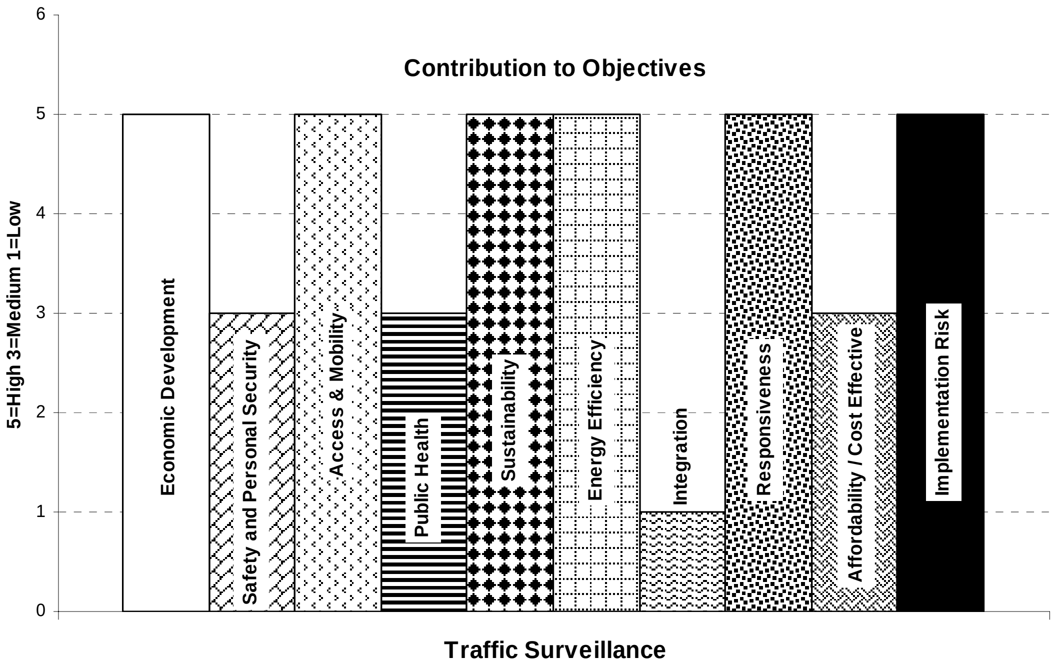
Benefit / Contribution Charts

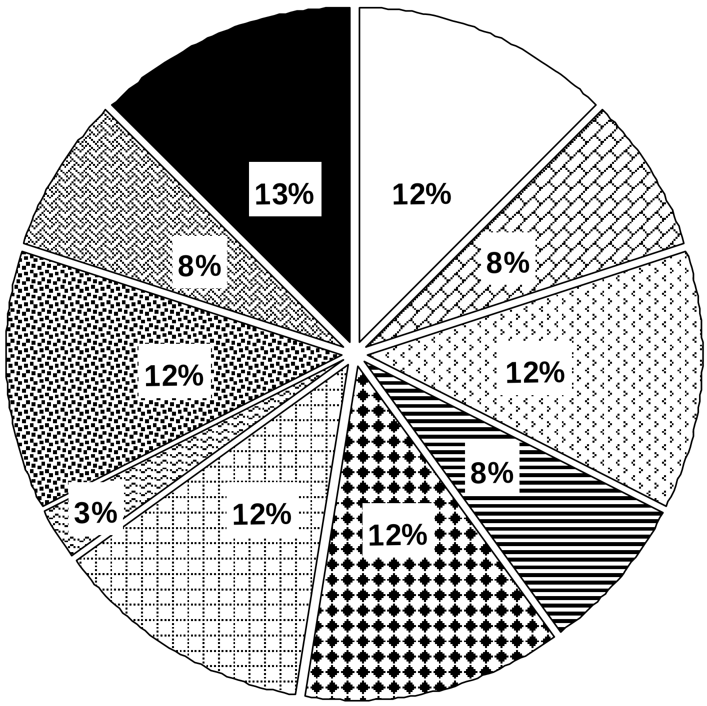
Motorway Management Systems

Motorway Management Systems

Traffic Monitoring and Surveillance

TOTAL 40

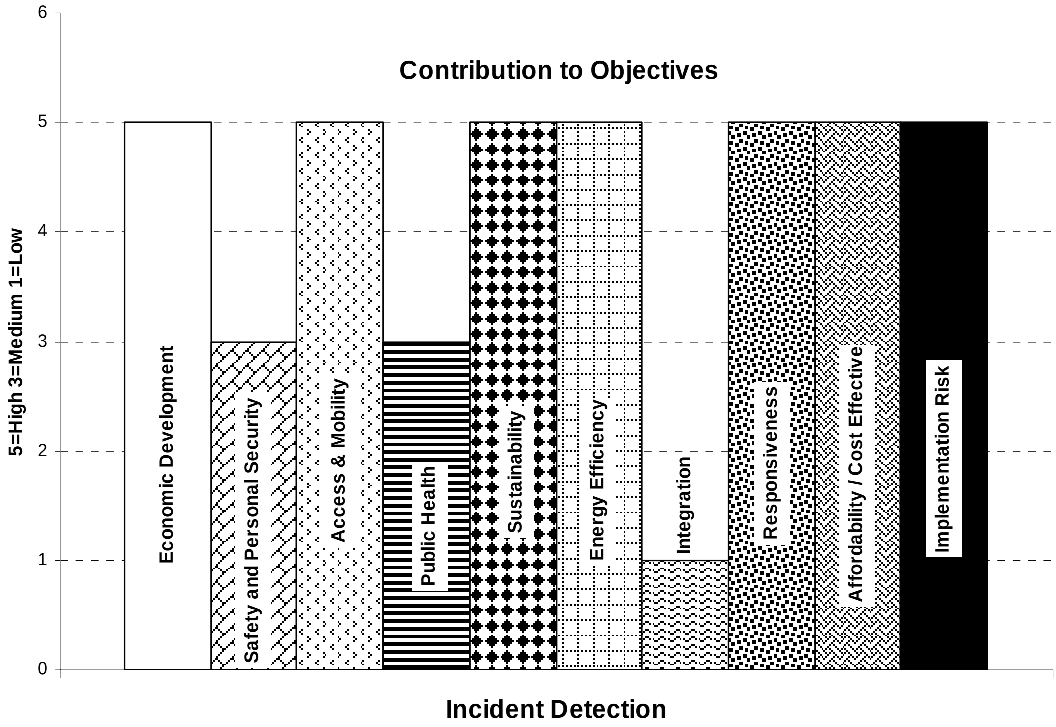


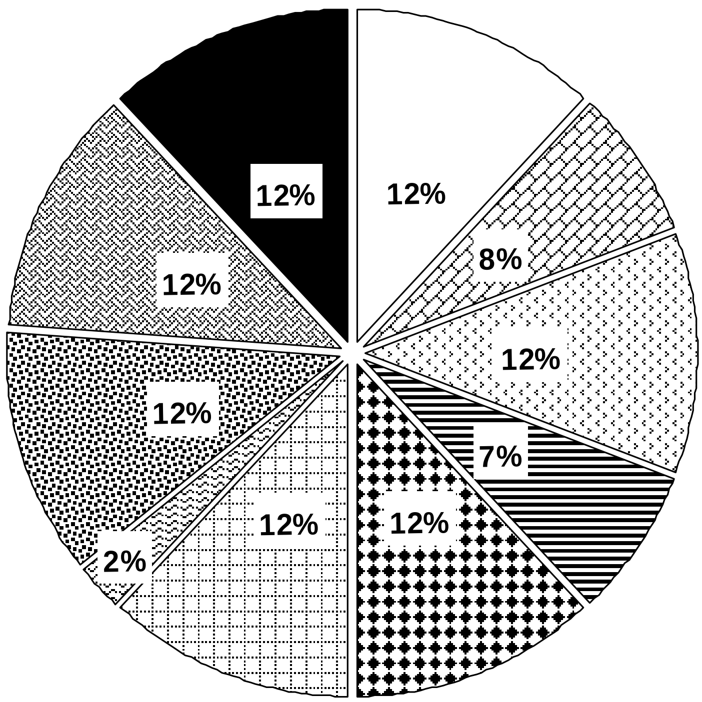


Motorway Management Systems

TOTAL 42

Incident Detection Systems

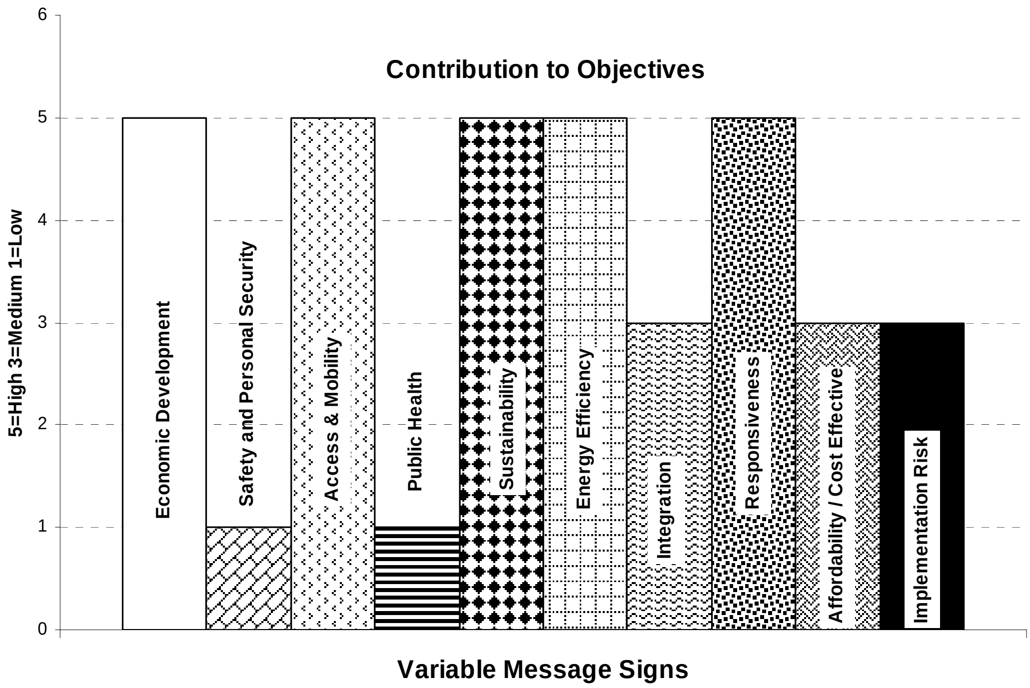


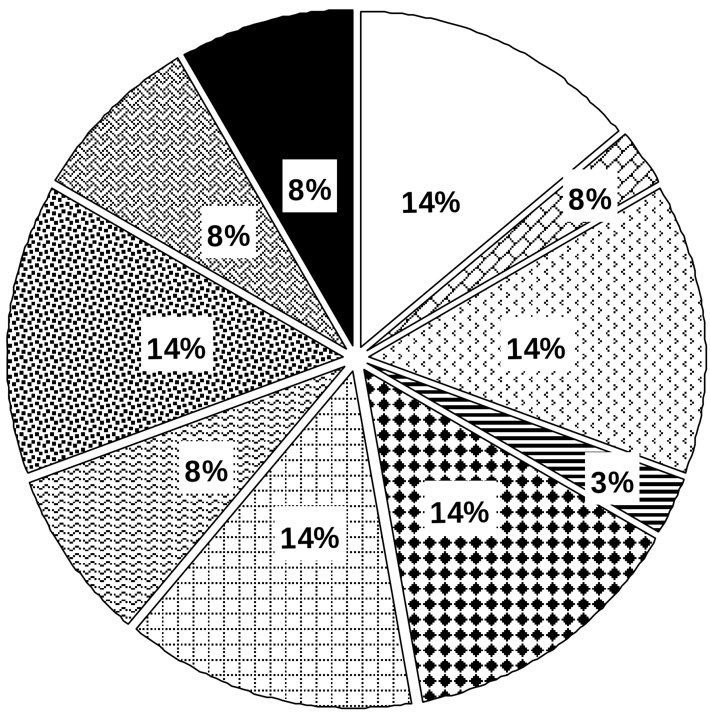


Motorway Management Systems

Variable Message Signs

TOTAL 36

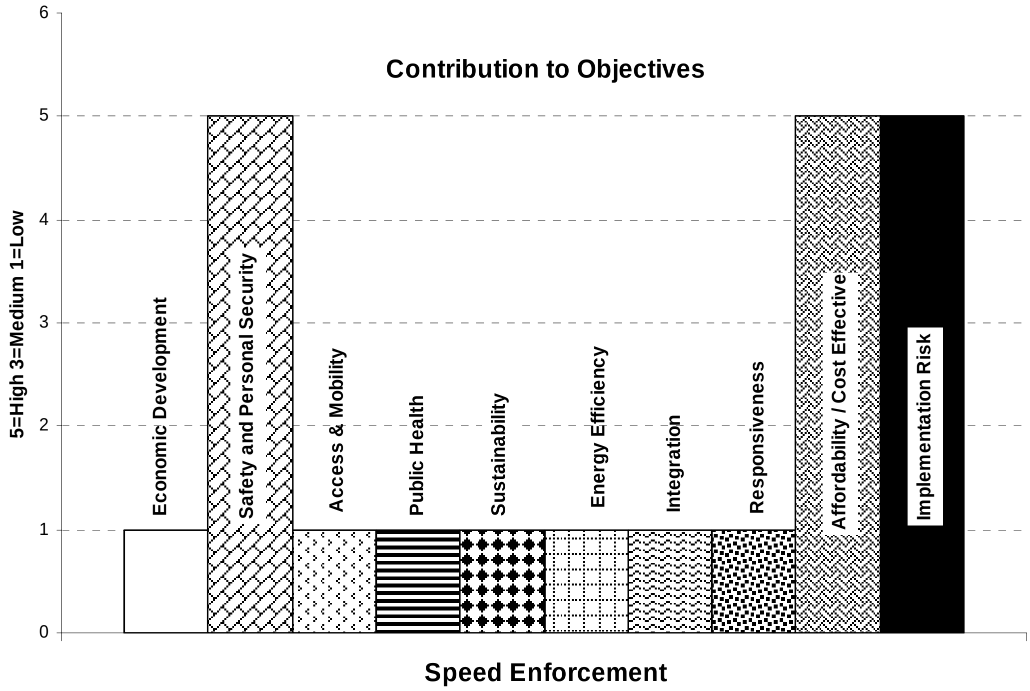


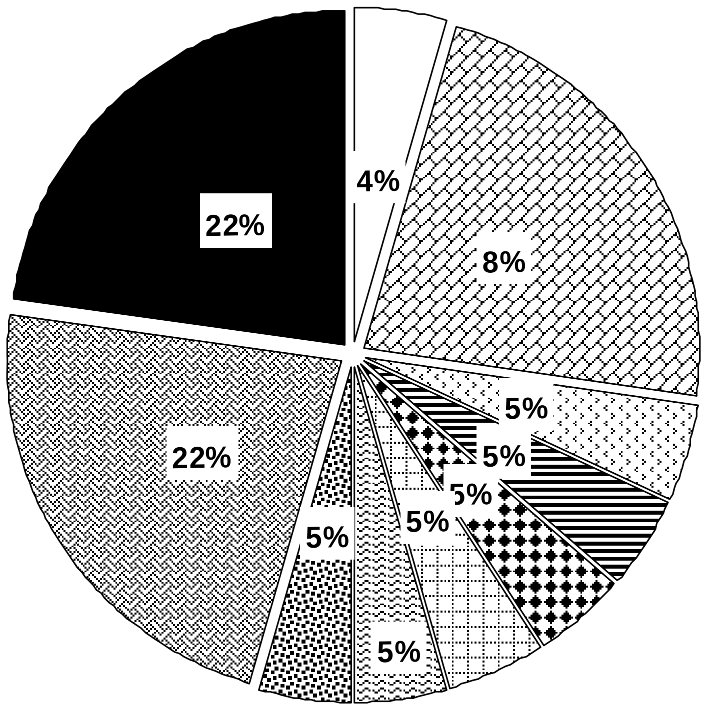


Motorway Management Systems

Speed Enforcement

TOTAL 22

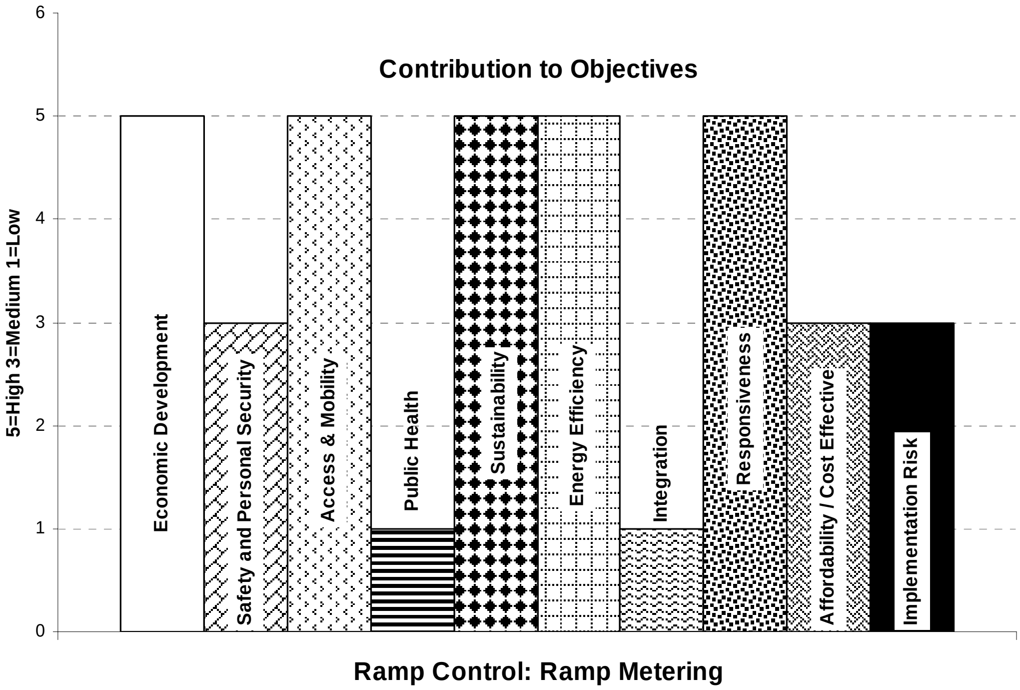


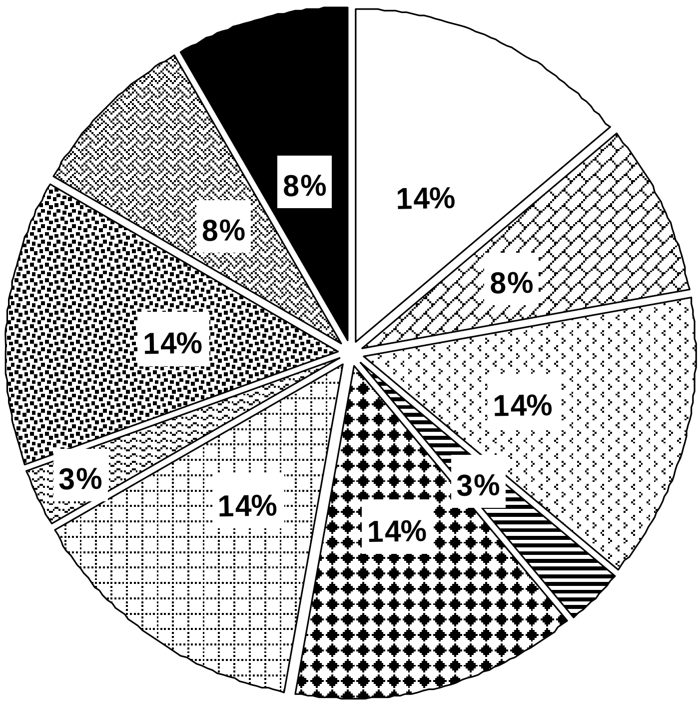


Motorway Management Systems

Ramp Metering

TOTAL 36

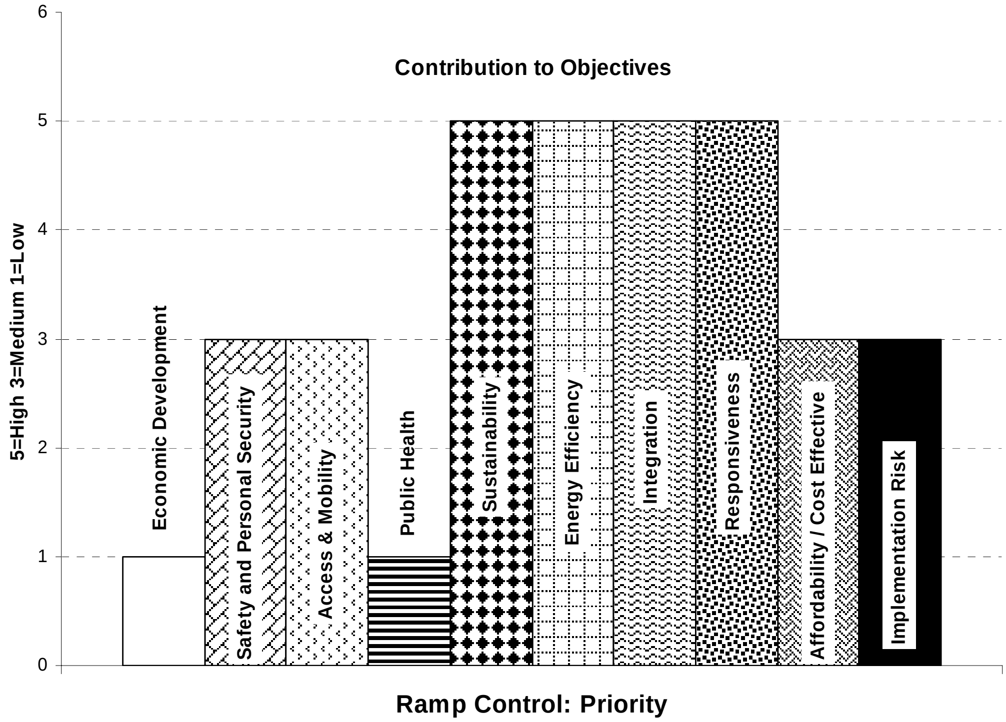


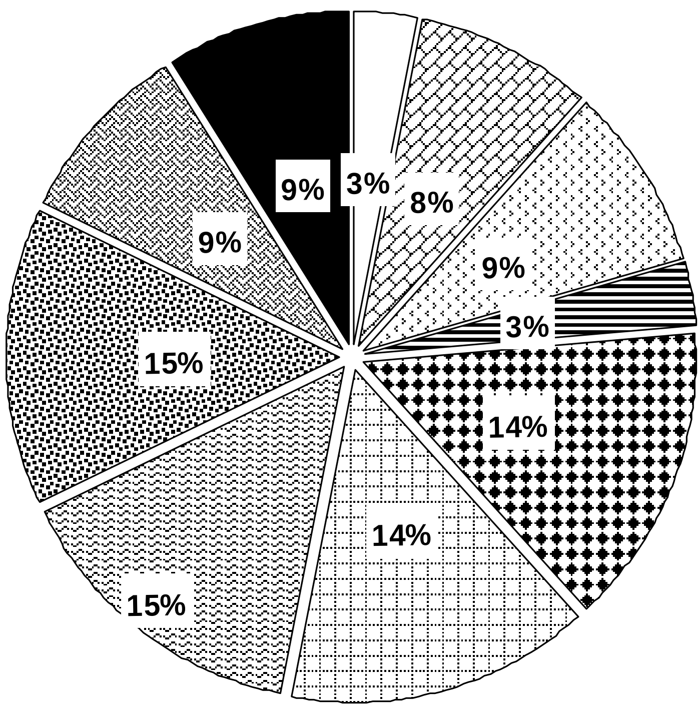


Motorway Management Systems

Vehicle Access (Ramp) Control Systems

TOTAL 34

