Literature review of the costs and benefits of traveller information projects

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Keywords: benefits, costs, information, journey, planning, real-time, systems, technology

An important note for the reader

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Abbreviations and acronyms

CCTV	closed circuit television
DMS	dynamic message signs
EEM	*Economic evaluation manual* (NZ Transport Agency 2013)
GPS	global positioning system/s
HAR	highway advisory radio
IDAS	(ITS) deployment analysis system
ITS	intelligent transport systems
RDS-TMC	radio data system – traffic message channel
RITA	USDOT's Research and Innovative Technology Administration
SCATS	Sydney Coordinated Adaptive Traffic System
TIS	traveller information systems
TOC	traffic operation centres
Transport Agency	New Zealand Transport Agency
TREIS	traffic road event information system
TTS	travel time savings
US DOT	United States Department of Transportation
VHT	vehicle hours travelled
VICS	vehicle information communication system
VII	Vehicle Infrastructure Integration (initiative)
VMS	variable message sign
V2V	vehicle to vehicle communication
WS DOT	Washington State Department of Transport

Contents

Executive summary

Traveller information systems (TIS) are focused on information dissemination and are the mechanism by which information about the road network and public transport systems, once collected, is distributed to travellers. TIS can be used to convey a broad array of information about the operation of the transport network including public transport schedule adherence, traffic congestion, crash locations and travel time.

The rationale for the use of TIS is that better informed travellers are able to make more informed choices about route, travel time and mode of travel. Intelligent transport systems (ITS) achieve this goal through data collection, information assimilation and information dissemination. TIS aim to increase travel efficiency by allowing better utilisation of the existing transportation systems.

The purpose of this literature review is to identify what cost and benefit information is available for operational TIS as reference material for future New Zealand projects.

Despite the abundance of claimed benefits (both direct and indirect) to the public through the use of TIS, very little objective and relevant information is available from around the world about the tangible and measurable financial benefits. The costs for TIS equipment can be established with relative ease. Due to the intangible value of TIS benefits, the preparation of a business case for installation is not a simple matter.

The literature review was conducted with the intent to bring together available information into a single source. The TIS were categorised into urban and rural, pre-journey and en-route and to achieve greater clarity in the evaluation, the benefits and costs were both classified into the sub categories ‘direct’ and ‘indirect’.

It was requested that benefit and cost categories be aligned with the New Zealand Transport Agency (the Transport Agency) (2013) *Economic evaluation manual* (EEM). Therefore, the EEM was used to select the initial cost and benefit parameters for determination of the criteria by which the TIS were to be categorised.

The EEM frequently refers to three metrics:

- travel time savings
- vehicle operating costs
- crash cost savings.

These metrics are retained as the focus of this study to demonstrate the strengths of the various TIS and to ensure alignment with current New Zealand practice.

Two further benefit measures were also included in this study.

- vehicle emission reduction
- customer satisfaction.

There were significant gaps in the literature available for review. The first gap in the review was the lack of information relating to rural TIS and also to services which are specific to New Zealand. Several other literature gaps/inconsistencies also became apparent:

- Social media had very little research material available, which is of no surprise given that the rise in social media has only recently occurred. Hence it would be difficult to capture in the research.
- It was difficult to access literature from non-English speaking countries. Therefore only documents written in English were included in the literature review.

- There was an overwhelming abundance of research from the USA – this may have skewed the results of the research.

A recurring theme in the research was the difficulty of isolating and quantifying the direct benefits obtained from TIS separately from other variables. However, it was also noted that large amounts of information were project or case-based research, which meant the results were real and had been tangibly extracted.

Many of the resources were less than five years old, therefore the information gathered from the literature review could be considered current and up to date.

Intuitively and evidentially, there is a perceived tangible value to TIS as travellers are willing to pay for such services within their vehicle or indirectly via handheld devices such as smartphones. However, deriving what these values may be is not easy to establish via existing literature or research.

The reader should note that the applicability of this research (and studies from other countries) did not correlate well to transportation and geography in New Zealand as a whole. This was mainly due to the relatively small size of New Zealand, the dispersed population and the extent of rural areas.

Abstract

The New Zealand Transport Agency selected URS NZ Ltd to conduct a literature review in 2013 to find available cost and benefit information for traveller information systems (TIS) and associated products. The outcome of this literature review will be used as reference material for current traveller information projects and as the basis for future New Zealand TIS projects.

This study aims to begin to fill the knowledge gap in the field of TIS and provide detailed information on the costs and benefits associated with the use of TIS. TIS have been accredited with providing various direct and indirect benefits to the end user during day-to-day journeys and on key transport routes during the pre-trip and en route travel stages. The claim is that TIS increases travel efficiency by better utilising the existing transportation network. The end users of TIS are essentially anyone who needs to travel – no matter what the mode. This includes pedestrians, cyclists, public transport users and drivers: travellers, motorbike riders, motorists, freight operators, commuters, drivers of emergency vehicles and all other drivers. Many governmental organisations as well as transport operators provide TIS which implies there is some perceived merit to the expenditure.

Literature was investigated from New Zealand and around the globe during the course of this project.

1 Introduction

1.1 What are traveller information systems?

Traveller information systems (TIS) are focused on information dissemination and are the delivery mechanism by which information about the road network and public transport systems can be distributed to travellers. TIS can be used to distribute a broad array of information about the operation of the transport network including public transport schedule adherence, traffic congestion, crash locations and travel times.

TIS have been accredited with providing various direct and indirect benefits to travellers (motorists, public transport users, active transport users and freight operators) on day-to-day journeys and along key transport routes during the pre-trip and en-route travel stages. The use of TIS allows travellers to make informed route, time and mode choices. This in turn reduces traffic congestion through distributing traffic more evenly over a network and consequently increases efficiency along key corridors. TIS are discussed in more detail in chapter 3.