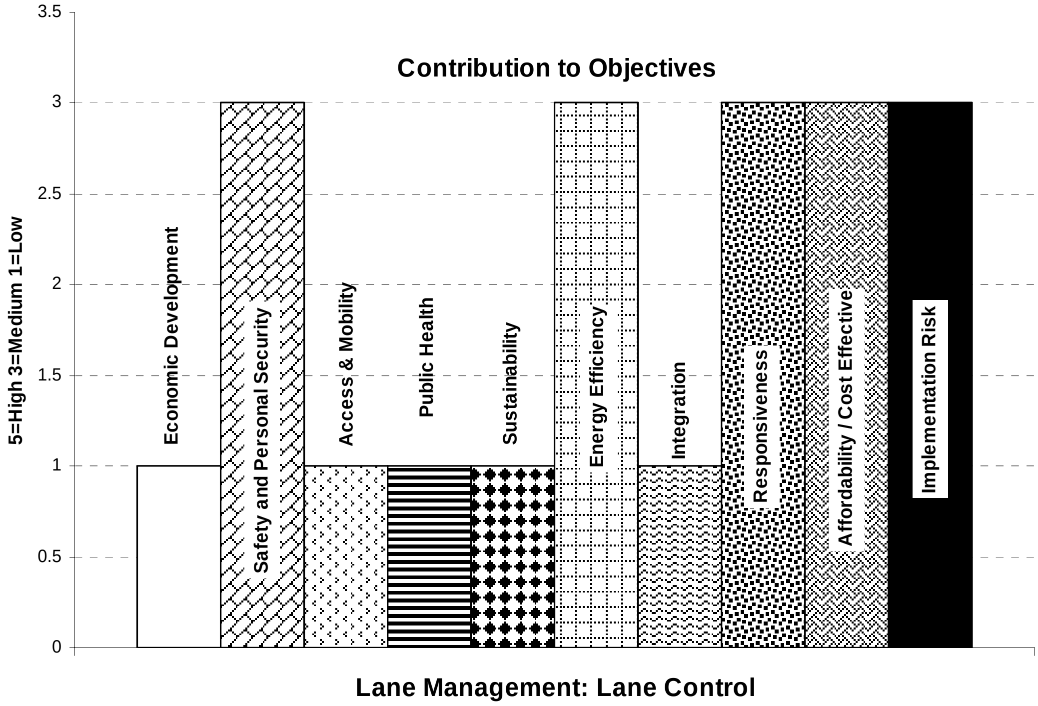


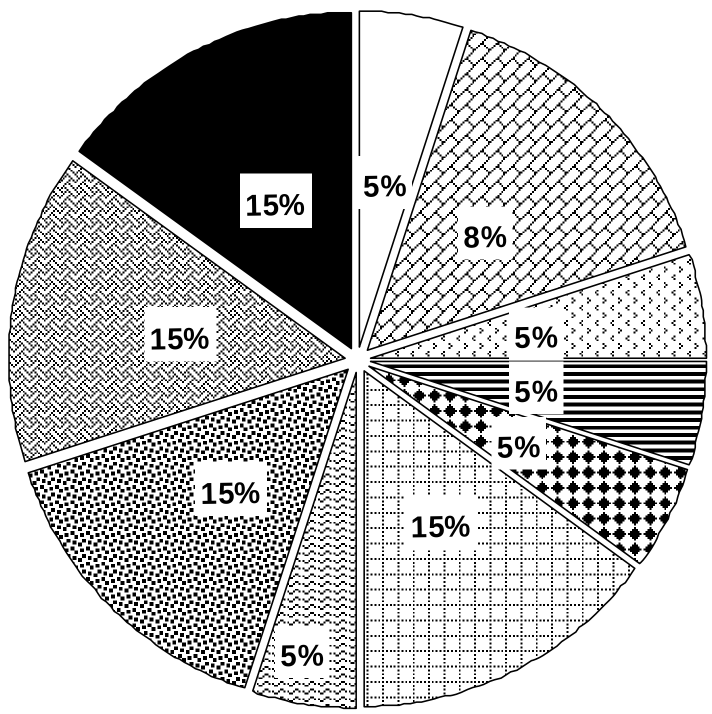


Motorway Management Systems

Lane Control Systems

TOTAL 20

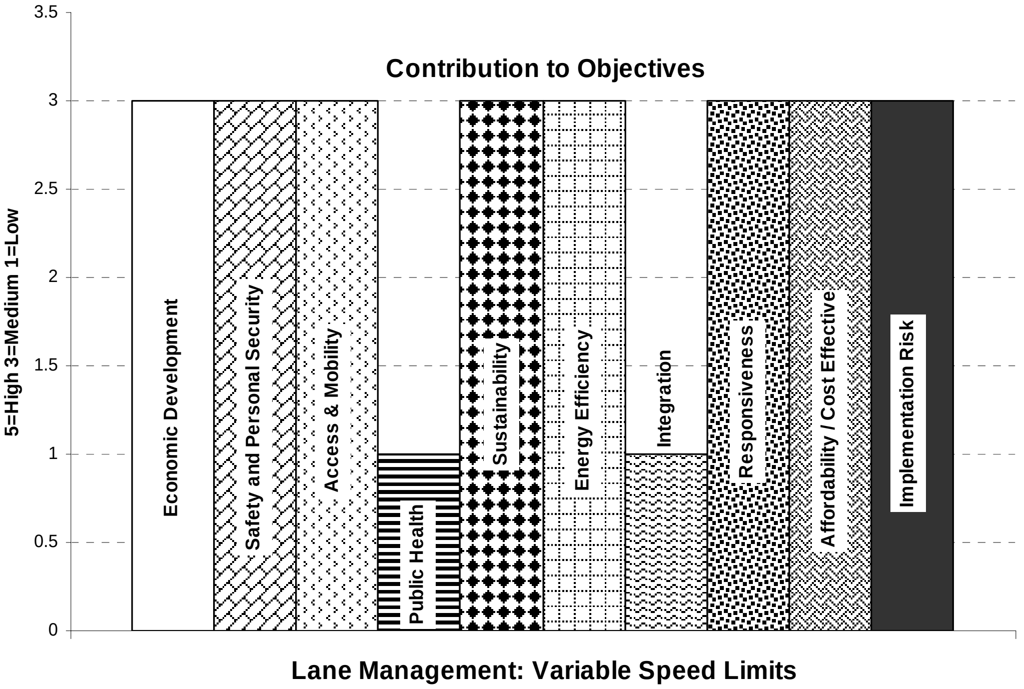


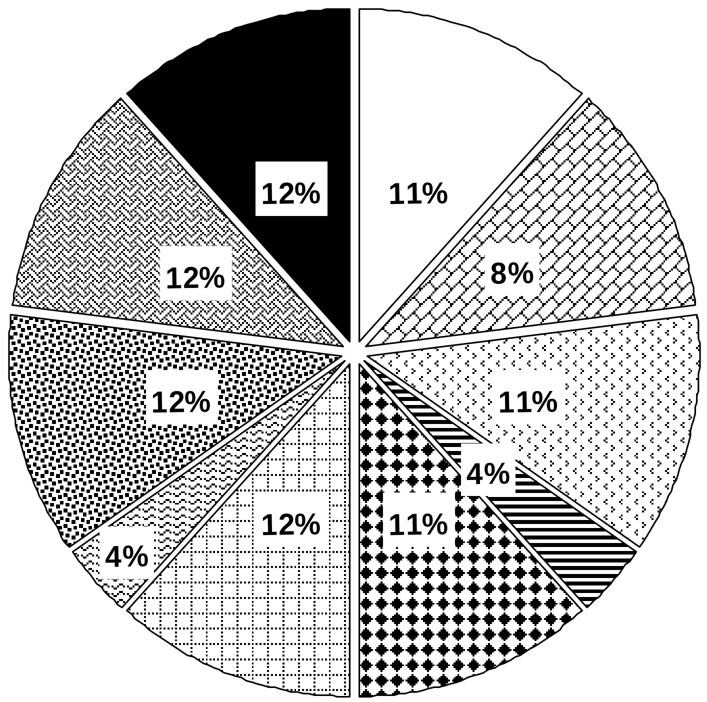


Motorway Management Systems

Variable Speed Limits

TOTAL 26

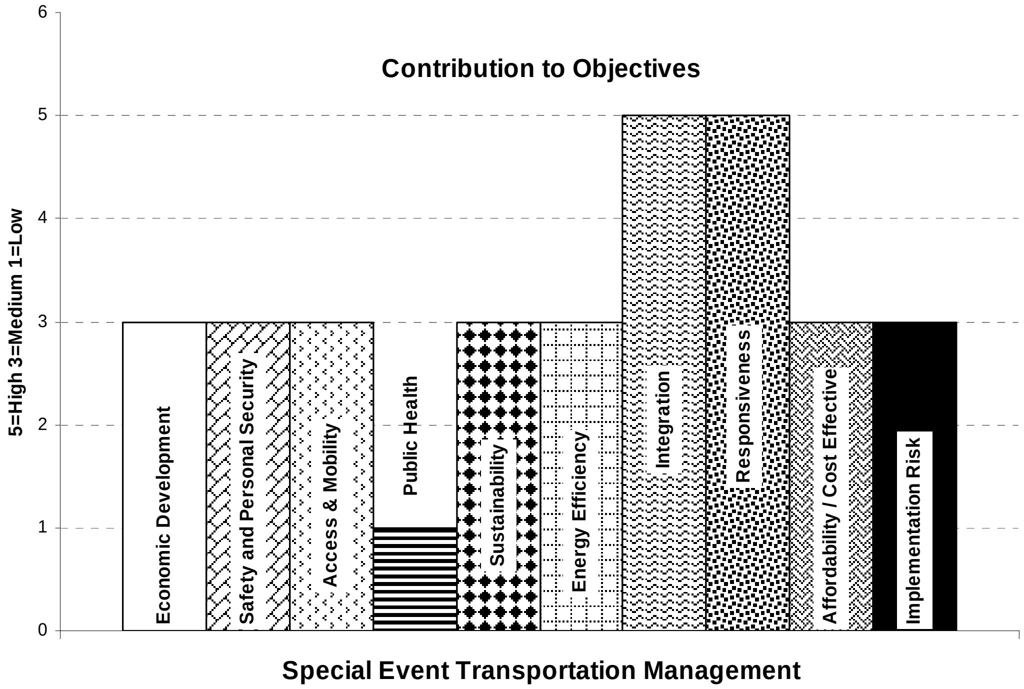


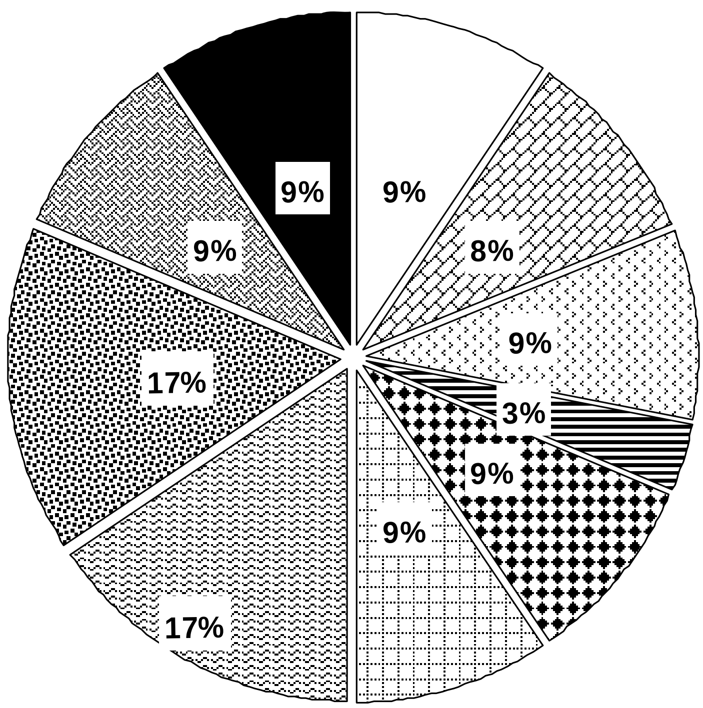


Motorway Management Systems

Special Event Transportation Management

TOTAL 32

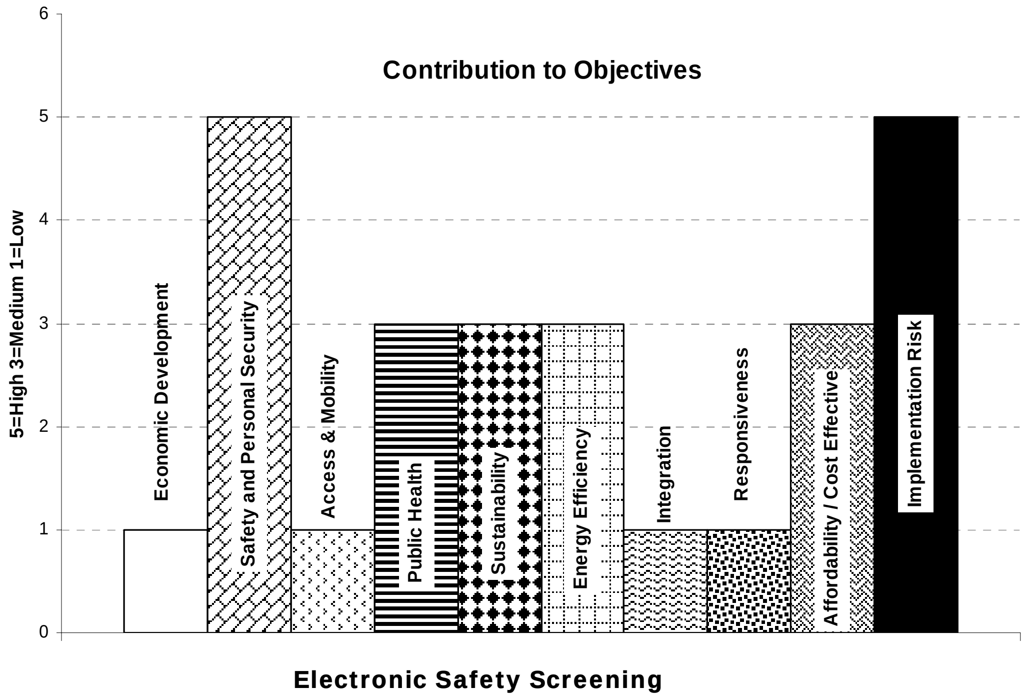


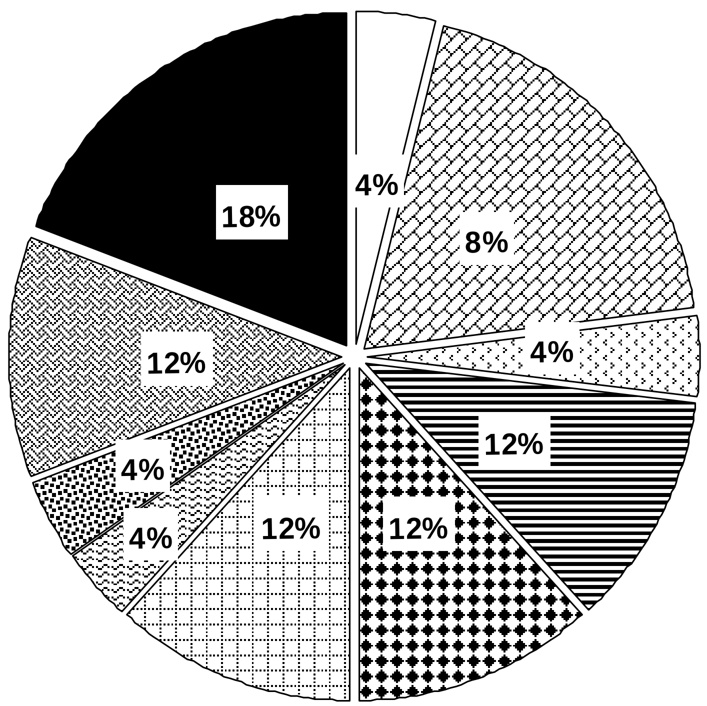


Motorway Management Systems

Electronic Safety Screening

TOTAL 26

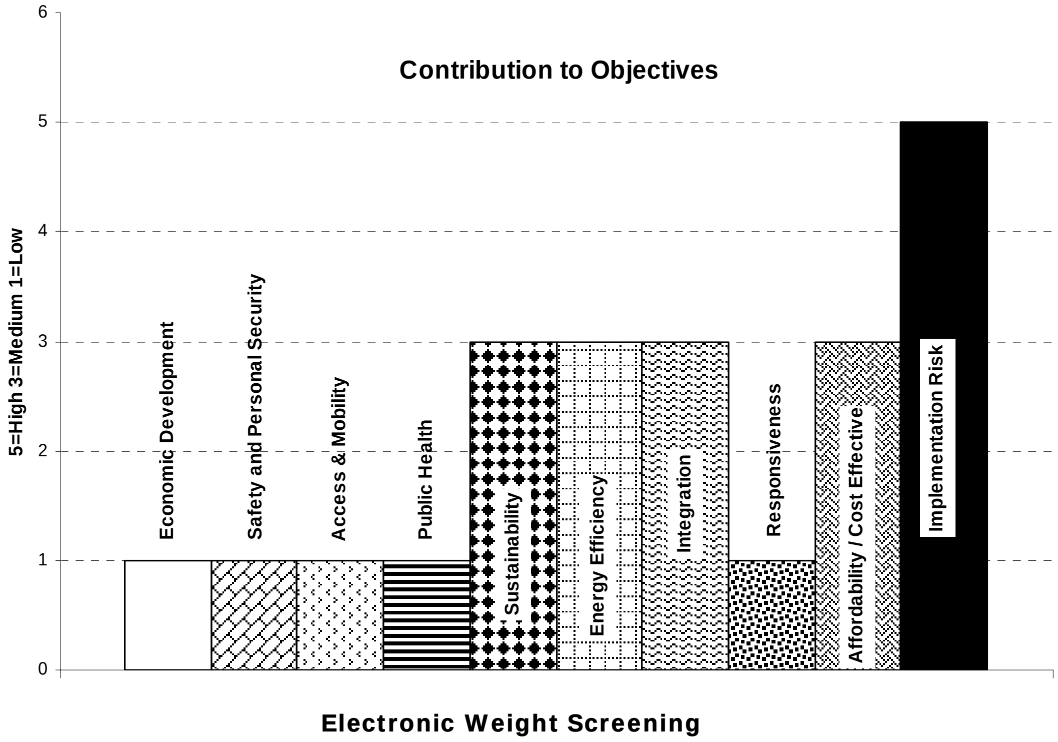


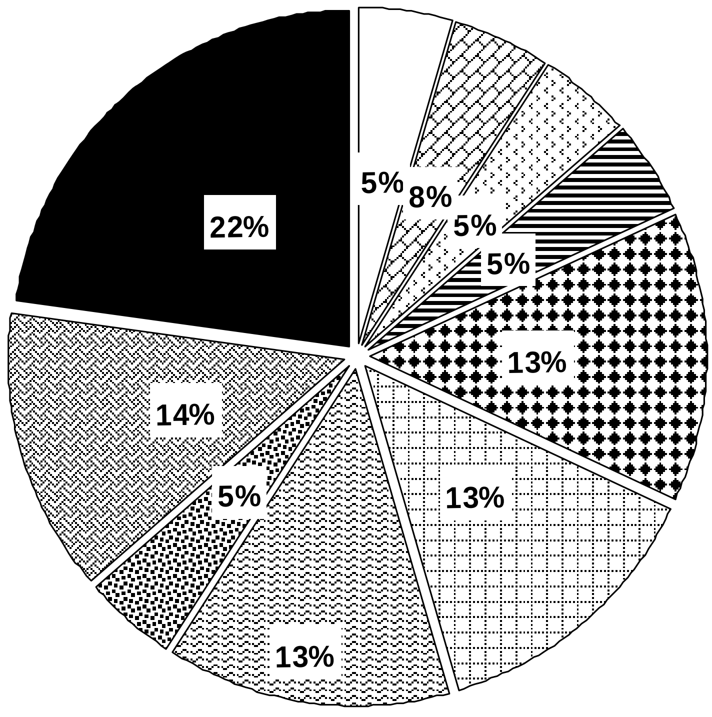


Motorway Management Systems

Electronic Weight Screening

TOTAL 22





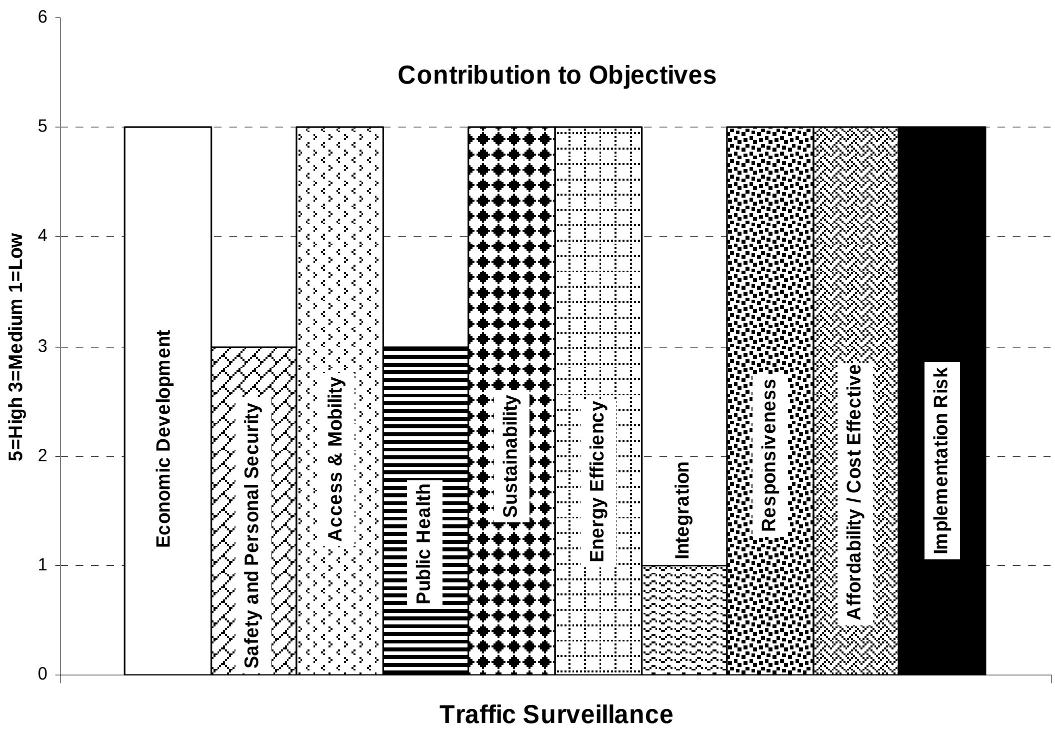
Appendix B

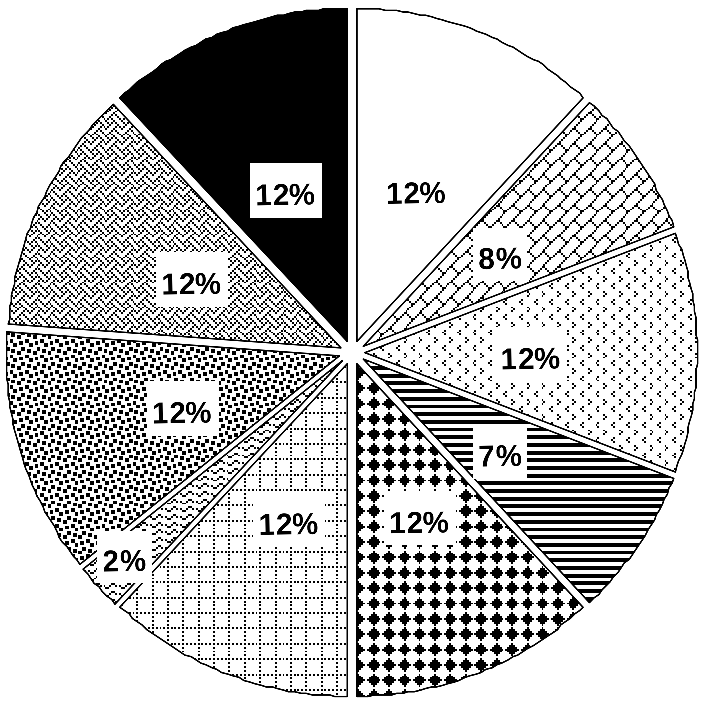
Benefit / Contribution Charts

Arterial Management Systems

Arterial Management Systems
Traffic Monitoring and Surveillance

TOTAL 42

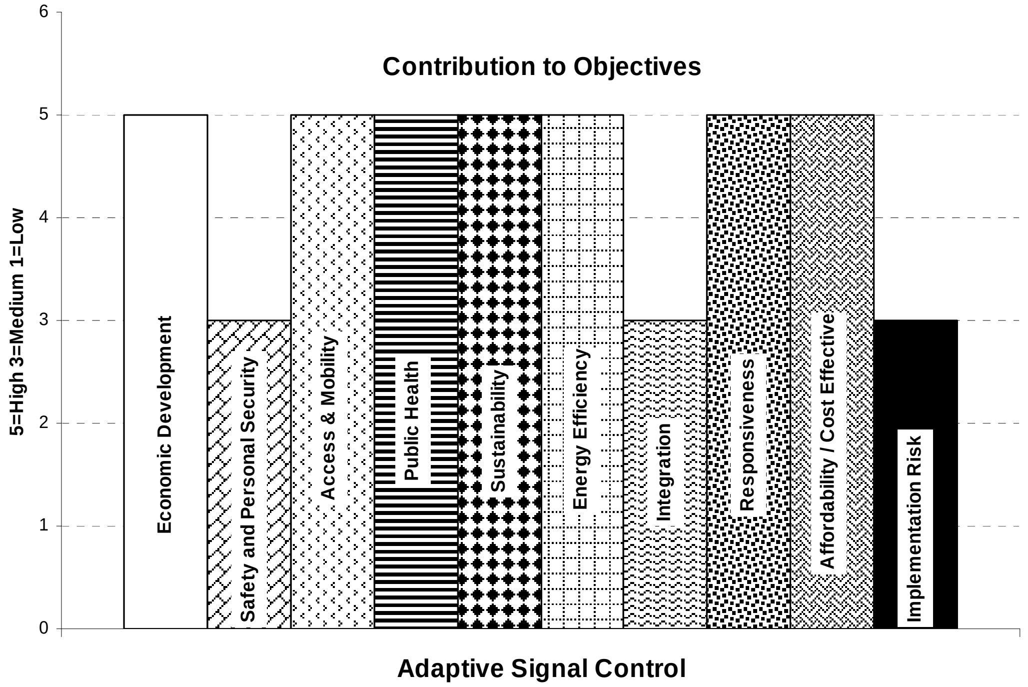


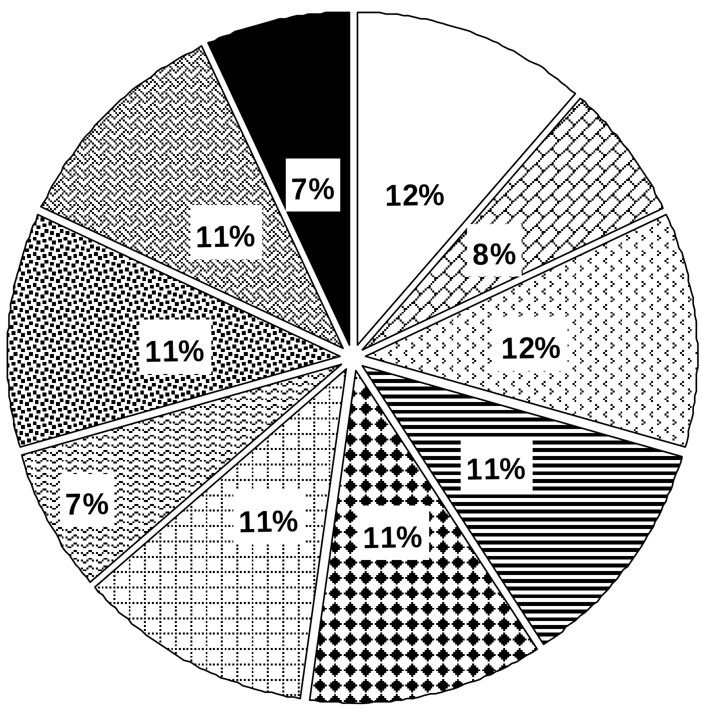


Arterial Management Systems

Adaptive Signal Control

TOTAL 44

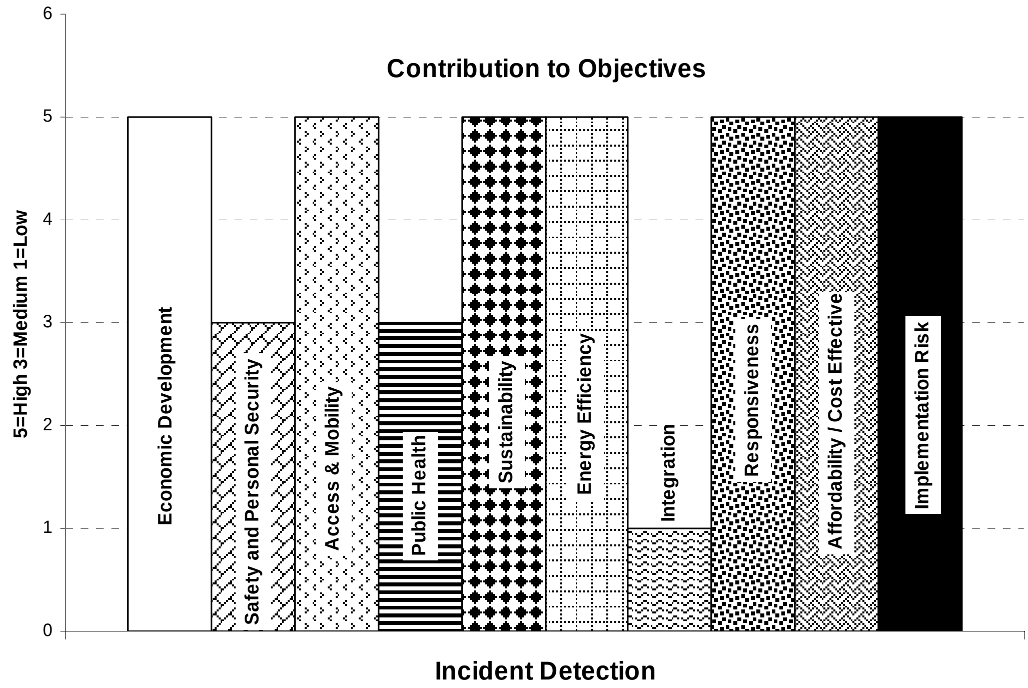


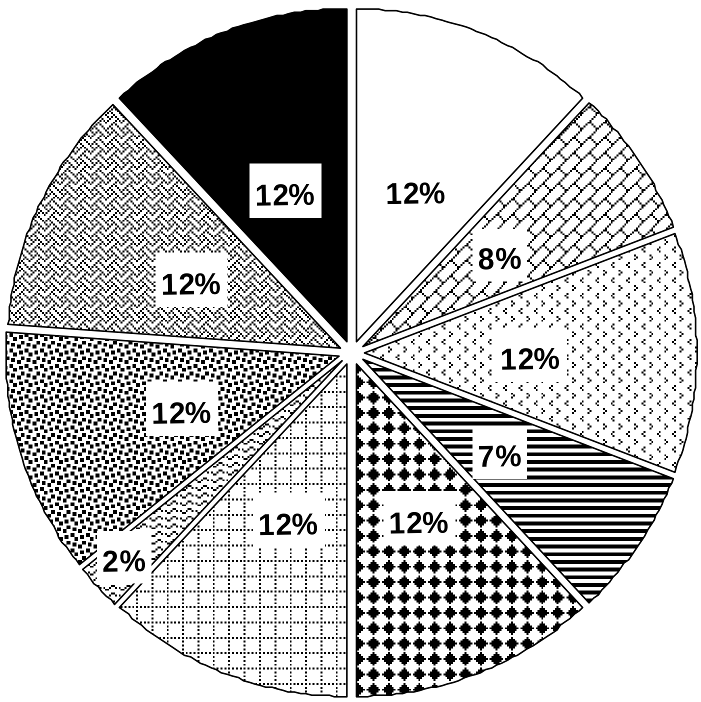


Arterial Management Systems

Incident Detection Systems

TOTAL 42

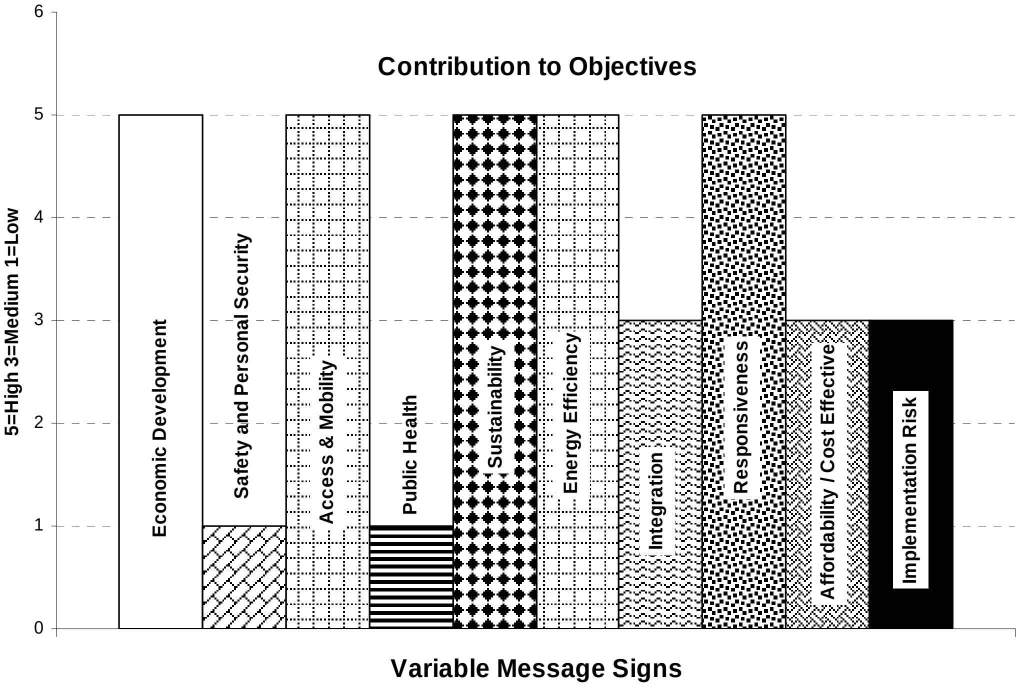


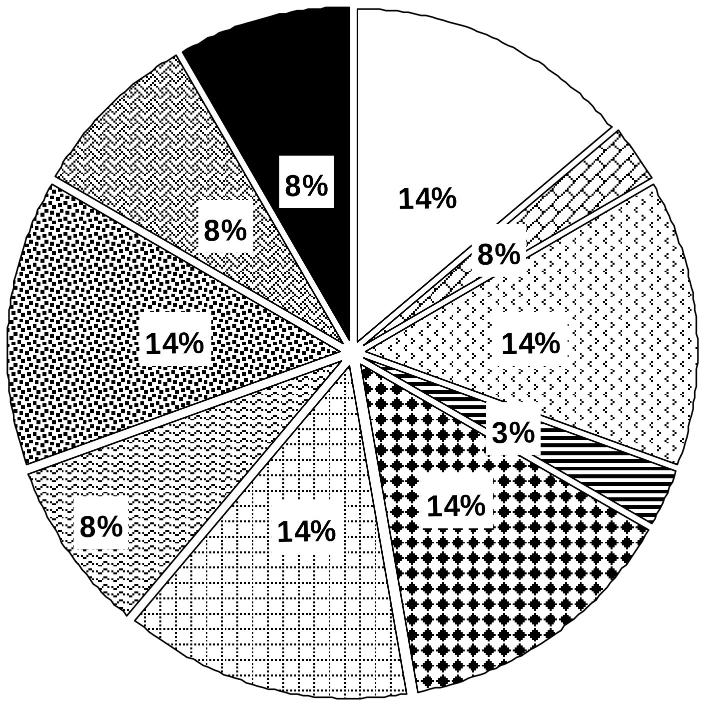


Arterial Management Systems

Variable Message Signs

TOTAL 36

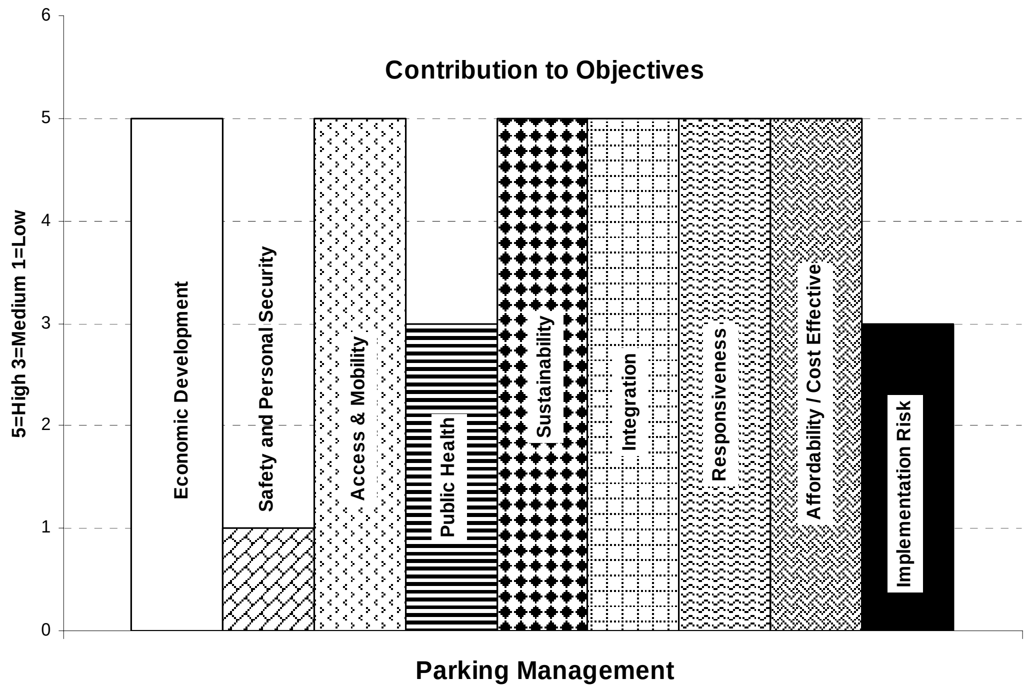


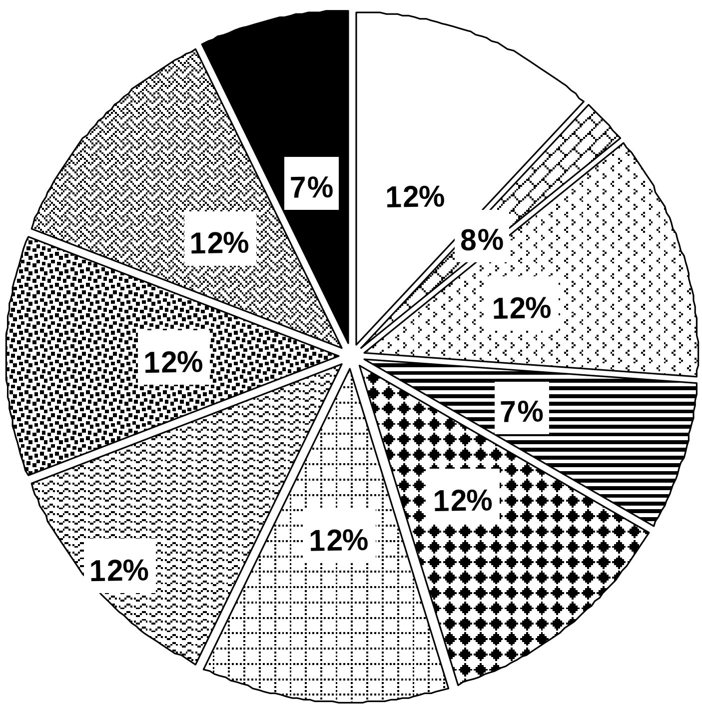


Arterial Management Systems

Parking Management

TOTAL	42

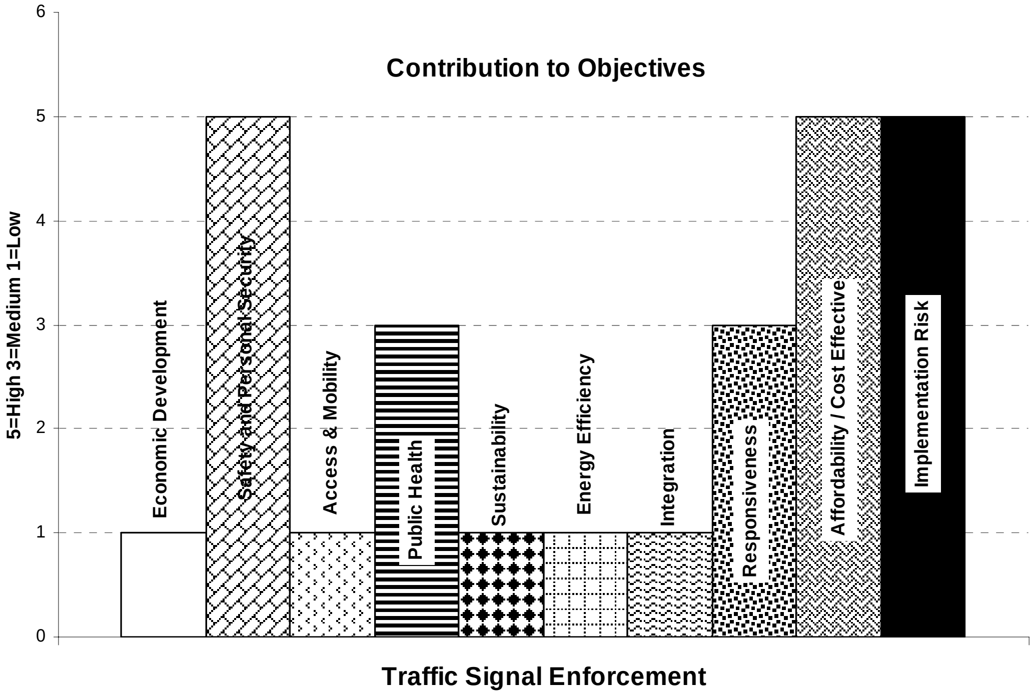


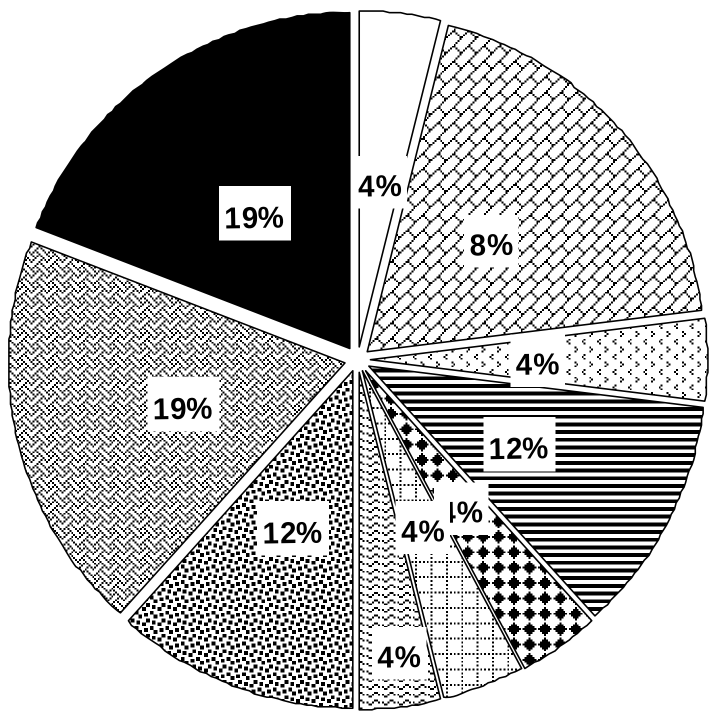


Arterial Management Systems

Traffic Signal Enforcement – Red Light Cameras

TOTAL	**26**





Appendix C

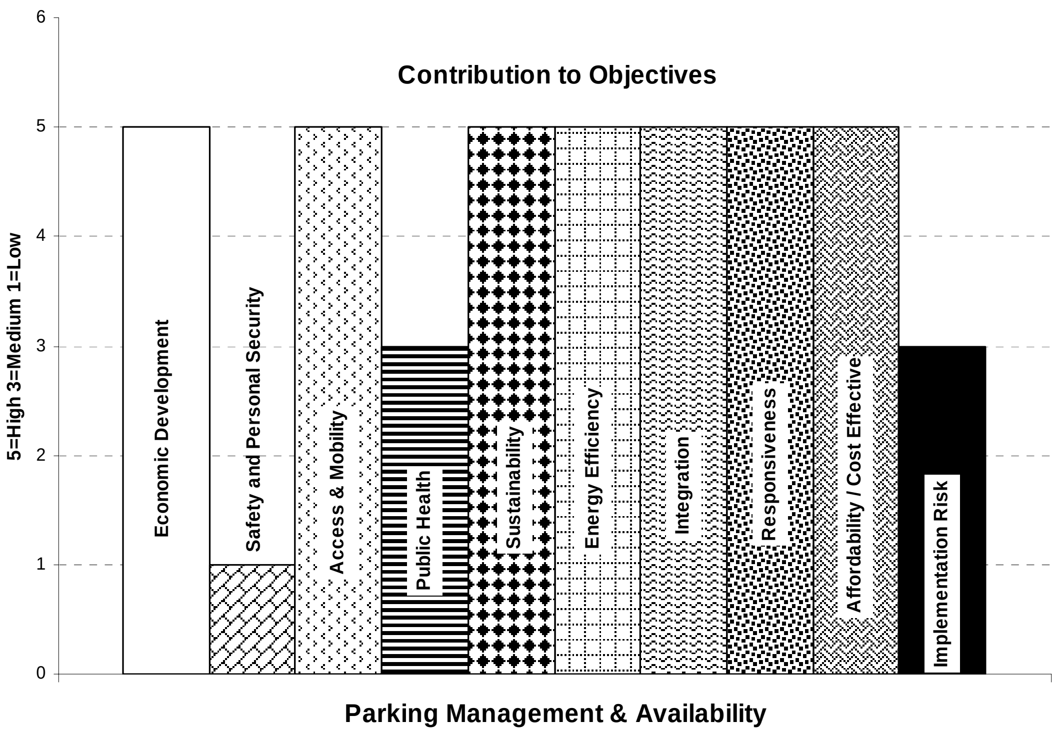
Benefit / Contribution Charts

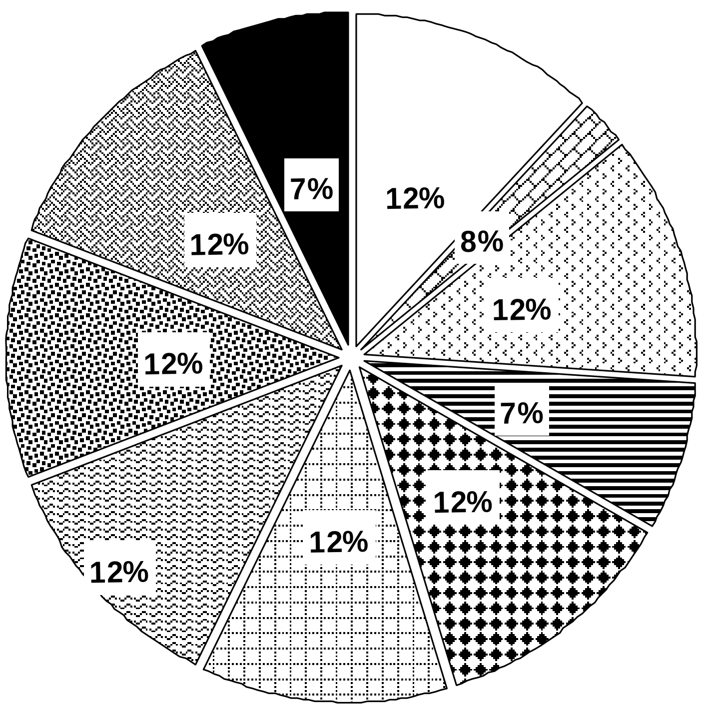
Integrated Urban Traffic Control Systems