1.2 Importance of TIS

In theory, if applied and managed well, TIS have the ability to reduce severe congestion in urbanised areas by informing the user of possible problems with their selected route. If information is provided sufficiently early, access to credible information allows drivers to make alternative choices about their travel route, time and mode. Each person who chooses an alternative travel choice helps ease the potential congestion. Where there is a limited number of alternative routes, there is some reliance on a proportion of motorists not actually following diversionary information, otherwise the alternative route would also become congested with traffic.

Tackling the inefficiency and unreliability caused by delays is an important problem that needs to be addressed. The provision of accurate, relevant and timely information to travellers could be an important tool to alleviate delays, consequently increasing the efficiency and productivity of local and regional transportation networks

The benefits expected from TIS are not restricted to individual car users on the road, but can also have huge benefits to commercial and freight companies when 'just in time' distribution practices are in place. The wide range of TIS now available means that further benefits can be delivered quickly, with an acceleration of value over time, particularly when congestion and/or incidents occur. Therefore TIS have the potential to benefit society as a whole, impacting at the private, public and commercial level.

Usage of TIS is growing around the world as network agencies and public transport operators seek to increase the efficiency and productivity of the existing infrastructure. These services are growing more essential in informing expectations of not only car users, but the freight sector, emergency vehicles and the wider public.

With the increased availability of inexpensive communications and hand-held devices, TIS are substantially less expensive (capital and ongoing costs) than was the case even a few years ago. As the type and volume of information available to hand-held devices is far greater than in the past, it could be argued that the benefits received by the end user continue to increase. Indeed, as the users of mobile devices are prepared to pay for the hardware, communication costs and also specialist software, it must be the case that such users place a tangible value on the information they can receive on such devices.

1.3 Report contents

This report summarises TIS in the New Zealand and international contexts. The following brief summary of each chapter will assist the reader in finding the information they require:

- Chapter 2: Purpose of the literature review. This describes the study scope and objectives.
- Chapter 3: Traveller information systems. This describes more detailed background information on what TIS are and how they fit into the wider intelligent transport systems (ITS) and information gathering process.
- Chapter 4: Literature review methodology. This describes how the literature was sourced.
- Chapter 5: TIS application examples. This details experiences of the implementation of TIS internationally. The chapter is broken down by specific TIS type and is therefore useful for anyone wanting to compare two or more TIS or wanting to improve the operation of a specific TIS.
- Chapter 6: Benefits and costs. This describes how each of the relevant benefits and costs are achieved/incurred by TIS. TIS costs are also considered.
- Chapter 7: Conclusions and recommendations. This sets out recommendations for further investigation and conclusions drawn from the literature review.

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2 Purpose of the literature review

2.1 Study motivation

Limited documented research exists to assist with identifying the tangible and measurable benefits associated with TIS. Perhaps this indicates that such benefits are not easy to derive in an objective manner on a scientific and/or cost-effective basis. Conversely, the derivation of costs, both capital and reserve, can be calculated with ease. The combination of these factors makes financial investment analysis less rigorous than would be preferred by government bodies.

Over the past 20 years, TIS have had a steadily growing popularity, particularly for public transport systems. However, despite this, no standardised reliable method for evaluating the actual benefits of various information services is in widespread use. Without a means to demonstrate quantifiable benefits in an objective manner, TIS projects will have difficulty obtaining transportation resources on a competitive basis compared with more traditional transportation projects such as highway capacity expansion or safety initiatives.

2.2 Scope

Throughout the world, there is a large number of different TIS in operation. The prevalence of such technology is increasing continually. The review conducted in this report had an international scope in order to capture this broad use of TIS from the experience of others.

This study consolidates available TIS cost and benefit information. It is intended to be used as reference material for current and future traveller information projects in New Zealand.

While all TIS were considered in the review, there was a focus on TIS provided by central, regional and local government as it was anticipated that this would be most relevant to the end users of this report.

2.3 Key literature review objectives

The key objective of this literature review topic was to clarify the cost-benefit information claimed and/or realised, either directly or indirectly.

Supplementary objectives were to:

- review, research and advise on best practice (where appropriate) for TIS including the associated costs and benefits
- produce criteria for categorising TIS
- bring together information on the scale/magnitude of benefits and costs associated with TIS.

2.4 About the literature review

The review presented in this report is both practical and applicable to the needs of the Transport Agency. The literature review covered much of the globe as well as previous research undertaken in New Zealand concerning TIS projects and the results of studies.

Criteria that allow for categorising quantitative and qualitative costs and benefits of the various TIS were produced. These criteria were aligned with the Transport Agency's standard approach to economic evaluation outlined in the *Economic evaluation manual* (EEM) (NZ Transport Agency 2013). The EEM provides guidance when assessing claimed (or modelled) versus realised (or actual) results. Some additional commentary has been made within the 'customer satisfaction' field.

Any monetary benefits or costs noted from outside New Zealand have been converted to the US$ (exchange rates in November 2013), but inflation/deflation has not been allowed for as technology price fluctuation over time does not match general price increase indices and varies geographically.

3 Traveller information systems (TIS)

TIS allow road users to receive information about a trip and assist them in selecting their mode of travel, time and route. As the technology available to society is advancing quickly, particularly with respect to mobile communications and hand-held devices, the opportunities for the use of TIS are expanding continually.

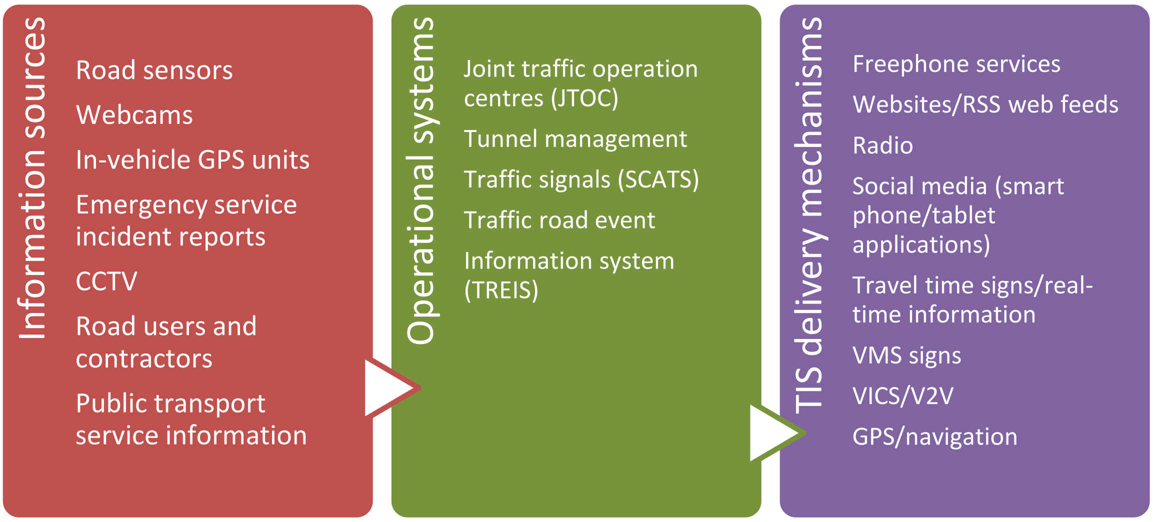
TIS are largely concerned with the dissemination of travel information. The origin of this travel information often comes from a large suite of technology systems, commonly termed ITS. TIS involve the application of modern technology, such as advances in communication, sensors and connectivity, to help improve traditional surface transportation problems. The means by which the necessary data for use in TIS can be collected and processed are extremely varied.

The three main elements involved in providing and supporting functional TIS can be described as information sources, operational systems and ITS delivery mechanisms.

- Information sources – digital data is captured using various technology, for example, road sensors, closed circuit television (CCTV), global positioning system (GPS). Not all data is sourced from ITS. Manual reporting is also a common method of obtaining information.
- Operational systems – digital data collected can be processed and used to monitor the network for example, traffic operation centres and tunnel management
- TIS delivery mechanisms – applications used to disseminate useful information to the public to better inform them before making trip choices.

Figure 3.1 details these three elements and how these relate to some of the traveller technology systems currently employed in New Zealand.

Figure 3.1 Key elements of TIS provision



3.1 TIS in the New Zealand context

The literature review focused on the specific types of TIS delivery mechanisms as detailed above.

The different elements of TIS are detailed below. Generally information sources and operational system elements contribute to more than just TIS. The information is based on the Transport Agency booklet (2011) *How the NZ Transport Agency keeps you moving*.

3.1.1 Information sources

An information source is described as the first element of ITS where digital data is collected, the raw data is fed into the operational system and after processing is turned into data which is ultimately used to provide information to the public through TIS applications. The raw data is collected from various information sources and these are described in detail in table 3.1.

Table 3.1 Information sources

Information sources	**Application in New Zealand**
Road sensors	Road sensors have a range of applications in New Zealand, a few of which include: • being built into urban motorway systems and giving a representation of the vehicle speed distribution across the motorway network • collecting data for traffic operation centres around New Zealand • detecting the presence of vehicles for the inputs to the Sydney Coordinated Adaptive Traffic System (SCATS)
Webcams	 Webcams are located in major cities and towns around New Zealand. They are accessible by the public and provide up to the minute imaging of the current traffic conditions. The image on the left is taken from one of these cameras, which can be viewed via the following web site: www.nzta.govt.nz/traffic/current-conditions/webcams/auckland/motorway/SH1-Northern.html
In-vehicle GPS units	In-vehicle GPS applications are common in the private and commercial sectors. GPS is used to provide route planning and real-time information on various modes of transport including private vehicles and buses.
Emergency service incident reports	Traffic operation centres in Wellington and Auckland can receive data from police incidents. This data can be processed to inform the public of the nature and/or severity of abnormal conditions via TIS, eg travel time signs. The Traffic Road Event Information System (TREIS) used by the Transport Agency collects information from emergency services (among other sources).
CCTV	CCTV cameras are located at key locations on the New Zealand transportation network. They feed information back to the traffic operation centres, where it can be used to make changes to traffic signal timings as necessary and inform the public of any traffic issues via TIS, eg variable message signs (VMS). CCTV is invaluable in identifying quickly the nature of an incident.
Road users and contractors	The Transport Agency has a free phone service which allows road users to report anything they have noticed on their travels which they think the Transport Agency should be aware of. Traffic operation centres in Wellington and Auckland can also receive feedback from contractors and the public through the Transport Agency's 0800 number. TREIS collects information from the public (among other sources).
Public transport service information	Public transportation information is collated and is available from a number of sources within New Zealand. This information is used to inform the public via TIS, some of which include: • websites • mobile apps • travel time signs.

3.1.2 Operational systems

The digital data is processed to provide useful traffic information; the following are processes used in New Zealand. With integrated systems, the dissemination of information, either to operational staff or to the wider public is dependent upon other ITS systems to gather base information in the first instance.