Integrated Urban Traffic Control Systems

Parking Management and Availability

TOTAL	42

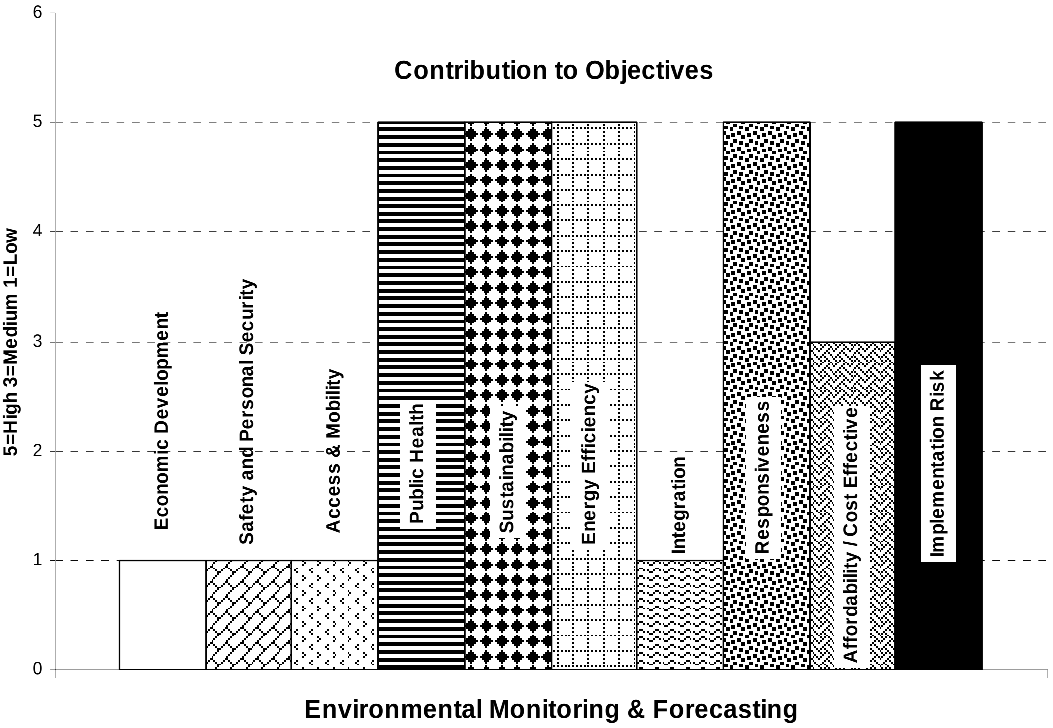


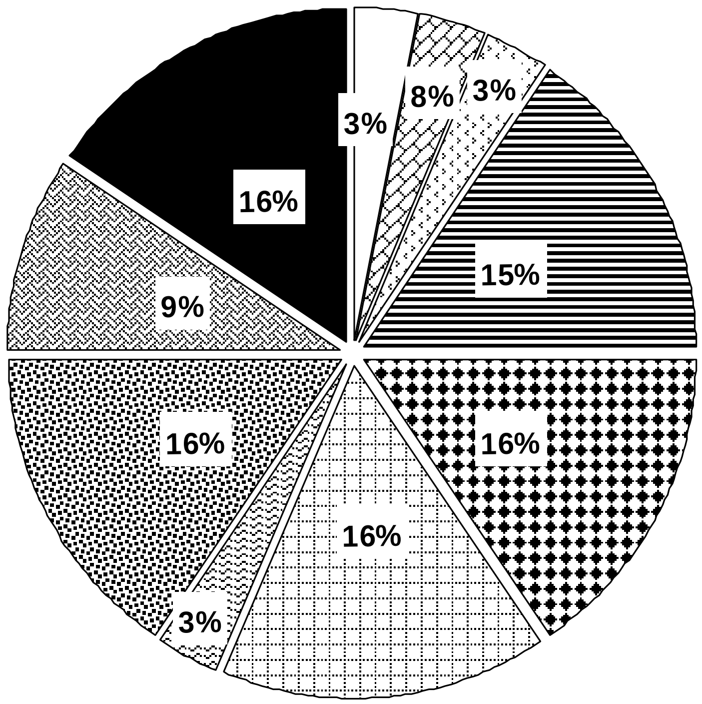


Integrated Urban Traffic Control Systems

Environmental Monitoring and Forecasting

TOTAL 32

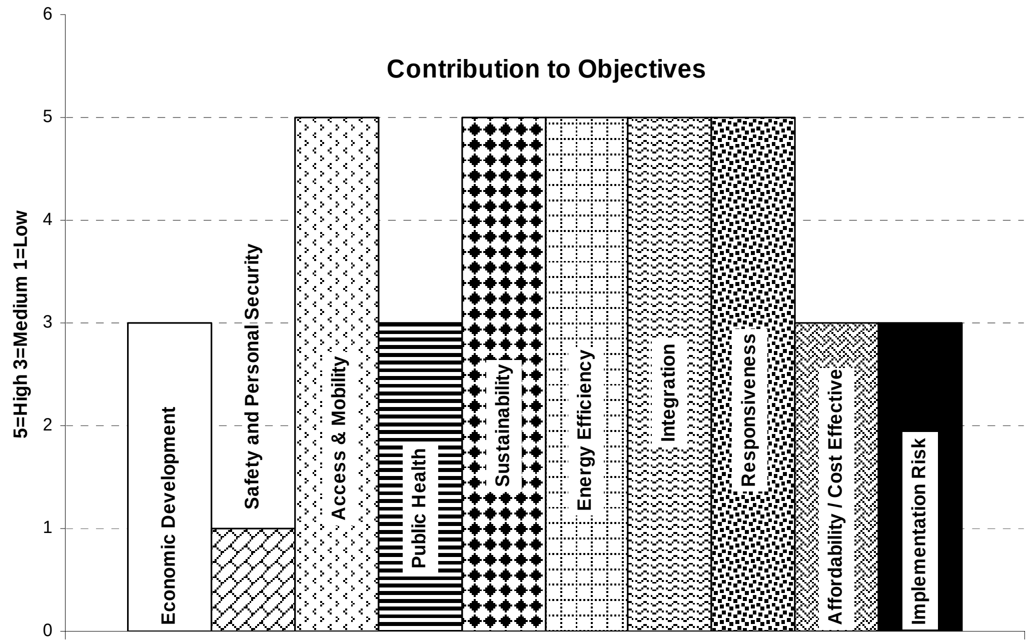


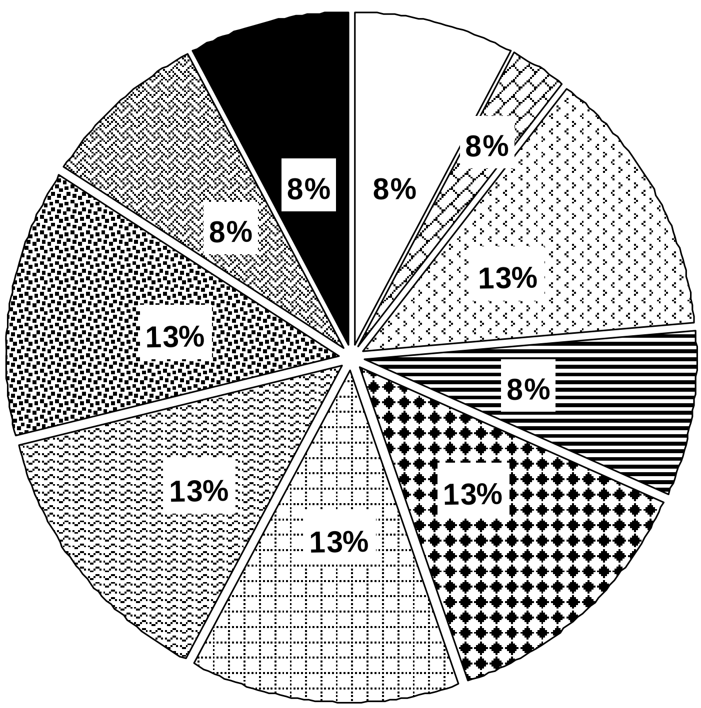


Integrated Urban Traffic Control Systems

Real-Time Public Transport Passenger Information Systems

TOTAL 38

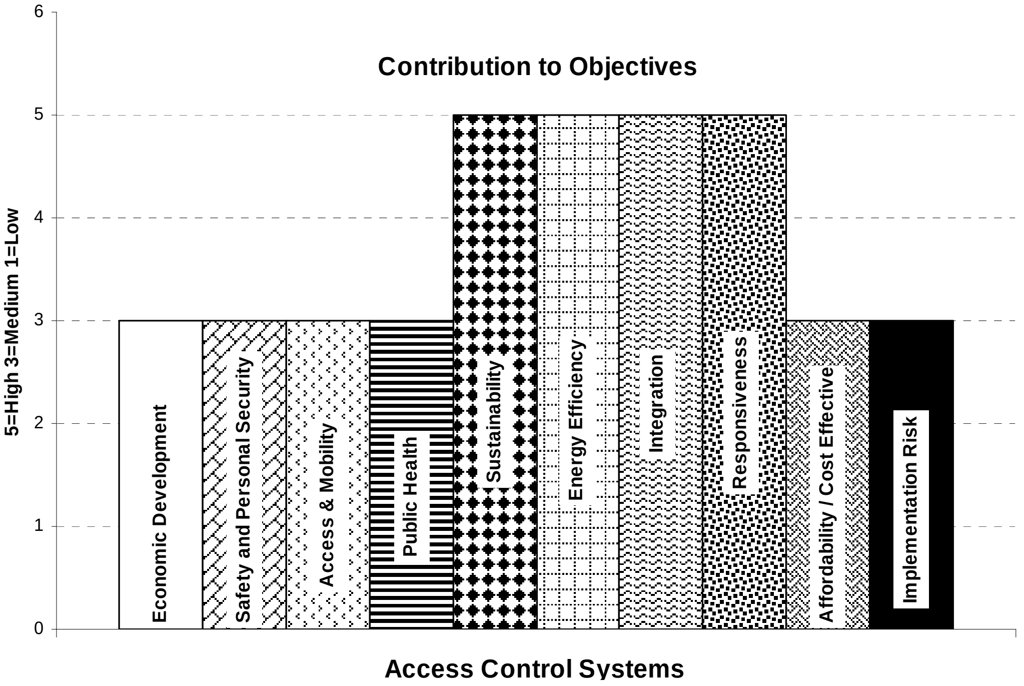


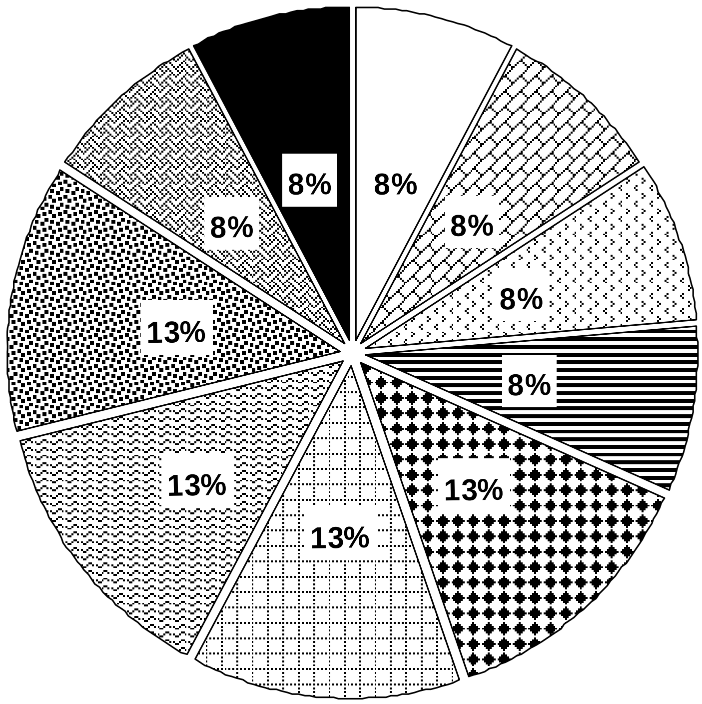


Integrated Urban Traffic Control Systems

Access Control Systems

TOTAL 38

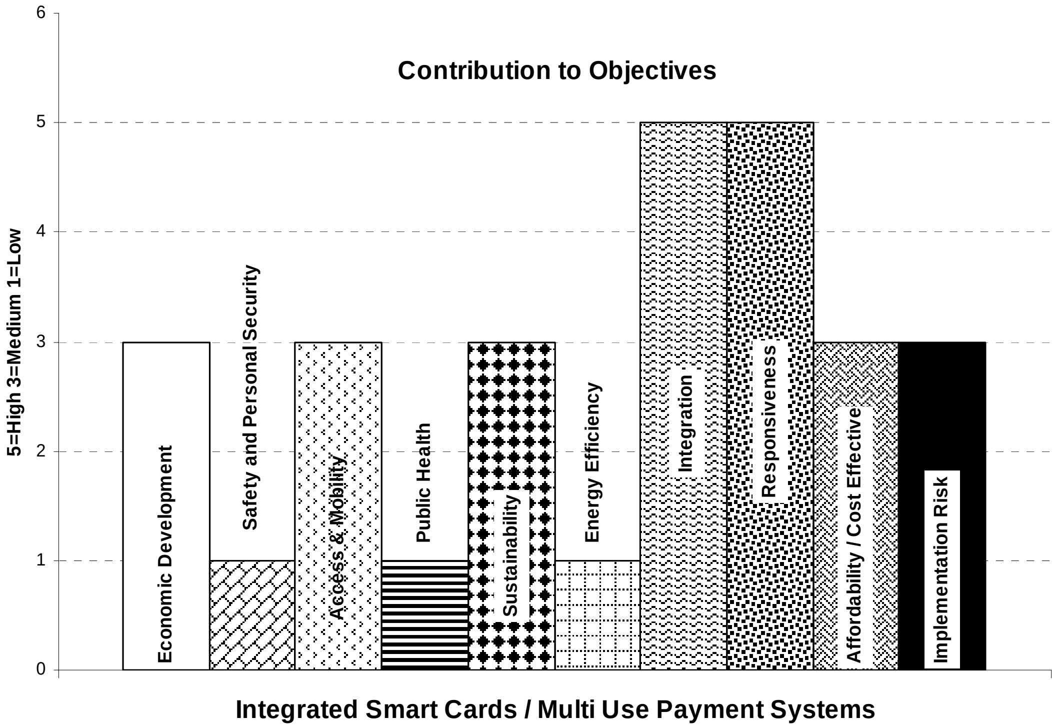


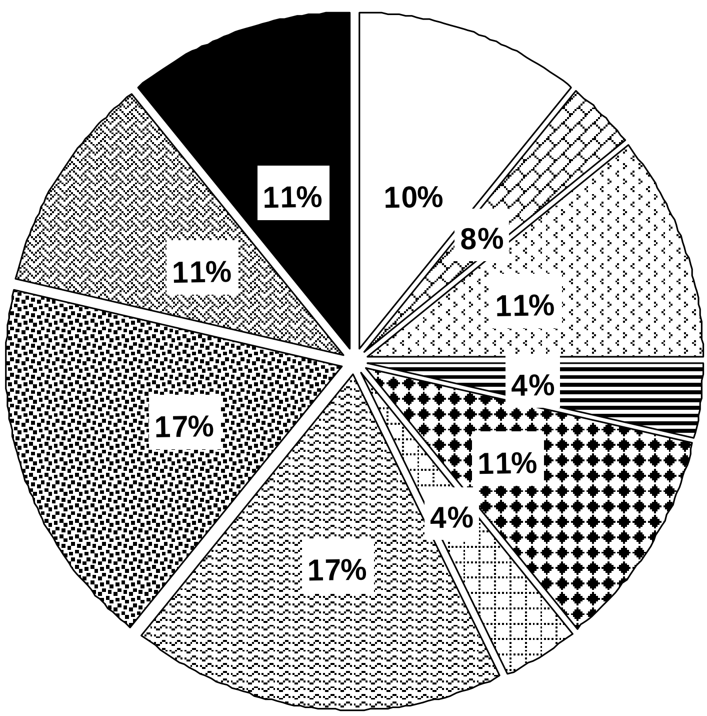


Integrated Urban Traffic Control Systems

Integrated Smart Cards / Multi-Use Payment Systems

TOTAL	28





Appendix D

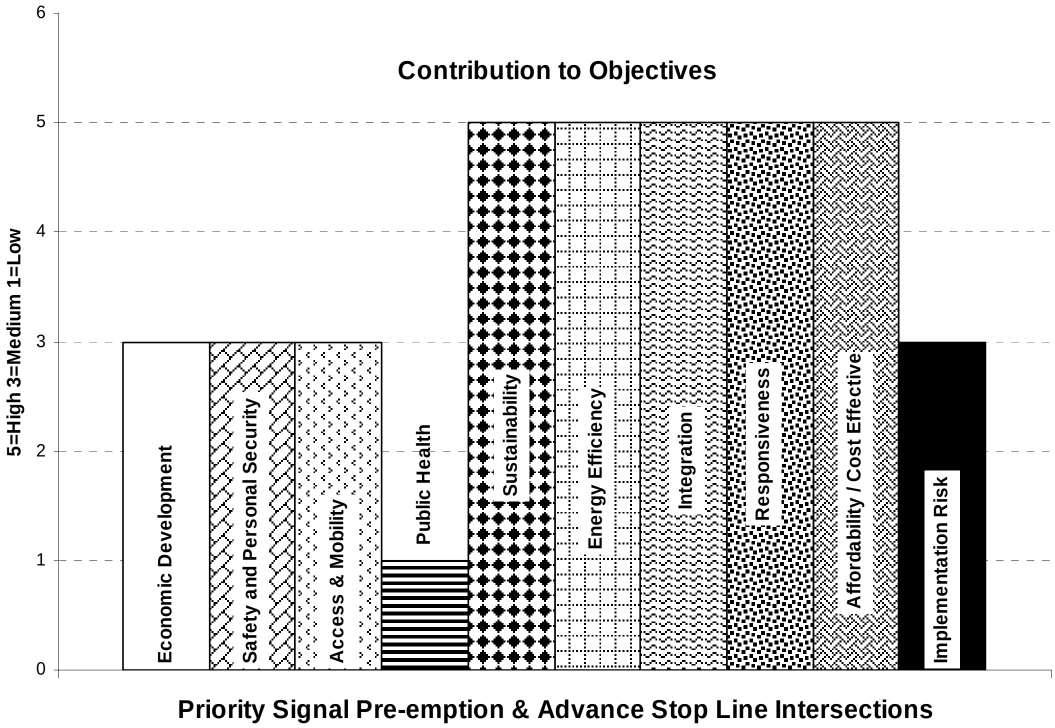
Benefit / Contribution Charts

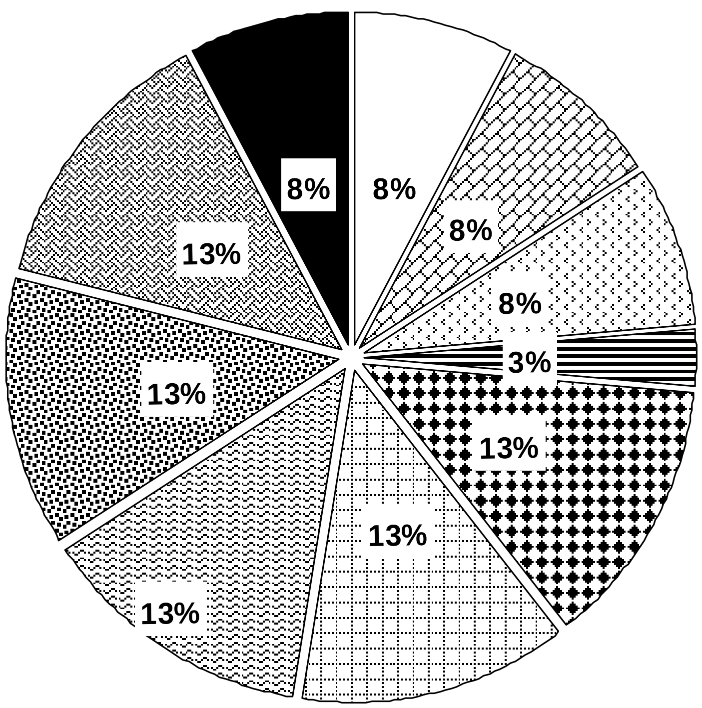
Bus Management Systems

Bus Management Systems

TOTAL 38

Priority Signal Pre-emption and Advance Stop Line Intersection

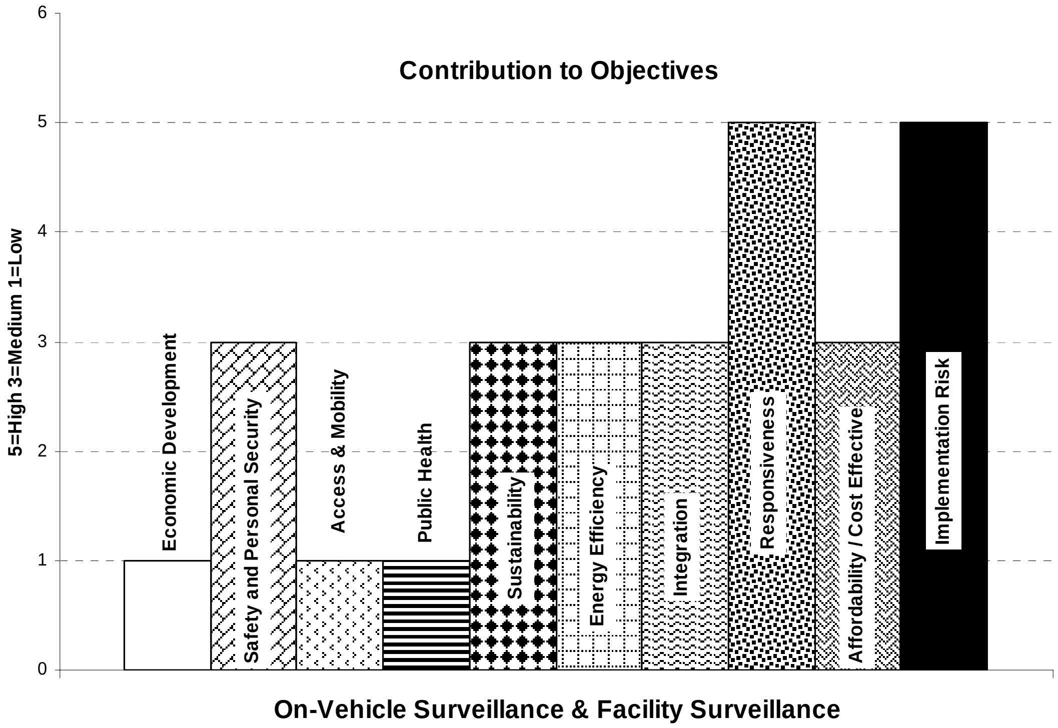


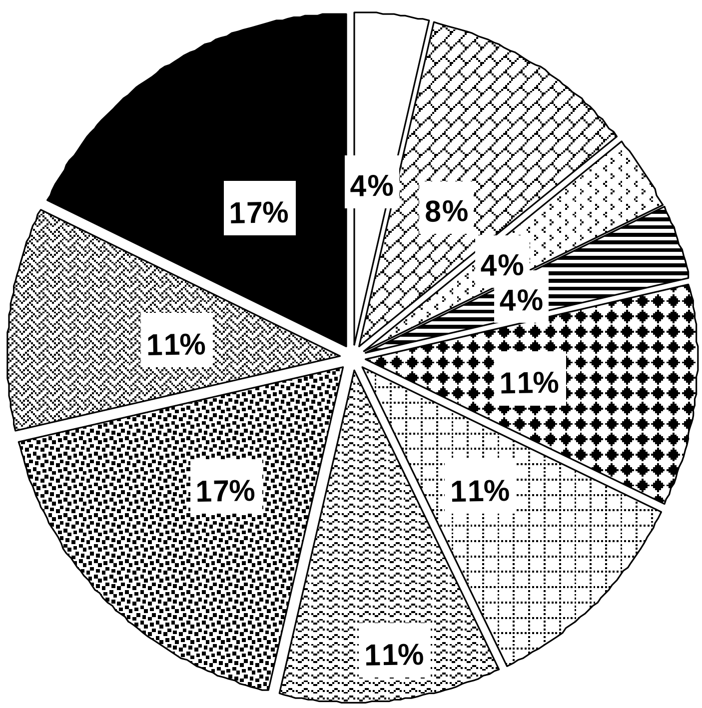


Bus Management Systems

On-Vehicle and Facility Surveillance

TOTAL 28

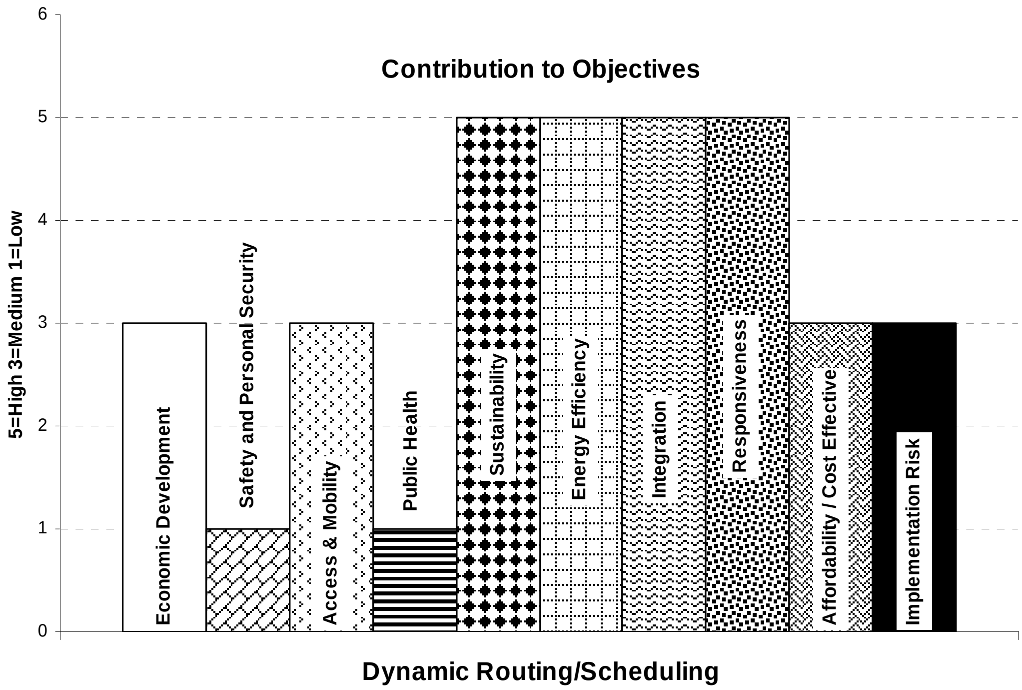


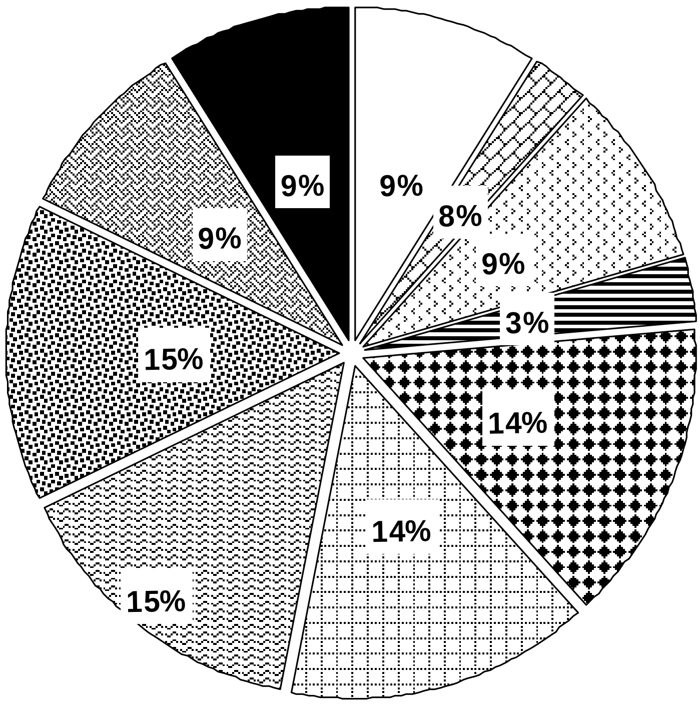