Table 3.2 TIS operating system

Operational systems	Application in New Zealand
Traffic operation centres (TOC)	There are two TOCs in New Zealand, one in Auckland and the other in Wellington. A third TOC is in the process of being established in Christchurch. The TOCs were formed as part of an initiative to reduce congestion in major cities by integrating nationwide traffic management. The TOCs gather information from a number of devices located in the transport system such as CCTV cameras and road sensors.
Tunnel management	Tunnels are monitored with incident and fire detection systems. The ventilation within the tunnels is also monitored and automatically reported to the local TOC.
Traffic signals	Traffic signals on major urban routes are controlled by SCATS. SCATS ensures the more efficient flow of traffic along major arterials through active coordination of traffic signals. Some intersections are also equipped with an emergency vehicle detection system to allow priority for these vehicles through the traffic signals.
TREIS	A system used by the Transport Agency to manage the occurrence of planned and unplanned events on the road network. Information entered into the TREIS is communicated automatically to Transport Agency staff and to road commuters via the highway information website.
InfoConnect	An initiative started by the Transport Agency to encourage businesses with the expertise and resources to build specialised applications and devices which make traffic information available to road users in a variety of ways. InfoConnect freely provides third party developers with data collected from the road network. The third party developer would need to add value and develop a TIS delivery mechanism to extract a fee (revenue) and create a willingness to pay.

3.1.3 Delivery mechanisms

The delivery mechanisms used in New Zealand have been identified in table 3.3 with a description of each mechanism.

Table 3.3 TIS delivery mechanism

Delivery mechanism	Description
Freephone services	Call service which delivers information about the road network. Information ranges from road closures to sources of major delay. The service can also be used to report incidents which may affect the performance of the road network.
Website/really simple syndication (RSS) web feeds	Websites offer commuters real-time information relating to the transport network. Information on major delays and road closures can be accessed through the website. RSS is where road users can receive road/traffic information via web feed formats.
Radio	Radio offers real-time traffic information disseminated at key times during the day such as morning and afternoon peaks. Information can be delivered directly to drivers through the car radio.
Social media (smartphones/ tablets)	The dissemination of information through social media such as Facebook, Twitter and apps. Information is largely user generated and relies on people reporting traffic information. Apps are generally available from third party suppliers.

Delivery mechanism	**Description**
Travel time signs	Signs which display estimated travel times. The display is updated periodically and the signs are typically positioned at key locations in the transport network and real-time information at bus stops.
VMS	VMS have the capability to display various different messages alerting drivers to delays ahead, route diversions or expected travel time. VMS are a variant of travel time signs.
Vehicle information communication system (VICS) and vehicle to vehicle (V2V) communication	VICS and V2V communications allow vehicles equipped with devices to become the information gathers and distributors. They are then able to create safety warnings and traffic information. For example, if a vehicle equipped with V2V technology travels through thick fog it will send a safety warning to other vehicles in the vicinity.
GPS/navigation	GPS determine the location of a GPS device, such as in a car or on a mobile phone. The location of the device can be monitored remotely. Navigation technology can use the data from the GPS to determine the fastest route between the current location of that vehicle and a given destination.

4 Literature review methodology

The methodology for this review comprised the following three stages:

Stage 1 Review and assess New Zealand and overseas literature, and advise on best practice, where appropriate.

Stage 2 a) Produce criteria for categorising different TIS.

b) Produce criteria for categorising the quantitative and qualitative costs and benefits and ensure the criteria align with the EEM, where applicable.

Stage 3 a) Document cost-benefit information from available traveller information projects according to above criteria.

b) Clarify whether the costs and benefits are claimed or realised and whether they are direct or indirect.

4.1 Stage 1: Review and assess TIS literature

A review and assessment of New Zealand and overseas TIS literature was undertaken to determine articles for inclusion in this report. The literature review encompassed journal articles, conference proceedings, text books, research reports and web articles. The review focused on the following countries and areas:

- New Zealand
- Asia
- Australia
- USA
- Canada
- United Kingdom
- Europe.

4.1.1 Literature review methodology

The literature review was aimed at international and national literature and sought evidence-based evaluations of TIS and the associated costs and benefits. The same systematic approach was applied by using a selection criterion for inclusion and exclusion of literature in each geographical area although due to different terminology for supplementary information (eg dynamic message signs/variable message signs) some variants on the search criteria were used.

The main internet search criteria are noted below.

- [ITS *or* TIS] *and* [freephone *or* telephone *or* 511] *or* radio *or* [internet *or* website *or* RSS] *or* social media *or* travel time sign *or* VMS *or* [VIC *or* V2V] *or* GPS

  and

- benefit(s) *or* cost(s) *or* evaluation.

4.1.2 Search strategy

The following search strategy (including selection criteria) was followed. Articles were primarily found on websites and electronic databases. Sources of information included:

- Google and other search engines
- conference papers/journals with relevant cross references and cited papers
- US Department of Transportation Research and Innovative Technology Administration (RITA) ITS benefits database (this includes some very useful cross references to other research articles identified separately in this report)
- RITA ITS costs database.

4.1.3 Local sources:

- NZ Transport Agency research reports
- EEM
- local councils/Auckland Transport
- New Zealand universities (including the Transportation Research Centre at University of Auckland)
- Ministry of Transport.

4.1.4 Overseas sources:

- Australian government transport and infrastructure agencies
- Australian universities
- Smart Transport Research Centre (Brisbane)
- Australian Transport Research Forum
- Transportation Development Centre (Canada)
- Canadian Transportation Research Forum
- Transportation Research Board, USA
- US Department of Transportation
- Transit Cooperative Research Programme
- Federal Highway Administration Research and Technology, USA
- Transport Research Laboratory, UK
- Quartel Plus/Apollon, Athens, Greece
- IBIS – Trondheim, Norway
- Faculty of Technology, Netherlands
- Department for Transport, UK.