Bus Management Systems

Dynamic Routing / Scheduling

TOTAL	34





Appendix E

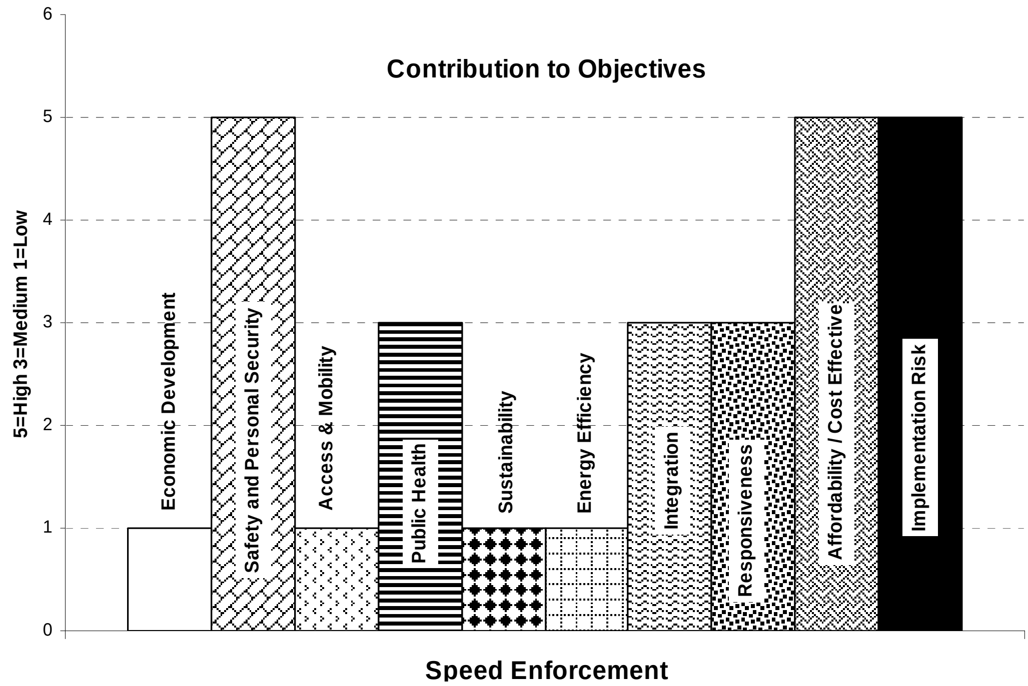
Benefit / Contribution Charts

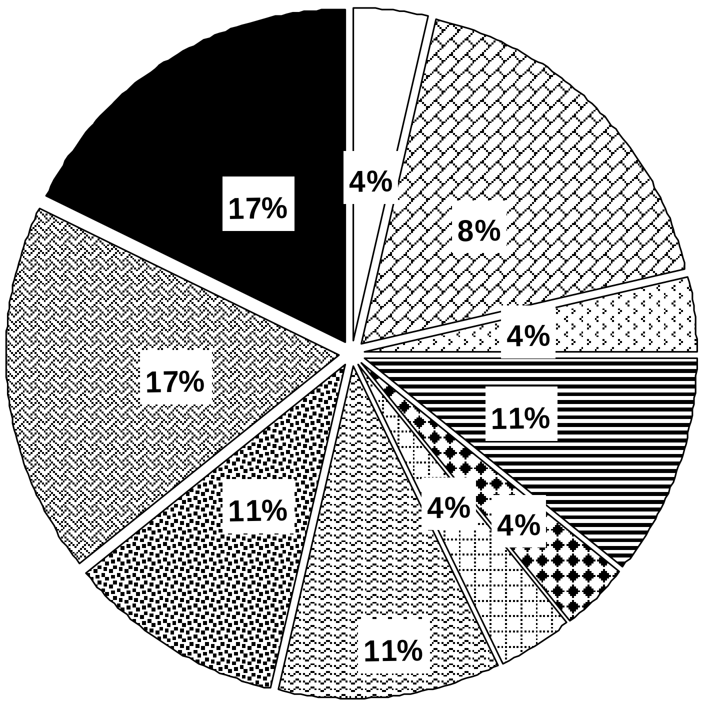
Rural Highway Systems

Rural Highway Systems

Speed Enforcement

TOTAL 28

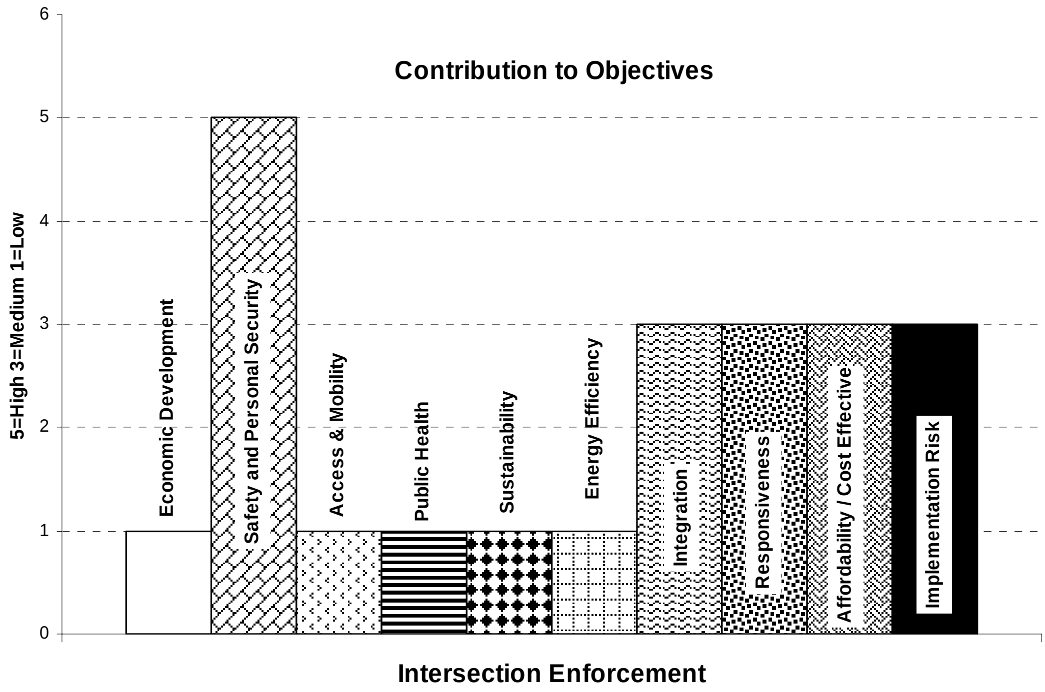


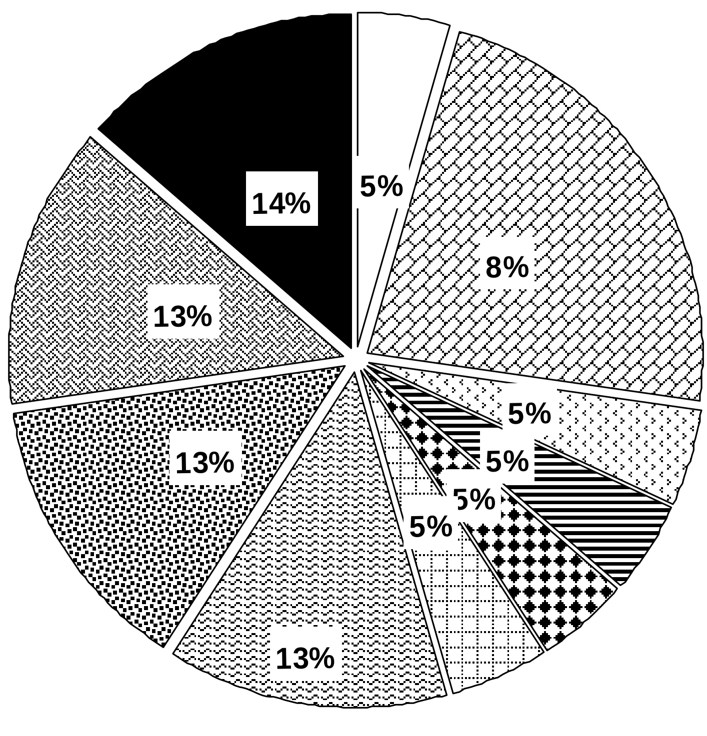


Rural Highway Systems

Intersection Enforcement

TOTAL 22

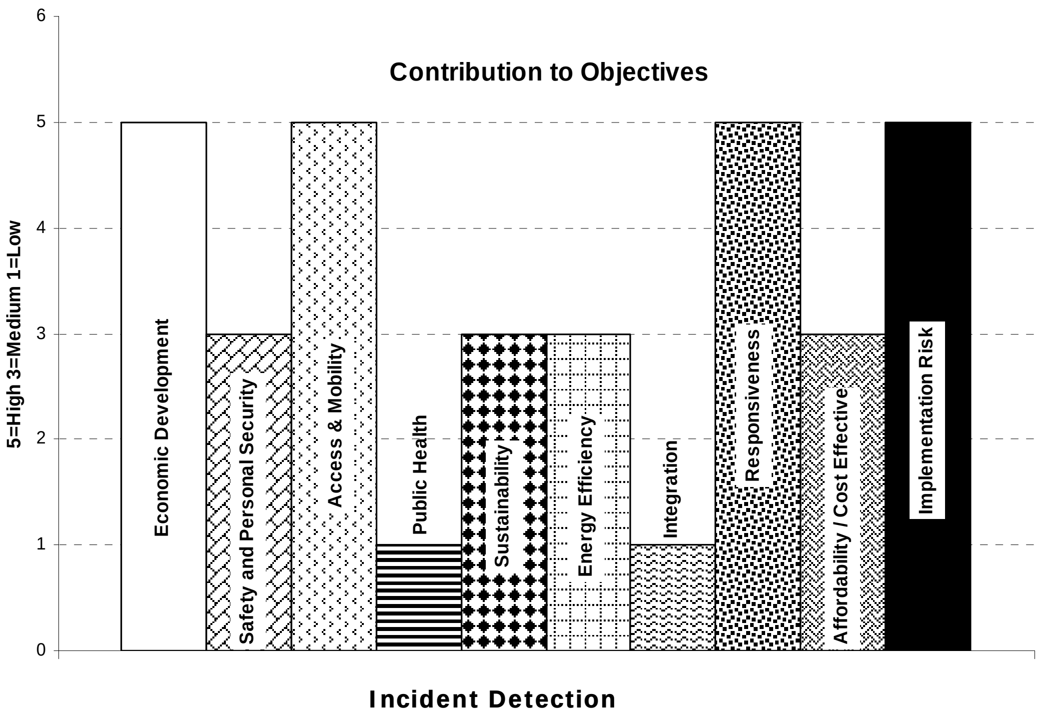


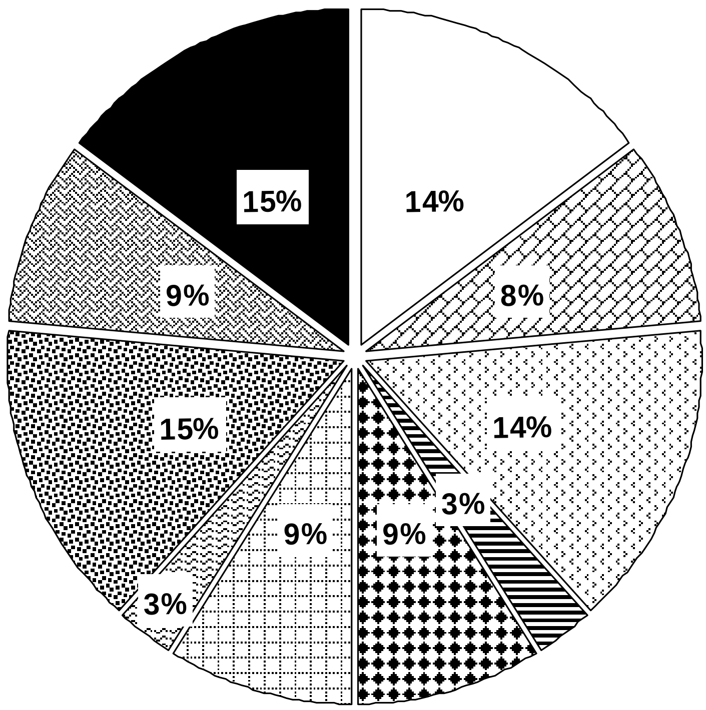


Rural Highway Systems

Incident Detection

TOTAL	34

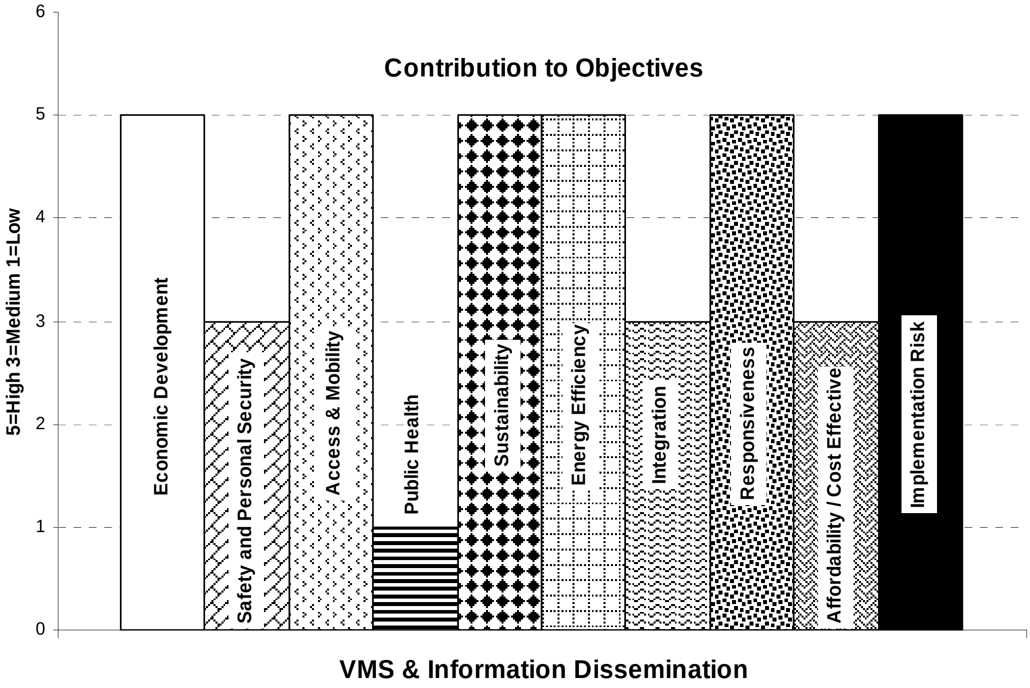


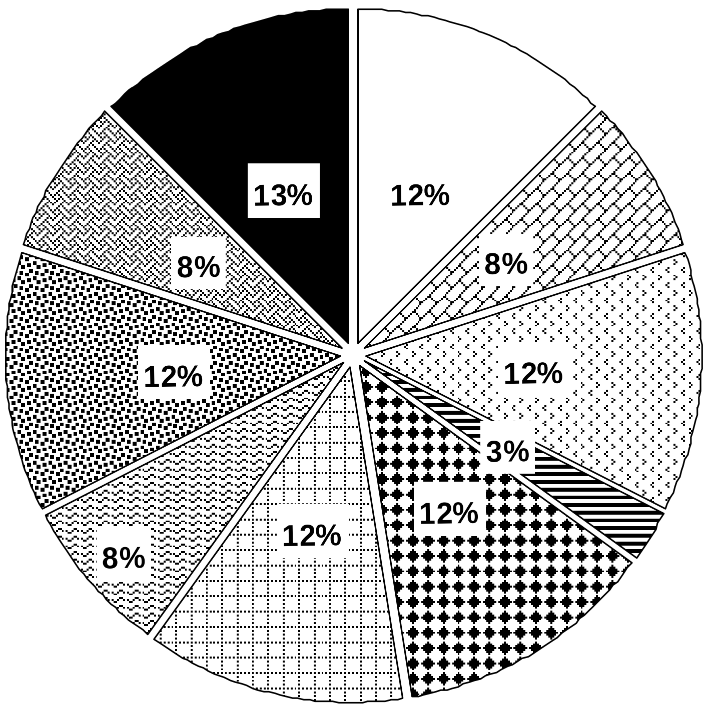


Rural Highway Systems

VMS and Information Dissemination

TOTAL 40

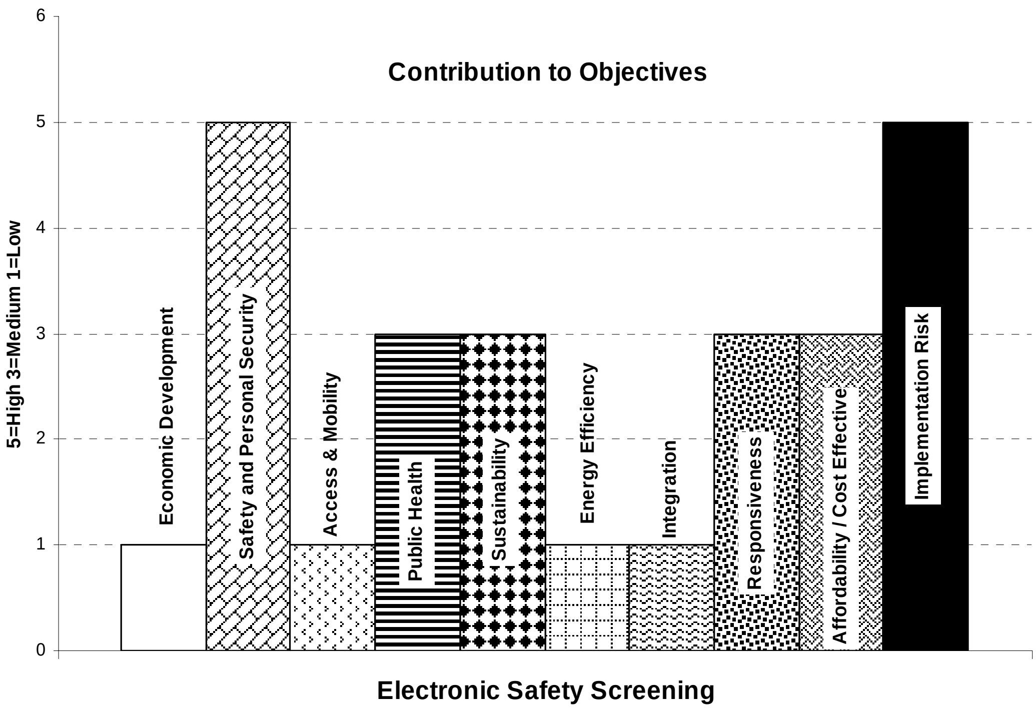


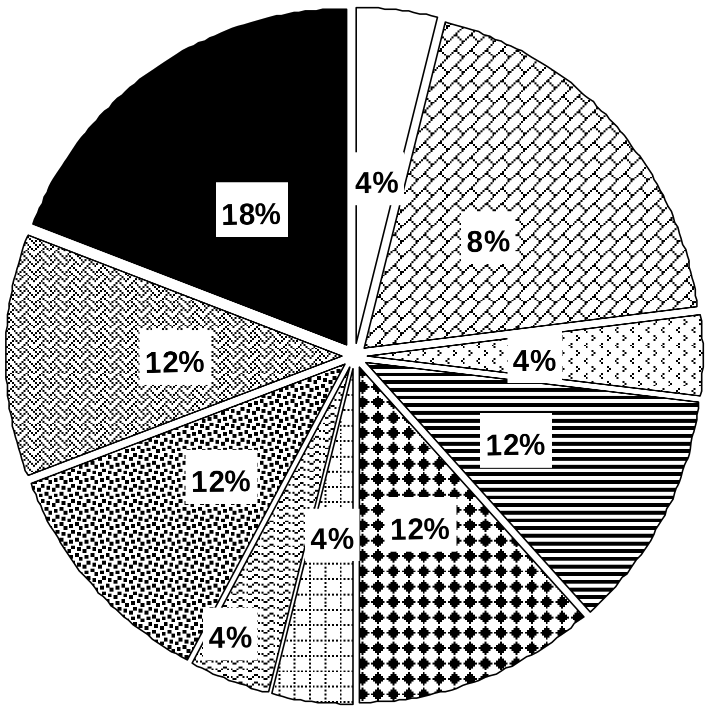


Rural Highway Systems

Electronic Safety Screening

TOTAL 26

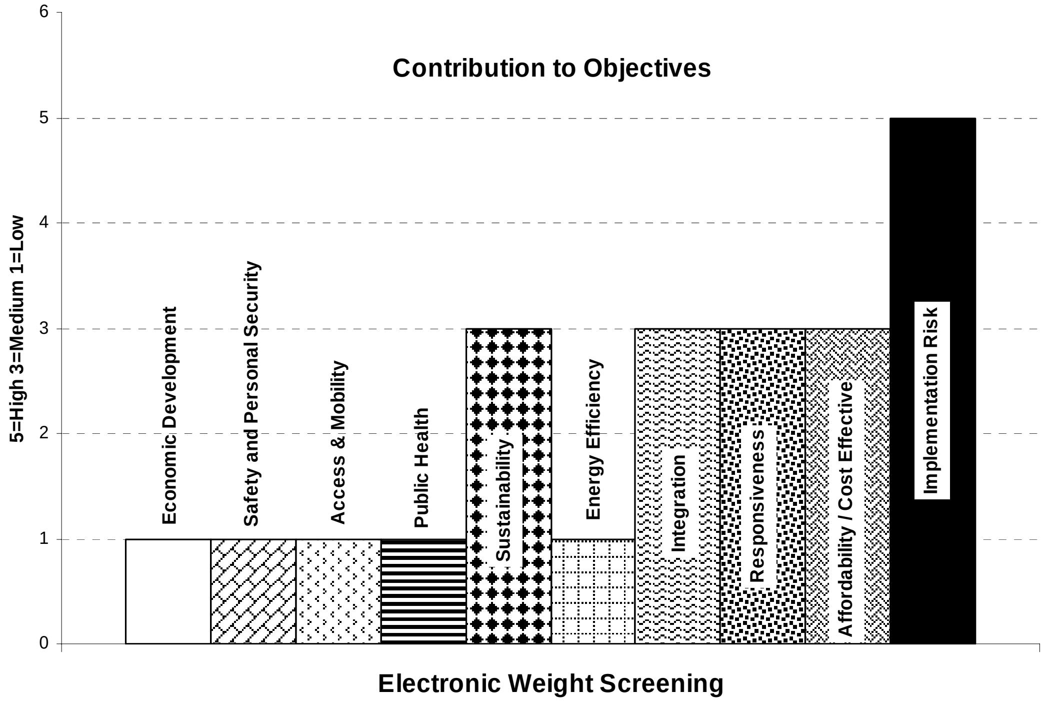


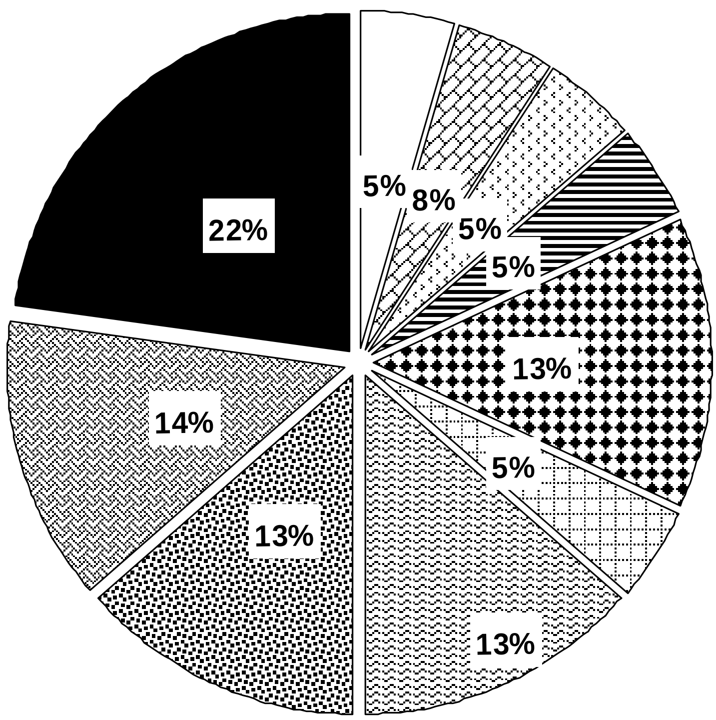


Rural Highway Systems

Electronic Weight Screening

TOTAL 22





Appendix F

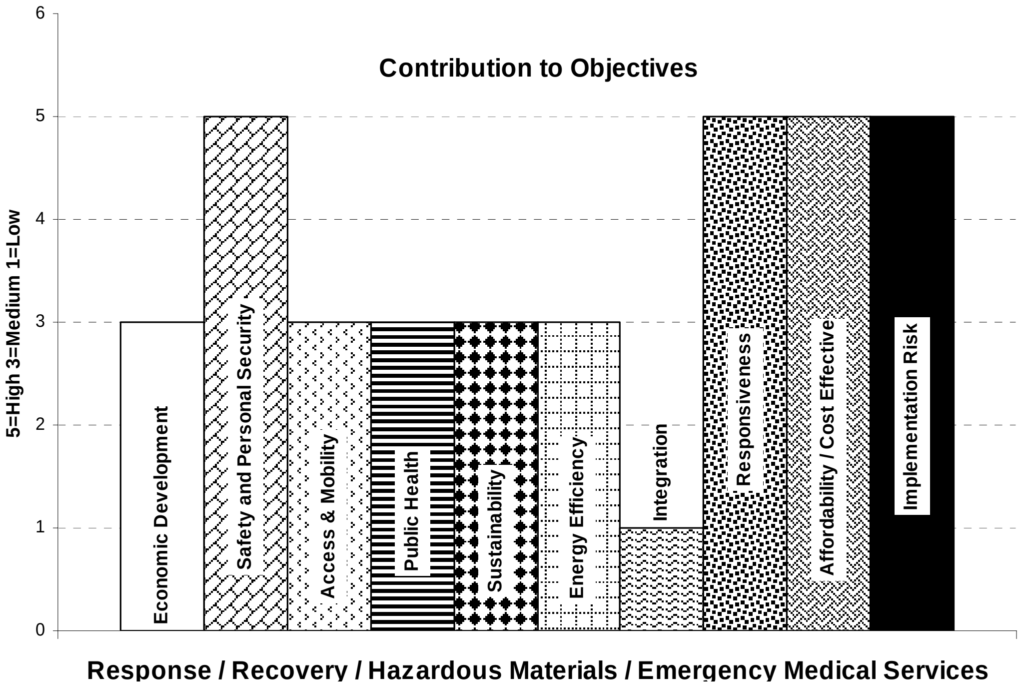
Benefit / Contribution Charts

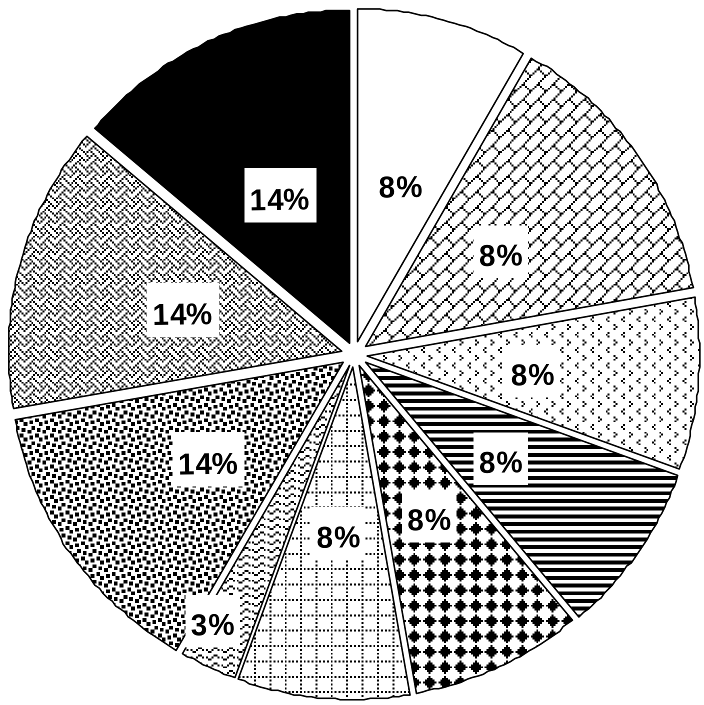
Emergency Management Systems

Emergency Management Systems

Mobilisation, Response and Recovery / Hazardous Materials Management / Emergency Medical Services

TOTAL 36





Appendix G

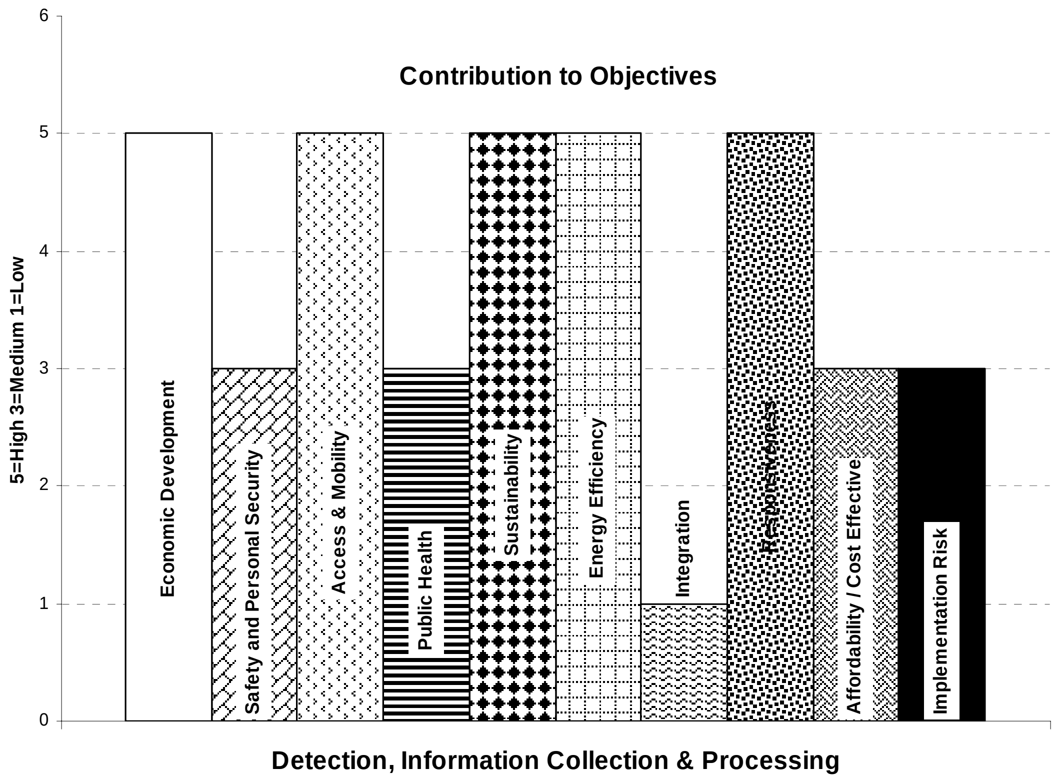
Benefit / Contribution Charts

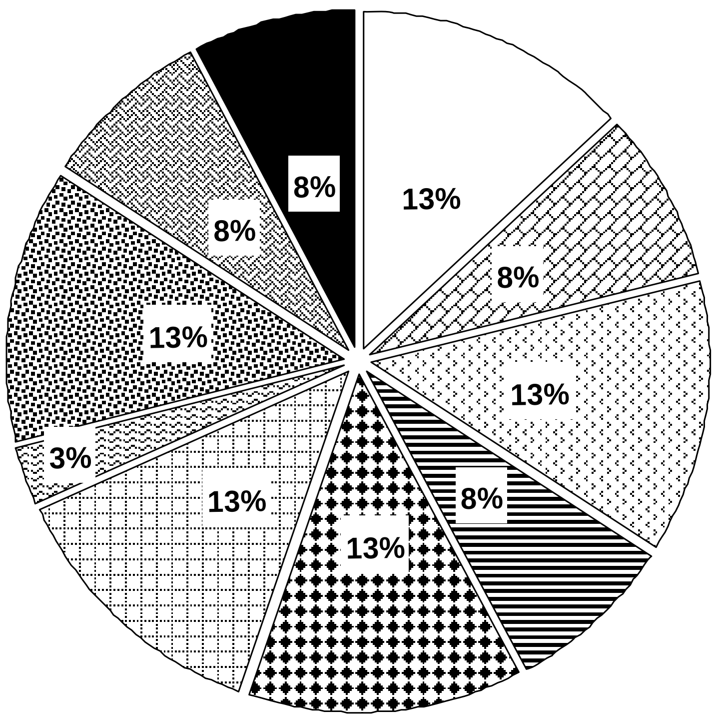
Advanced Traveller Information Systems

Advanced Traveller Information Systems

Detection, Information Collection and Processing

TOTAL	38

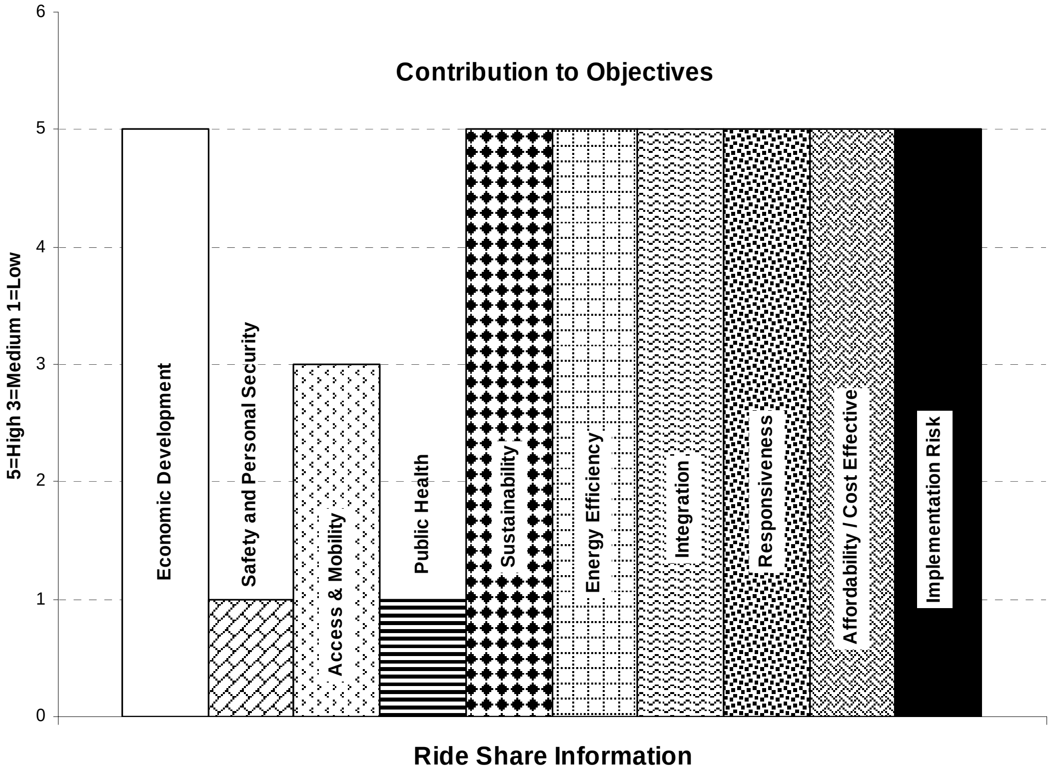


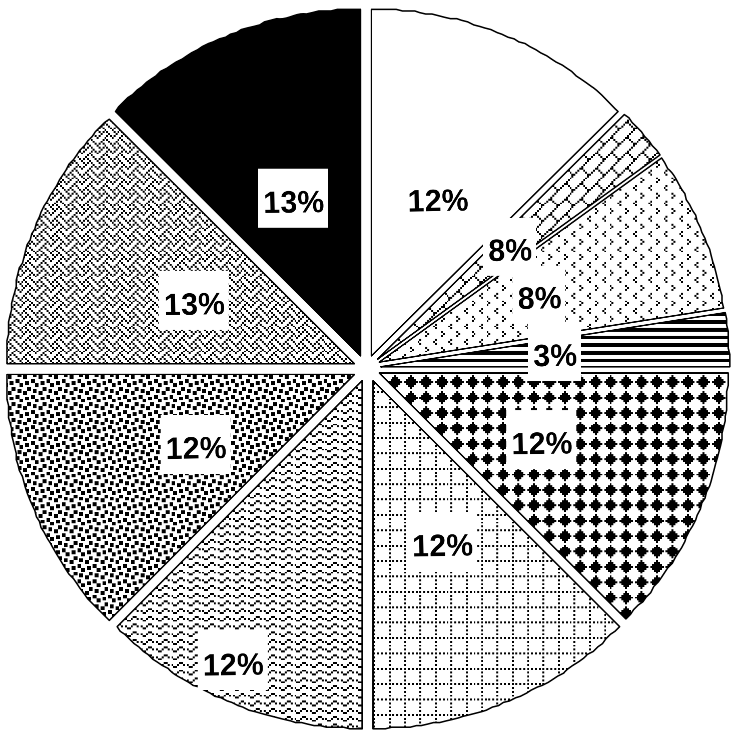


Advanced Traveller Information Systems

Ride Share Information

TOTAL 40

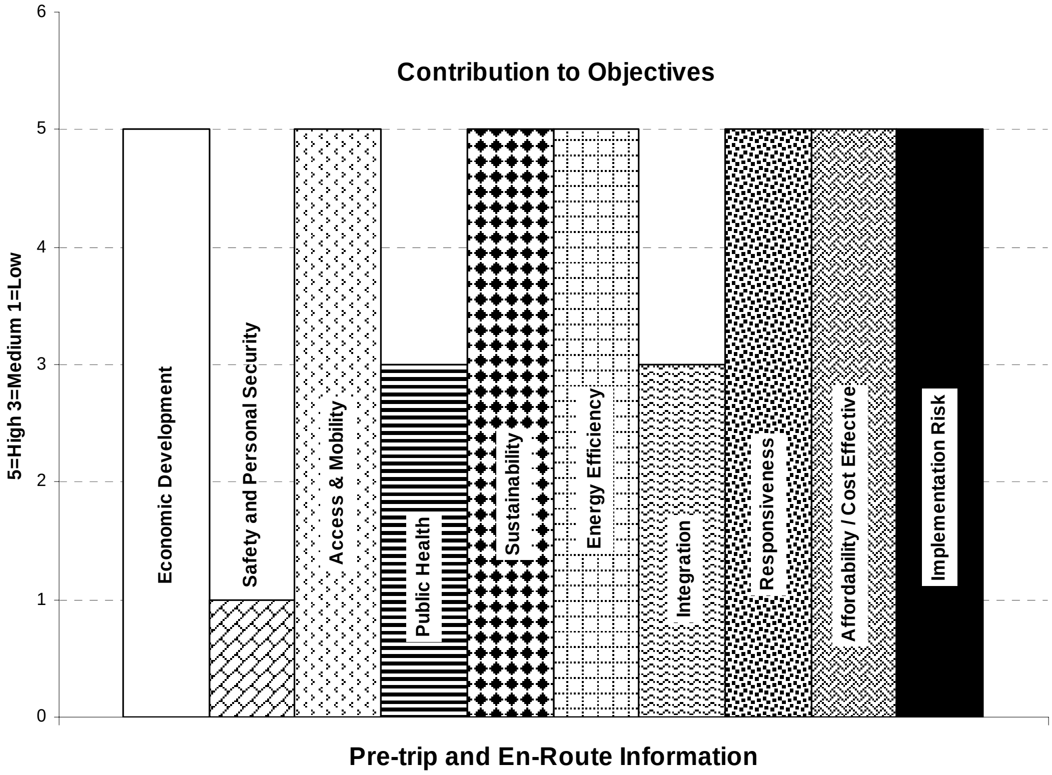


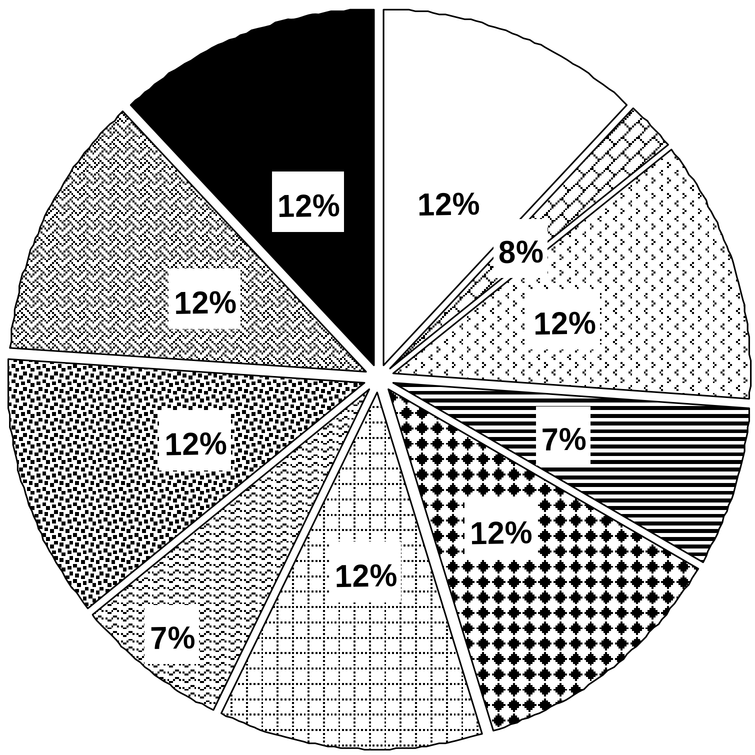


Advanced Traveller Information Systems

En-Route and Pre-Trip Information

TOTAL 42

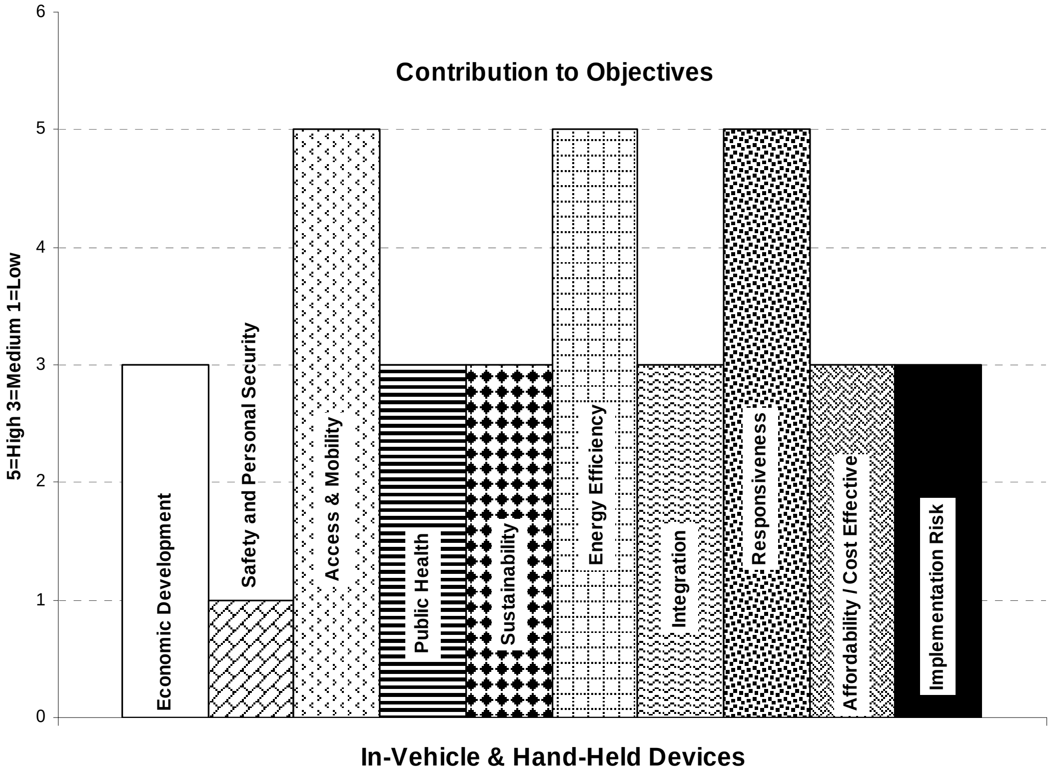


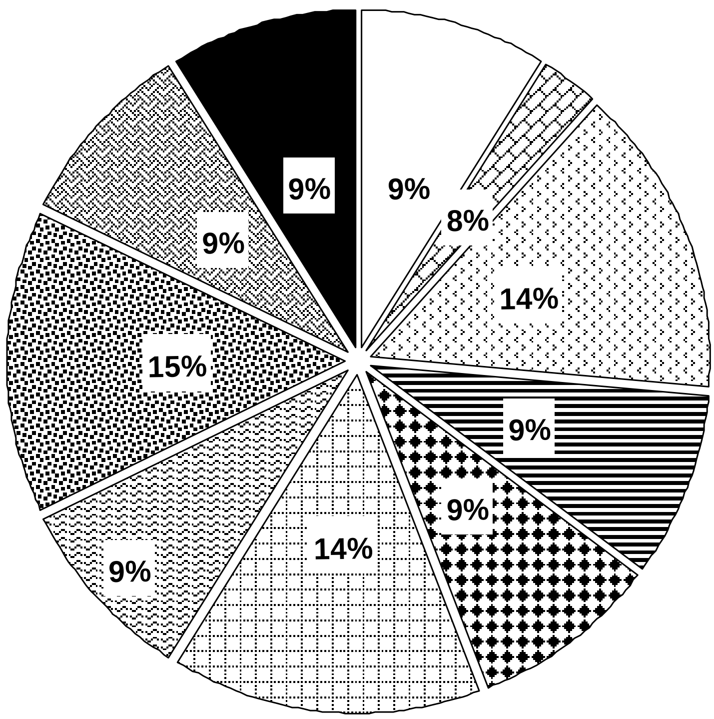


Advanced Traveller Information Systems

In-Vehicle and Handheld Devices

TOTAL 34





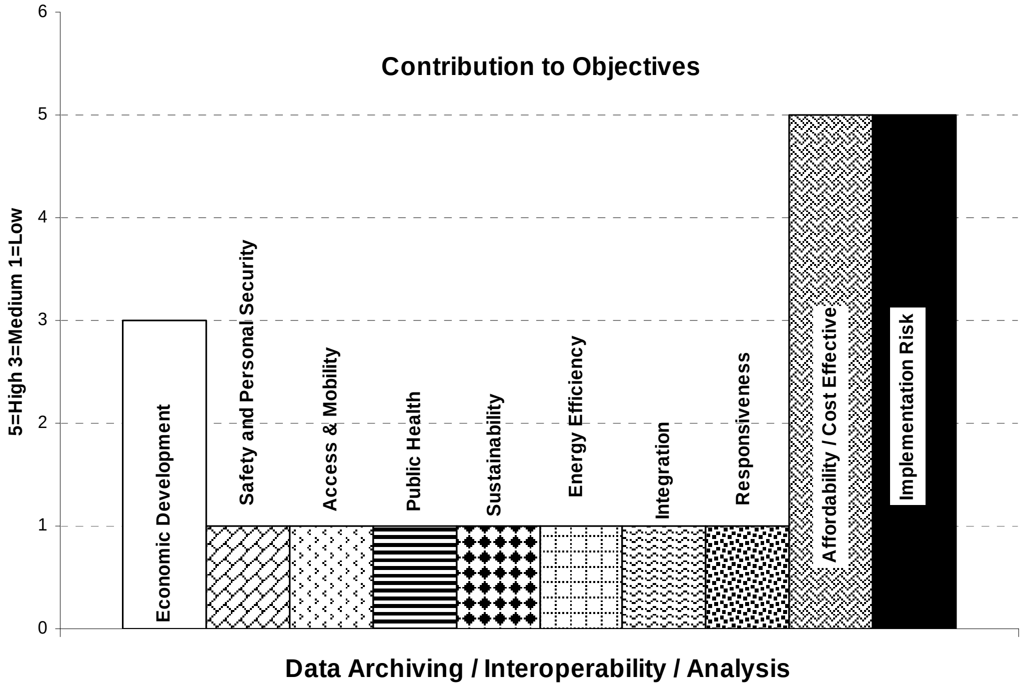
Appendix H

Benefit / Contribution Charts

Information Management