To try and refine the focus of the review, some inclusion criteria were established to filter potential papers. Articles for consideration in the literature review were selected based on:

- discussion of the TIS or TIS elements listed in sections 4.1 or 4.2

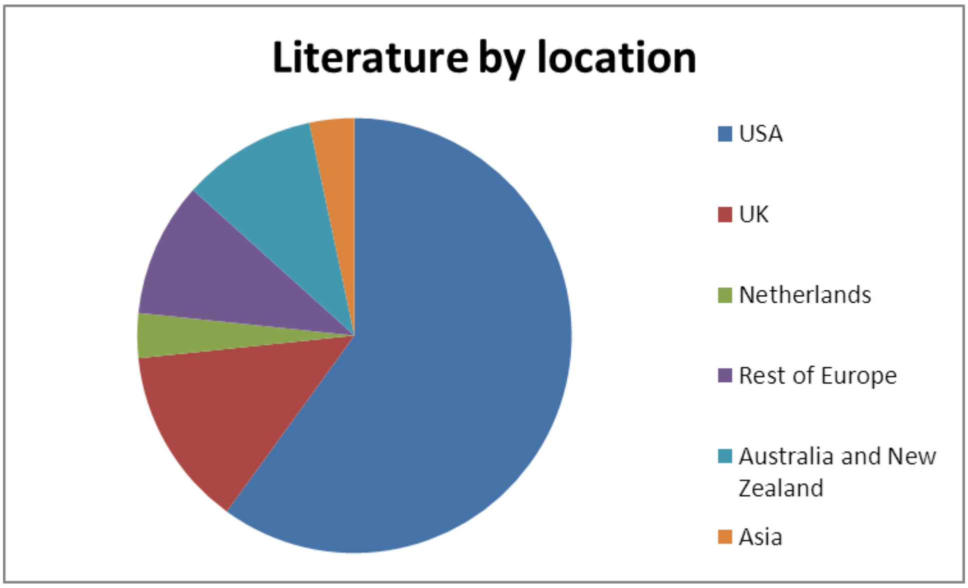
- references to benefits or costs of TIS services or elements
- a publication year of 2000 or later
- being published in English.

4.1.5 Search results

- Initially, 87 papers were selected, each with either full text or mostly relevant text.
- Inclusion criteria were applied to these papers but 56 of them did not meet the search criteria. A full list of these papers is shown in appendix B.
- 31 papers remained for inclusion in the review. A full list of these papers is shown in appendix A.

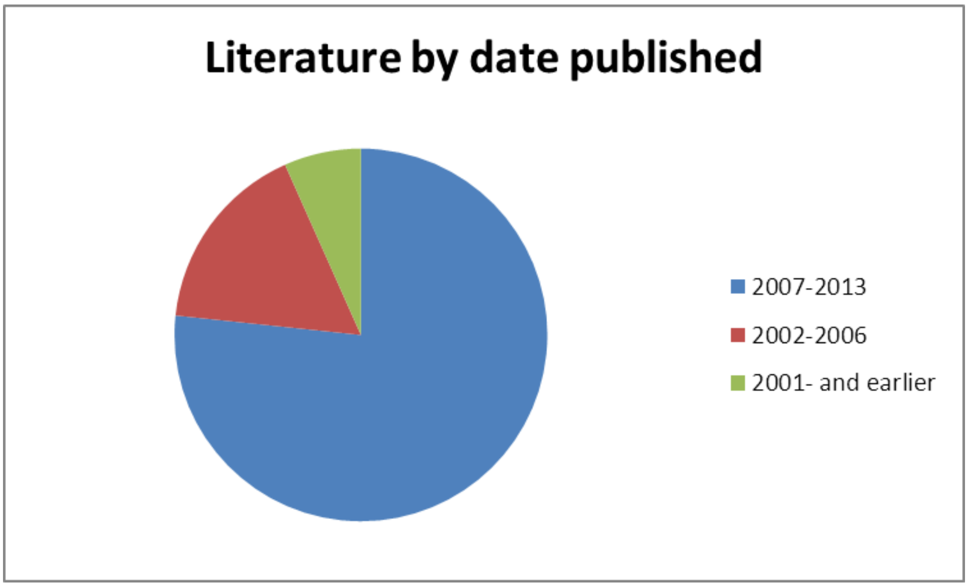
Most of the material considered during the research originated from the USA as shown in figure 4.1. One reason for so many US documents is ease of access. Another reason is that the USA has one of the largest road networks in the world, has been deploying ITS since the early 1990s and has been collecting ITS cost and benefit data since the mid-1990s. In comparison, it was discovered that much of the research carried out in Asian countries is difficult to access and it is often not in English. European research (including the UK) did provide some good data sources.

Figure 4.1 Literature by location



Literature gathered by date was also examined and is shown in figure 4.2. It can be seen that the majority of documents were published within the last five years. It was considered that recent research might be more easily applied to meet current needs of New Zealand; however, if there were gaps in the research, the project team expanded the search criteria to gather necessary information, on occasion from older articles.

Figure 4.2 Literature by date published



The amount of research on each type of TIS was investigated, as were all the separate elements of TIS. The most commonly documented subjects were websites and VMS. Social media was mentioned least, which was again of no surprise given that the rise in social media has only recently occurred, hence very little literature exists.

It was interesting to note that although websites were mentioned in the greatest number of articles, there was less information regarding the tangible benefits from website provision of traveller information. Instead, articles referring to websites focused more on explaining how information could be disseminated rather than looking at the actual benefits provided by having the facility in place.

4.2 Stage 2: Criteria for categorising TIS

There is a difference in the information required by urban and rural motorists/travellers and in the information required during normal and abnormal conditions. Typically, in rural areas fewer people may require travel information but when they do, their need is more significant, eg severance from schools and hospitals during 'road events', while in urban areas many people may be affected but in a less significant way, as there are alternative route and mode options.

It is not possible for all TIS delivery mechanisms to be applicable in all situations. Therefore as part of this literature review scope, TIS was categorised into rural and urban situations and pre-trip and en-route situations. For example VMS and travel time signs are not intended for pre-trip planning and are therefore categorised as en-route TIS. It is noted that the majority of the delivery mechanisms can be accessed en route with the current technologies available.

4.2.1 Urban

For the purposes of this report, urban TIS are defined as services aimed at enhancing the performance of the urban transport system. Urban transport systems offer multiple feasible modes and route choices and are generally situated in a built-up environment. Urban TIS generally have the ability to benefit and communicate with a large number of transport users. However, the focus of improvements tends to be on issues with a relatively major consequence, eg reducing congestion.

4.2.2 Rural

Rural TIS are aimed at enhancing the performance of rural transport systems where there are generally very few viable route choices and vehicles tend to be travelling at higher speeds. Rural TIS benefit transport users who are travelling longer distances and generally have different priorities for information than travellers in urban environments. Where public transport services are infrequent, real-time information regarding the arrival of a service can be very useful for the traveller. Rural information about current and short-term future weather and road conditions and information about crashes and other incidents are consistently highest in priority for rural travellers (Deeter 2009). The impact of rural TIS tends to be greater, but for a smaller number of road users, eg mitigating potential community severance during extreme events. The prevalence of road freight in New Zealand means that while rural TIS tend to benefit fewer transport users, there is a wider population who benefit indirectly.

The application of ITS to rural highways has increased over recent years as the costs of communications, in particular, have fallen. This has led to increasing innovation and implementation of TIS in many countries aimed at better resolving their rural highway safety and route security problems (James 2006). Previously, this would have been infeasible on cost grounds.

4.2.3 Pre-trip

Pre-trip TIS are those that are intended for use by travellers before their road journey has begun. The potential benefits from pre-trip services include lower congestion, less vehicle use and reduced impact on the environment. Further, the potential traveller can make best use of their time prior to heading for the chosen mode/route of travel.

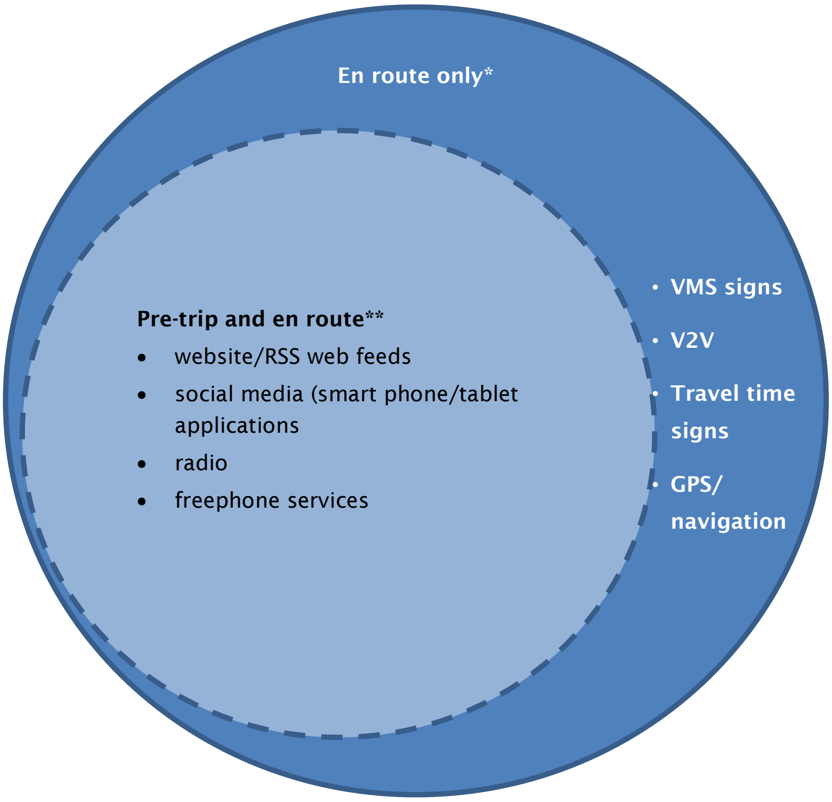
4.2.4 En route

En-route TIS are those used by the traveller while they are travelling to their destination. The ability to provide en-route information about traffic conditions can lead to a reduction in congestion due to crashes or changes in road conditions and improve safety. Potential benefits could be derived from travel efficiency and environmental impacts (the level of this impact is expected to be low). Where real time is readily available to the traveller, if necessary, due to unexpected conditions, that traveller can re-route with confidence.

4.2.5 Pre-trip vs en route summary

Pre-trip information may affect the choice of mode, route or departure time and in some cases the decision whether or not to make the trip. En-route information can also have an impact on travel efficiency by affecting the choice of route (http:its-toolkit.eu/2decide/node/44).

Figure 4.3 Pre-trip and en-route TIS



* While TIS in the 'en-route only' category are intended for use while travelling, some organisations choose to make the same information available online via a website, eg the Transport Agency's VMS and travel time signs. In this situation the website is a separate 'pre-trip' TIS with identical data source and data processing stages to the en-route information.

**TIS in the 'pre-trip and en-route' category are available en route if the user has access to appropriate technology. However, these may have safety implications due to distraction if used while driving and in a single occupancy vehicle, unless updates are automatic based on pre-set criteria.

4.2.6 Criteria for categorising costs and benefits

It was requested that the categorisation of TIS costs and benefits be aligned with the EEM. Input towards determining the criteria was also provided by the Transport Agency during meetings and reviewing progress on the project.

4.2.6.1 Benefits

The following benefits from the EEM, which are applicable to TIS, were considered during the research:

- vehicle operating cost savings
- trip reliability increase
- crash cost savings
- travel time cost savings
- driver frustration reduction benefits (customer satisfaction)
- health benefits
- vehicle emissions reduction benefits.

Driver frustration reduction benefits are based on vehicle passing options (passing lanes) through the construction of dedicated passing lanes, climbing lanes, slow vehicle bays and improved alignments. This benefit did not fit with TIS and was not taken forward during the research. Instead customer satisfaction was used as a potential useful benefit to compare different TIS. However, no literature was found that used a monetised measure of customer satisfaction suitable for inclusion in a cost-benefit analysis.