Information Management
Data Archiving / Interoperability / Analysis

TOTAL 20



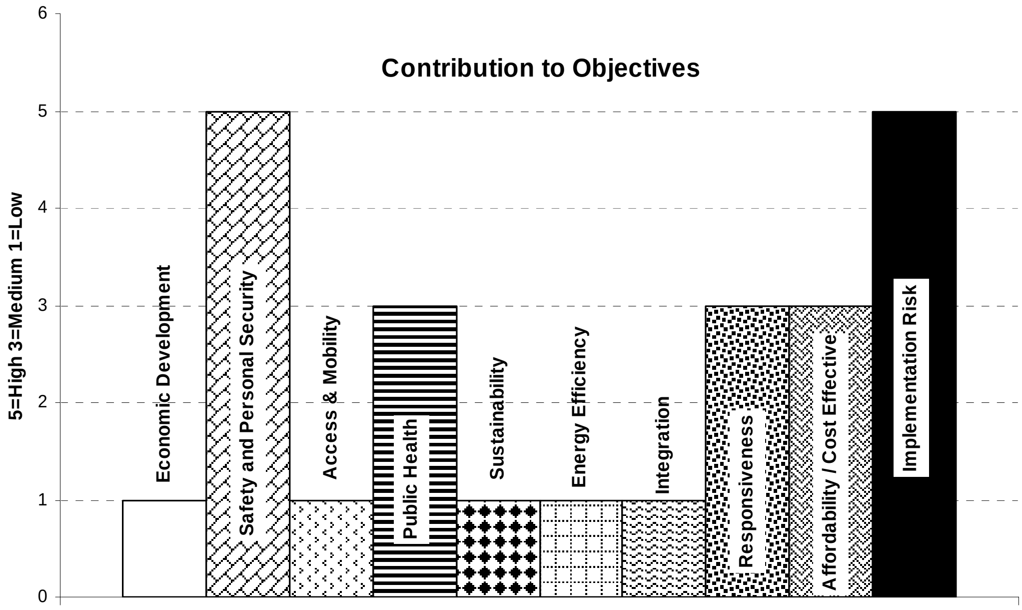
Appendix I

Benefit / Contribution Charts

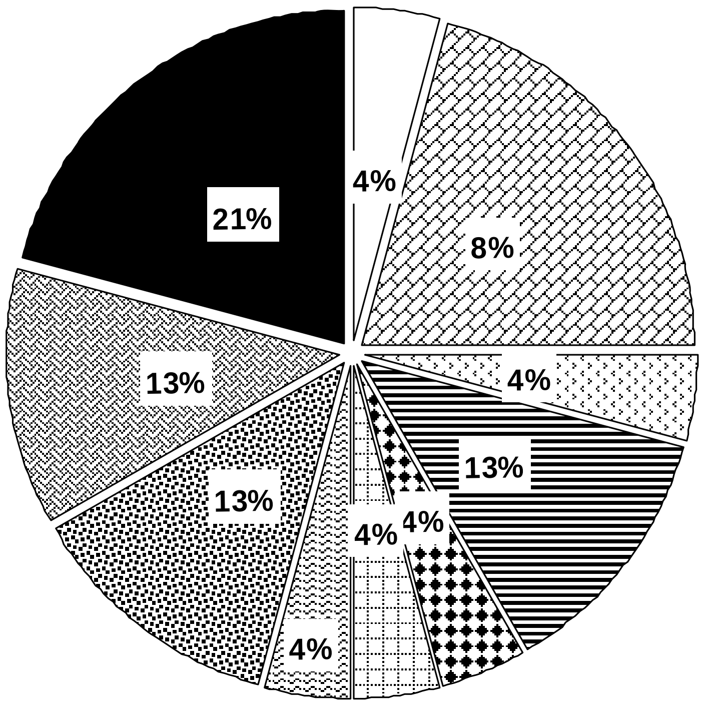
Crash Prevention and Safety

Crash Prevention and Safety
Road Geometry Warning Systems: Ramp Rollover / Curve Speed / Downhill Speed

TOTAL	24

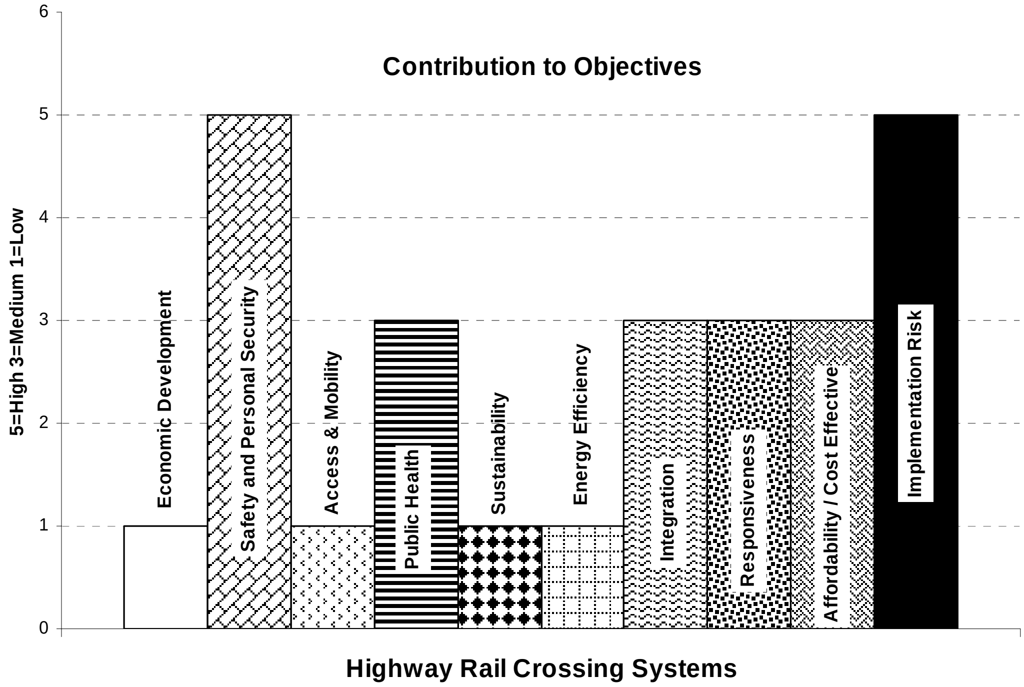


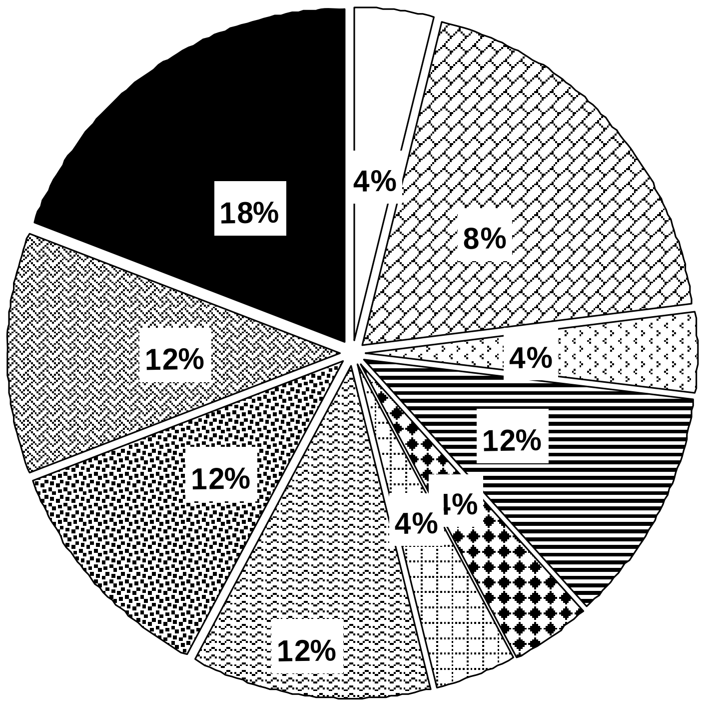
Road Geometry Warning Systems: Ramp Rollover / Curve Speed / Downhill Speed



Crash Prevention and Safety
Highway Rail Crossing Systems

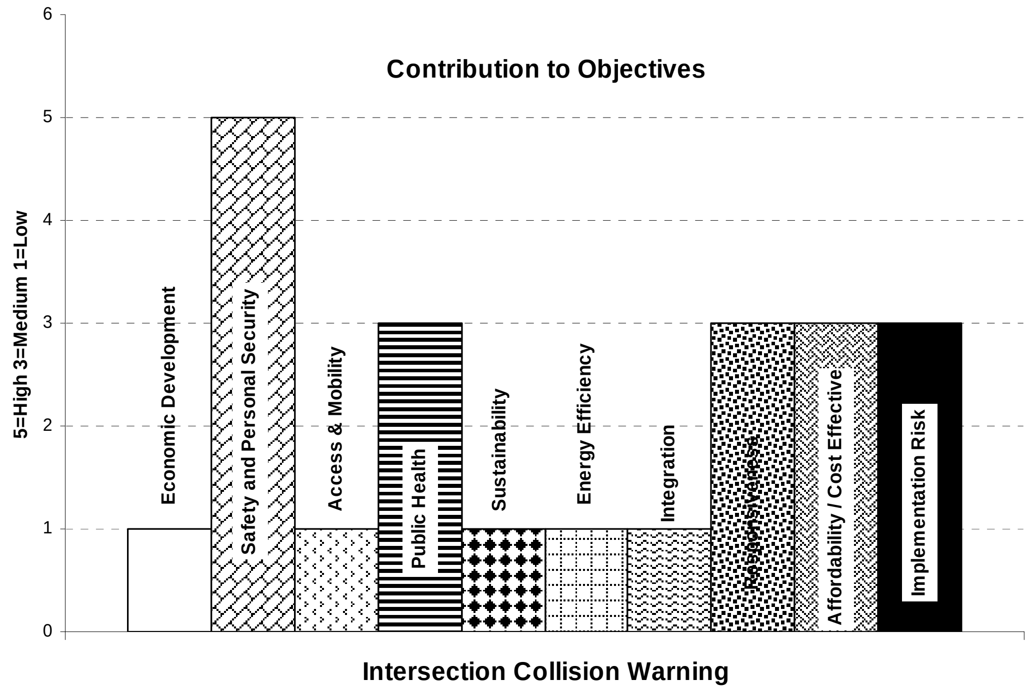
TOTAL 26

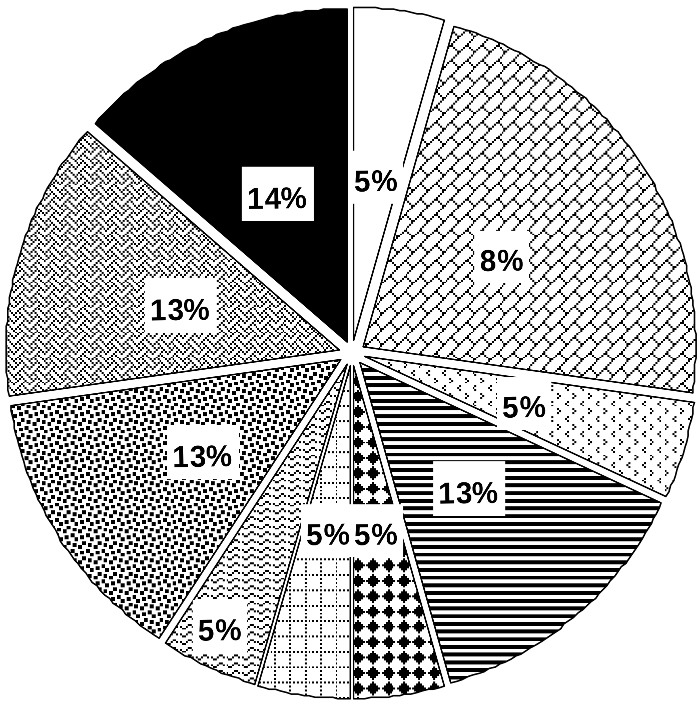




Crash Prevention and Safety
Intersection Collision Warning

TOTAL 22





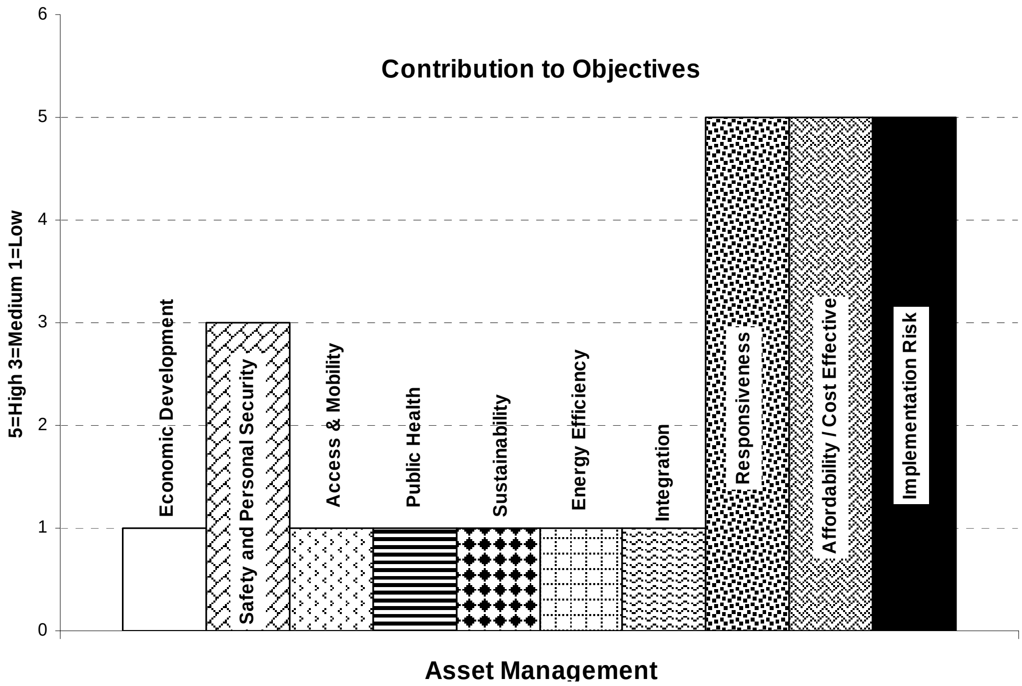
Appendix J

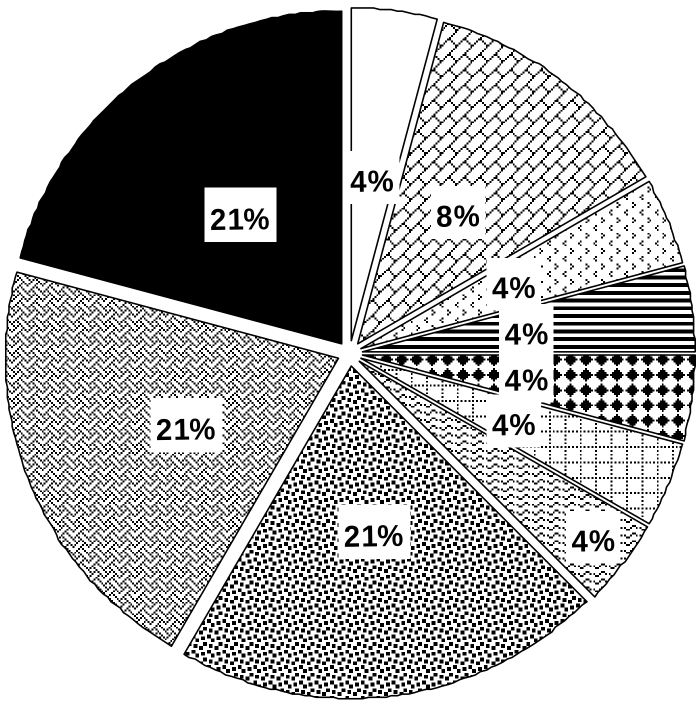
Benefit / Contribution Charts
Roadway Operations and Maintenance