Trip reliability is a secondary benefit and can be accounted for by the primary benefits of travel time cost savings, vehicle operating cost savings, vehicle emissions reduction benefits and crash cost savings. This benefit was not taken further in the project.

Benefits to the environment and public health result from the reduction of vehicle emissions. The reduction of particulate emissions has a monetary value assigned in the EEM and is included in the cost-benefit analysis.

4.2.6.2 Costs

Three cost categories for inclusion in the denominator of the cost-benefit ratio were considered:

- capital
- operation
- maintenance.

To achieve greater clarity in the evaluation of TIS, the benefits and costs were both classified into the sub-categories, direct and indirect, as prescribed in the project scope.

4.2.6.3 Direct versus indirect benefits and costs

Direct benefits and costs are felt by road users and governing road authorities. The direct benefits in the evaluation are travel time cost savings and vehicle operating cost savings, and the direct cost is the capital investment required to acquire the use of the TIS. Indirect benefits and costs affect the wider society.

The benefit and cost criteria were aligned with the Transport Agency's standard approach to economic evaluation when assessing claimed (or modelled) versus realised (or actual) results and table 4.1 lists the benefits and costs taken forward in this project.

Table 4.1 Benefit and cost criteria

Benefits		Costs
Direct	Travel time cost savings	Capital
	Vehicle operating cost savings	
Indirect	Crash cost savings	Operation/maintenance
	Vehicle emissions reduction benefits	
	Customer satisfaction	

4.3 Stage 3 – Document costs and benefits

Stage 3 involved the documentation of cost-benefit analysis from New Zealand and globally, in accordance with the criteria developed in stage 2. The articles found in stage 1 of the literature review were narrowed down using the shortlist criteria below:

- coverage of TIS on the list generated in stage 1
- evaluation of costs and benefits that fitted the criteria developed in stage 2
- sources that had best practice details about specific TIS.

5 TIS application examples

5.1.1 General comments

Throughout the world, especially in countries with mature transport systems, TIS are widespread and applied to private and public transport systems. These systems are provided by public bodies, private organisations such as train and bus operating companies and also by individuals themselves by the purchase of in-vehicle units and portable computing devices that can access data and information provided by others. In a similar manner to the provision of information 'to the person' in subject areas such as sport, news and financial markets, the demand and expectation of travel information is growing rather than diminishing.

This chapter examines individual elements of TIS that are provided.

5.1.2 Freephone

Overseas, freephone systems have been used to disseminate information to travellers with some success. They are generally used in conjunction with websites, television and radio services, and information sent to wireless devices. An example of this is the SmarTraveler project, which began providing information to the Eastern Massachusetts area in January 1993. Travellers could receive information (including construction and event information, and traffic conditions) by calling in on a touch-tone telephone, by accessing a website, or through radio (Ullman et al 2000). A Washington DC simulation study found that regular use of pre-trip information reduced the frequency of travellers' early and late arrivals by 56% and 52% respectively, with freephone systems identified as an information delivery method (US Department of Transportation 2008). Also, a modelling study in Boston, Massachusetts estimated that changes in travel behaviour due to better TIS could result in a decrease in vehicle emissions, including a 25% reduction in organic compounds, a 1.5% decrease in nitrogen oxides and a 33% decrease in carbon monoxide emissions (Maccubbin et al 2008).

In the USA, in July 2000 the Federal Communication Commission by recommendation of the US Department of Transportation (US DOT) designated 511 as the national traveller information telephone number. The Washington State Department of Transportation (WS DOT) operated a state-wide 511 service by 2003 with the service receiving 4.6 million calls per year (Kristof et al 2005) and by 2006 about 50% of the US population had access (Persad et al 2006). The service is funded by gas (vehicle fuel) taxes and therefore free to the user. The operation and maintenance costs which do not include the costs to acquire the traveller information were about US$300,000 per year for all components of the system (Kristof et al 2005).

There has generally been high customer satisfaction with freephone systems as well. Satisfaction with the freephone system deployed in the USA ranges from 68% to 92%, and 99% of users in Virginia said they would call the freephone system again (Pincus 2011). A review of user feedback and case studies suggests that freephone systems play a critical role in travel information, and that travellers find the information useful (Deeter 2009). Finally, survey responses from key professionals at state and local agencies in five US states indicated that TIS-related ITS systems, including enhanced 911 systems, have a high potential to benefit emergency services (Pincus 2011).

The costs of freephone systems generally stem from the capital costs of call boxes and their installation (these capital costs range from US$4000 to US$6800), maintenance contracts, and cellular service fees (USDOT 2010). The cost per box due to knockdowns varies from US$1000 to US$7000, depending on the state, and can vary considerably within states. The annual maintenance cost per box varies, with figures quoted in the literature from US$150 to US$580 per year (Button 2001). With the advances in mobile phone (cell) technology, the economics of freephone systems have changed significantly.

Marketing has proven useful to encourage the uptake of freephone systems. The USDOT used dynamic message signs (DMS). ‘Road Conditions, Dial 511’ was posted on all DMS located throughout the state, 24 hours per day for a seven-day trial period. During the campaign the daily call volume increased 30 fold and the percentage of cellular phone calls increased, suggesting that many travellers called while still en route (Maccubbin et al 2008). While this result should be weighed against potential disbenefits of phoning while driving, it is clear that marketing is most effective when targeted at the types of users who would be most interested in that information (Maccubbin et al 2008). Indeed, since this research, the use of mobile phones (cellular phones) while driving has been made illegal in many countries. However, should a passenger be present, they could use a mobile phone to obtain the information.

5.1.3 Websites (journey planning/traveller information)

Websites to disseminate traveller information have been used overseas and in New Zealand. They are often deployed in conjunction with radio and television services, freephone systems and wireless device systems. Examples of this are those outlined above, including the SmarTraveler programme, the Washington DC simulation, and the modelling undertaken in Boston, Massachusetts.