Roadway Operations and Maintenance

Asset Management

TOTAL 24

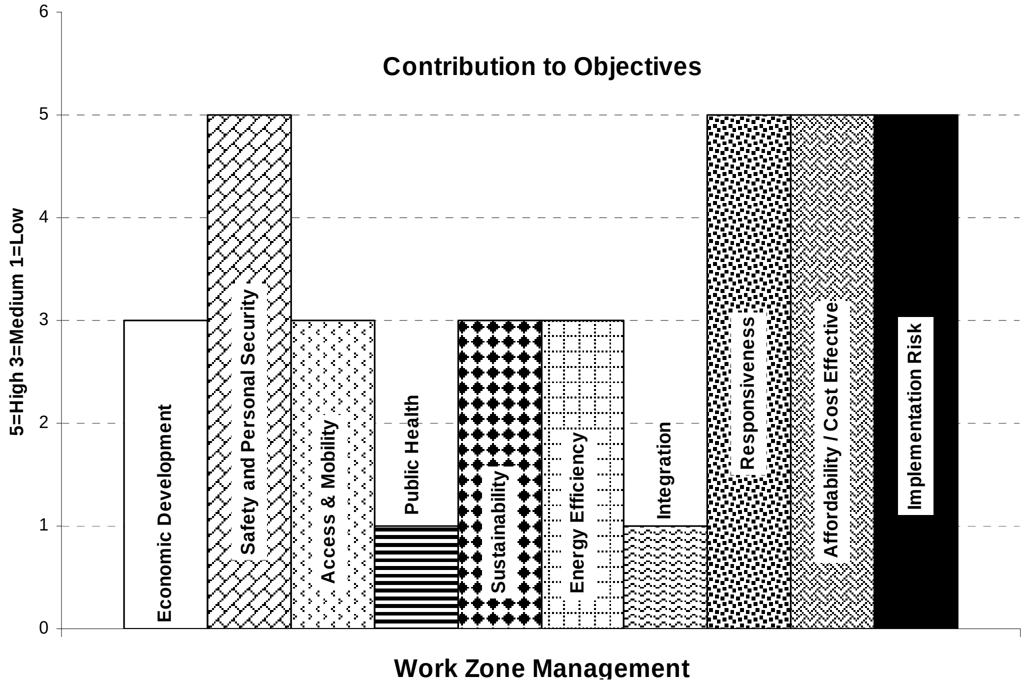


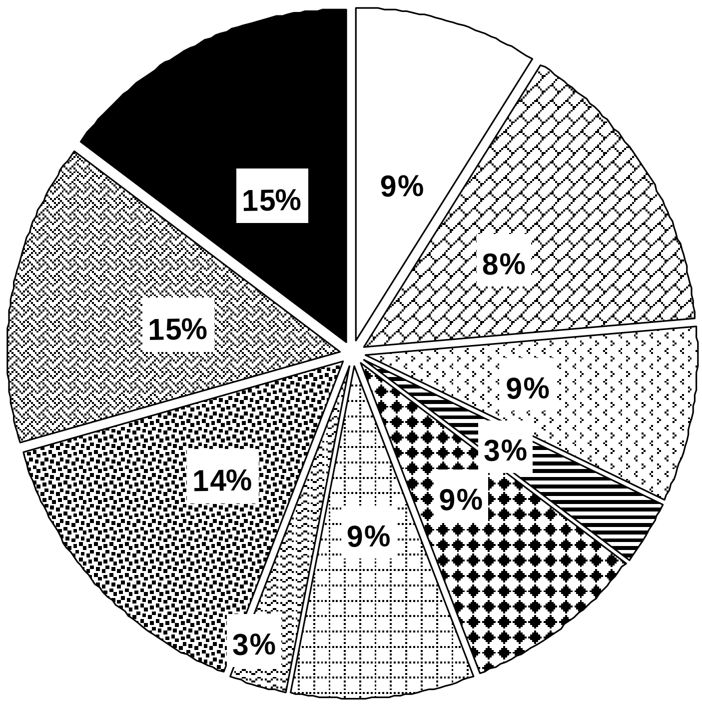


Roadway Operations and Maintenance

Work Zone Management

TOTAL 34





Appendix K

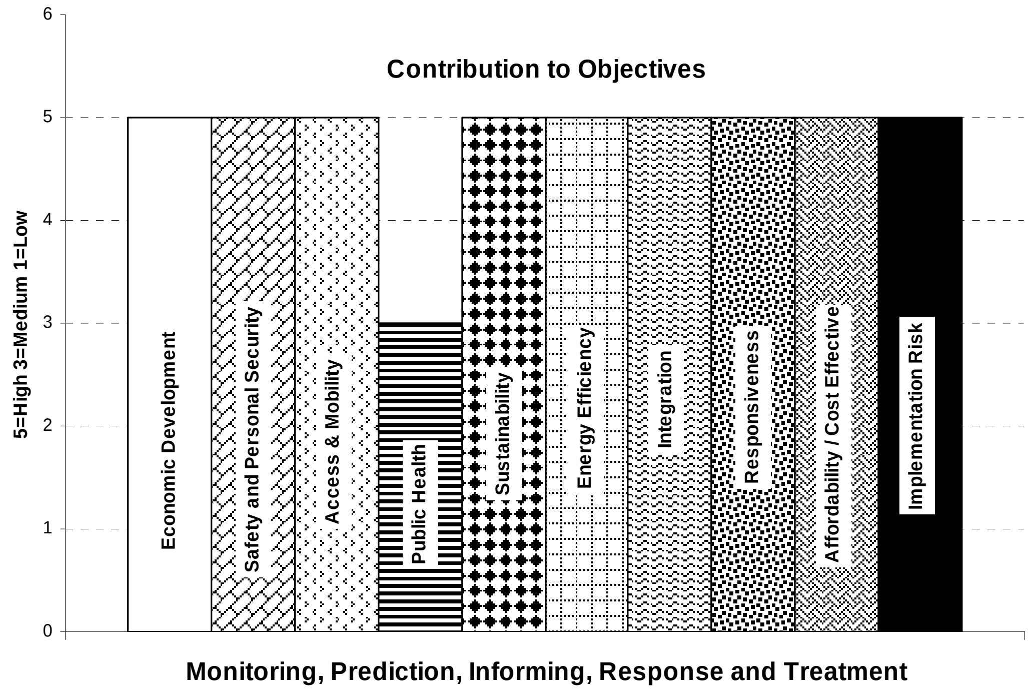
Benefit / Contribution Charts

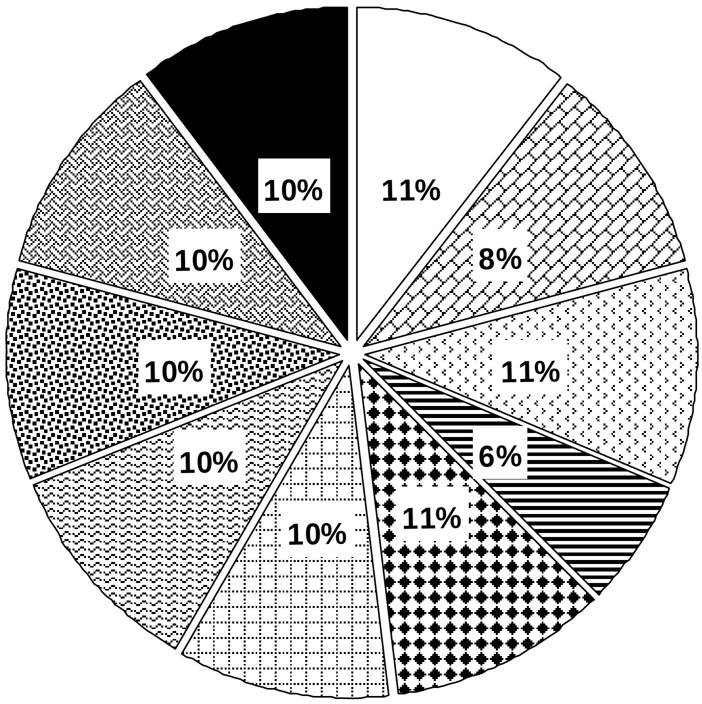
Road Weather Conditions Management

Road Weather Conditions Management

Road Weather Conditions Management

TOTAL 48





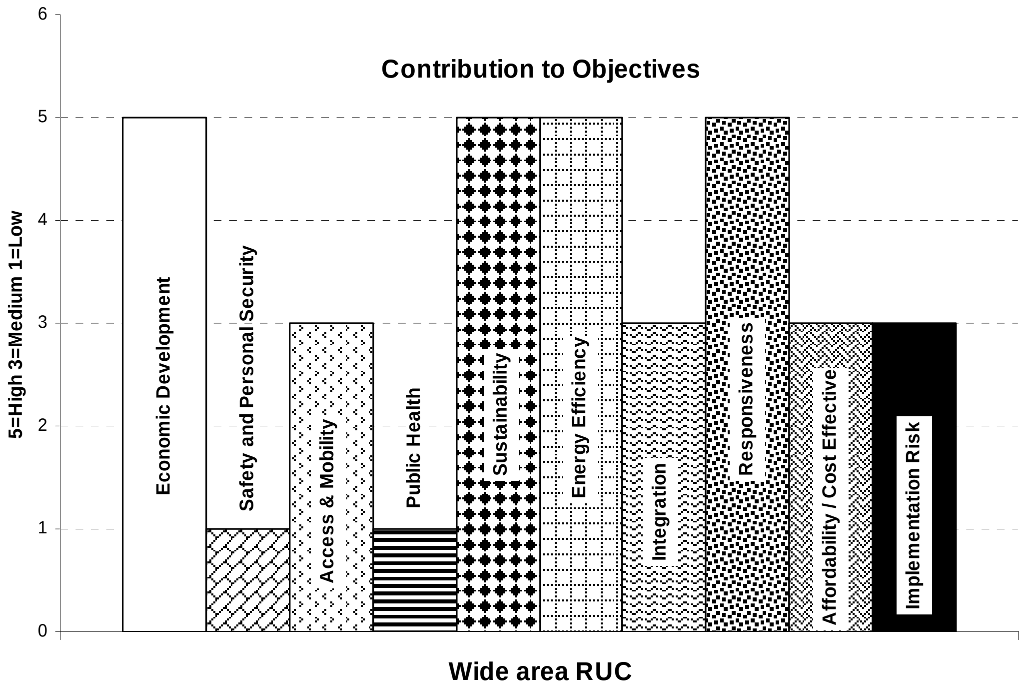
Appendix L

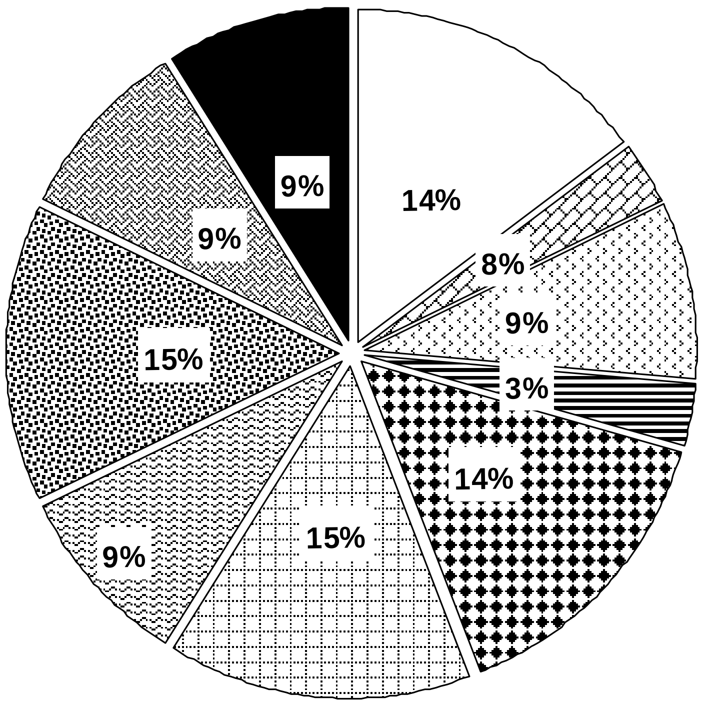
Benefit / Contribution Charts
Electronic Road User Charging

Electronic Road User Charging

Wide Area RUC

TOTAL 34

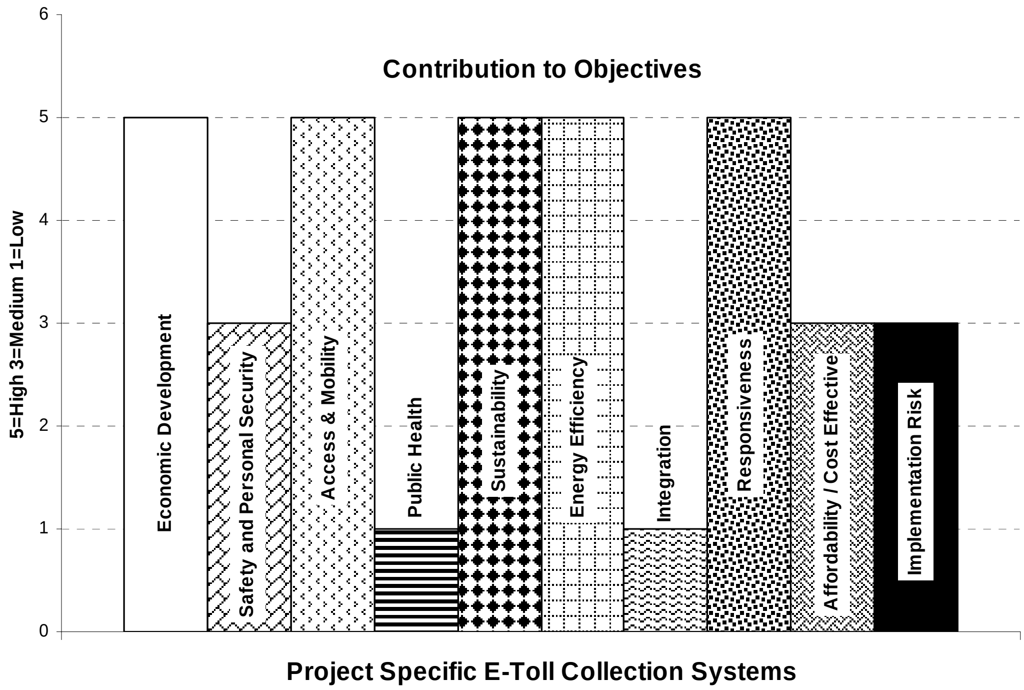


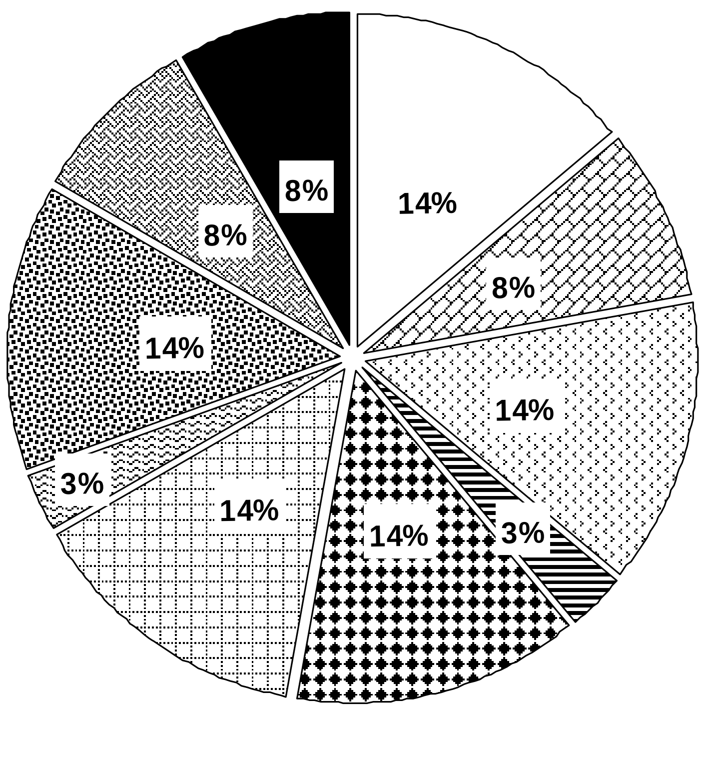


Electronic Road User Charging

Project Specific E-Toll Collection Systems

TOTAL 36

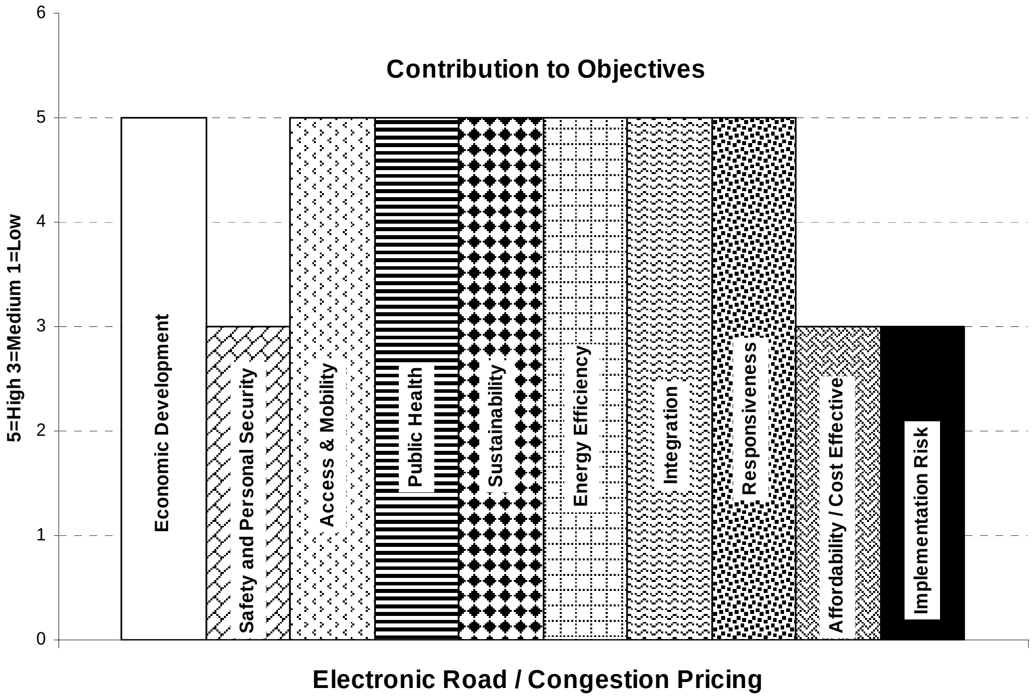


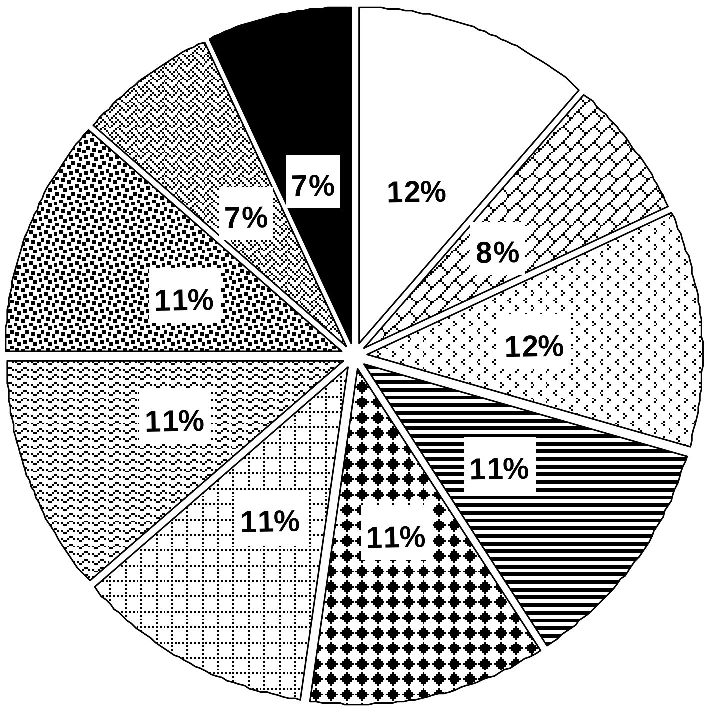


Electronic Road User Charging

Electronic Road / Congestion Pricing

TOTAL 44





Appendix M

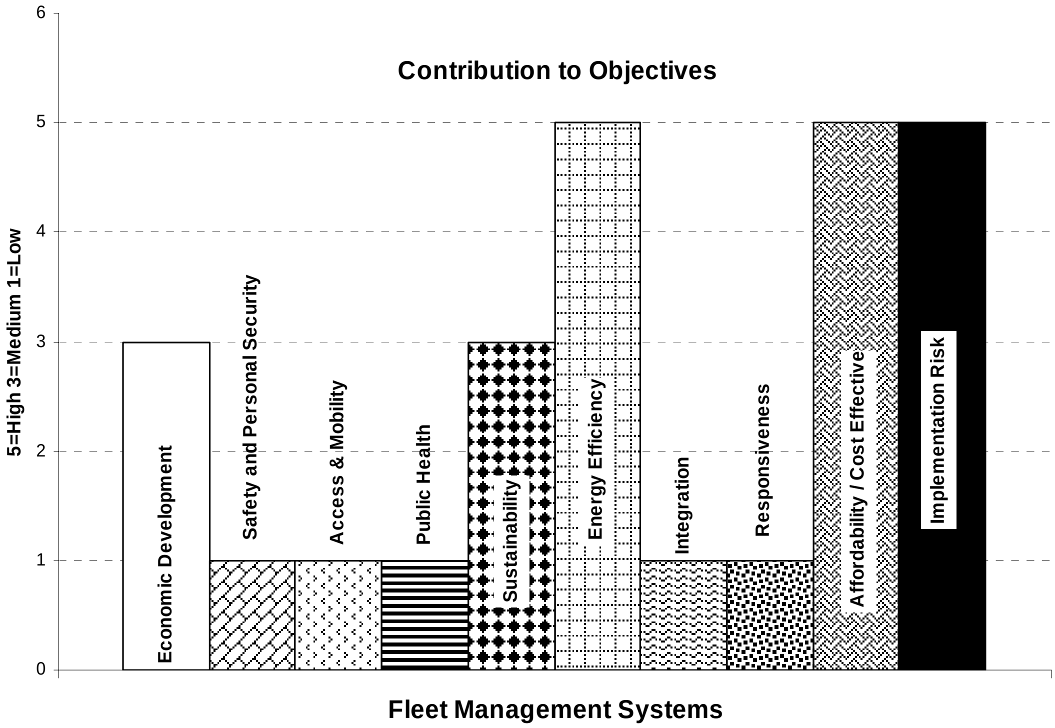
Benefit / Contribution Charts

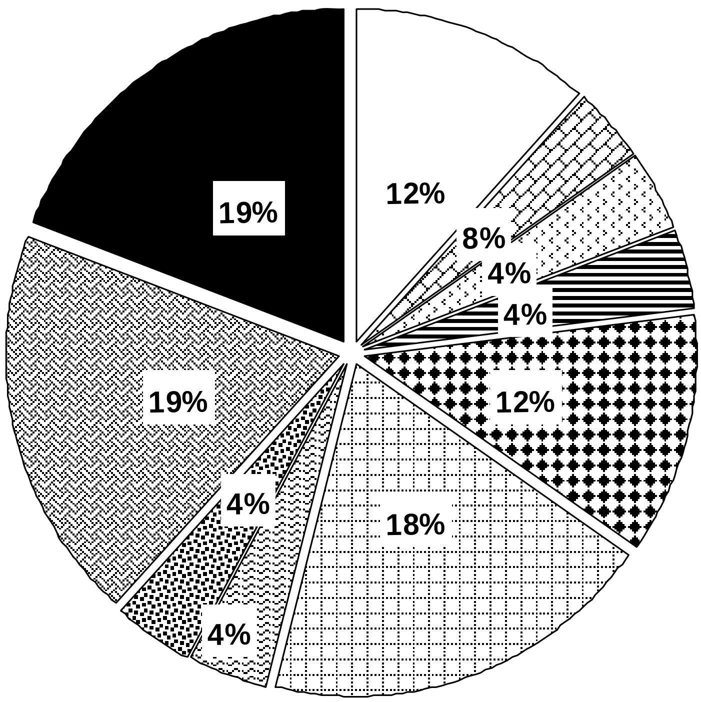
Fleet Management Systems

Fleet Management Systems

Fleet Management Systems

TOTAL	26





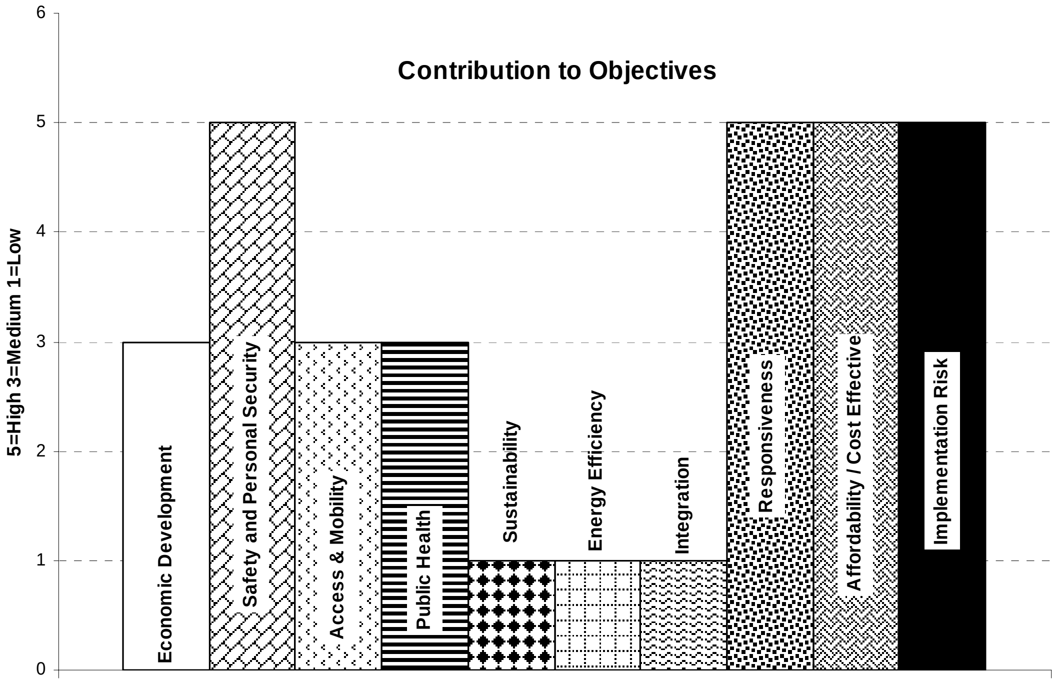
Appendix N

Benefit / Contribution Charts
Tunnel Management Systems

Tunnel Management Systems

Tunnel Management Systems

TOTAL 32



Surveillance, Fire Systems & Response Coordination