Reception of schemes involving websites has generally been positive. An evaluation of the SmartBus ITS programme for the Chattanooga Area Regional Transportation Authority found that two thirds of bus tracking website users said that they used transit (public transport) more frequently due to the availability of real-time information (Pincus 2011). Evaluation of other schemes in the US has shown that 80% to 94% of motorists who use traveller information websites think that weather information enhances their safety and prepares them for adverse road weather conditions (Pincus 2011). A survey in Oregon, studying the TripCheck website, found that 83% of commuters considered internet-based traffic and weather information to be important (James 2006).

The websites can have significant uptake – the TripCheck website generates well over a million hits per month (James 2006) and a UK-based Journey Time Planner website generated over a million hits in the first 10 months after its inception (Gillies et al 2004). Website schemes have also been successful in helping users change their travel routes. A survey found that in Pittsburgh and Philadelphia, USA, 68% and 86% of users (respectively) changed their travel route and 47% and 66% (respectively) changed their original time of travel, after consulting traffic information found online (Deeter 2009).

The capital cost of a website for the dissemination of traffic information is highly dependent upon the level of service provided, the content, data sources and sophistication of the website. However, a typical website for TIS would be expected to cost between US$18,000 and US$22,000 (USDOT 2010) with some ongoing revenue costs.

Based on interviews with developers of top traffic and transit information websites, the websites should assess what their users want and should facilitate the dissemination of the information in an efficient and effective manner. TRIMARC (www.trimarc.org) designed their website with the ability to click signs or cameras to get more detailed information (Maccubbin et al 2008). In a 2010 survey, webpages were reported as the most widely used method of information dissemination, with 90% of freeway management agencies and 40% of arterial management agencies having websites to disseminate information (Pincus 2011).

Developers of successful traveller information websites received feedback and used these comments to address technical issues or update the information provided. Houston TranStar looks for continuous improvements, reviewing the site on a monthly basis and implementing new features every two to three months (Maccubbin et al 2008).

5.1.4 Radio

Radio schemes involve the relaying of traffic information via public broadcast. For example some radio stations in New Zealand provide traffic updates during peak periods and major incidents. These are often sponsored by local/national businesses. No benefit–cost analyses of these New Zealand schemes have been conducted.

There are various types of radio schemes that have been implemented in the USA including highway advisory radio (HAR), commercial and satellite radio traffic channels. Highway advisory radio is very limited compared with commercial radio due to the 'staleness' of the pre-loaded information notifying motorists of static conditions such as construction and lane closures. The WSDOT operates 55 highway advisory radios with the majority located in urban areas (for commuter congestion and non-recurring traffic), rural areas (for weather conditions) and near construction sites (Kristof et al 2005). Commercial radio is heavily favoured as a source of en-route in-vehicle traffic information. Data is obtained by radio stations from sources including the traffic management centre database, police and fire services with regular updates approximately every 10 minutes during rush hour (Persad et al 2006).

Radio schemes have also been trialled overseas, but not to the extent that phone and web-based systems have. They tend to be deployed alongside other ITS schemes. They have shown some benefits, as part of the schemes outlined above, but also in Grand Canyon National Park, where dynamic message signs and HAR were installed as part of a shuttle bus programme in 2008. The scheme was estimated to result in a reduction of between 66,000 and 99,000 vehicle-miles driven, and fuel savings of between 2,600 and 2,800 (US) gallons (Pincus 2011).

Capital costs are around US$15,000 to US$40,000 per system, depending on the range and capabilities, with maintenance costs of US$600 to US$1800 per year (USDOT 2010).

5.1.5 Social media

Some transport operators are already exploring social networking services as a way of getting closer and interacting with their customers. Two public transport operators in Portugal have had some success with social media: Metro do Porto, a light-rail network operator and Carris, the surface public transport operator in Lisbon. Both organisations use Facebook and Twitter to make announcements, including planned engineering works, service updates, special offers, event notifications and marketing campaigns. Users are able to comment on the information provided and to add their own posts, generating lively debates. In addition, users of route B of Metro do Porto have established an independent Facebook site to share information and discuss the quality of the service.

Over 50 US transit agencies, including major actors such as TriMet, in the metropolitan area of Portland, Oregon, Dallas Area Rapid Transit in Texas, and San Francisco's Bay Area Rapid Transit District (BART), as well as smaller operators, now have Facebook and/or Twitter accounts and are actively using them to encourage their residents to make better use of public transportation (Crawford 2011). Crawford (2011) also discusses a specific project that has integrated Twitter into two new UK travel portals, Travel Bristol and TACTRAN (for the Tayside and Central Scotland Transport Partnership). The report emphasises that smart phone technology has created 'smart travellers' with evidence suggesting social media is being increasingly used in-trip both for reporting on and sharing details of travel issues en route from official sources and other traveller's tweets and messages on Facebook. The report also highlights potential efficiency and cost savings on the installation and maintenance of travel information infrastructure, eg kiosks (Crawford 2011).

WDOT uses ‘Know Before You Go’ messages on Twitter to disseminate travel information such as traffic reports, tolling information, construction works and ferry alerts to travellers before making their journeys.

These sites often contain useful information but not in a structured format. The information is not easily searchable and not very useful as a result. Real-time structuring of the comments provided by users, referenced spatially to network and route could vastly improve the usefulness of this kind of interaction (Nunes et al 2011).

A survey of social media users at the University of Texas found that 38% of participants were willing to share incident information with their social media group. It also found that the willingness of participants to share incident information varied significantly between age groups. Additionally, when a purpose-built social media transportation hub was created on Facebook, it was well received (Qiao et al 2011).

The costs of using social media to disseminate information vary depending on the extent of involvement with the social media platform.

5.1.6 Travel time signs

Variable message signs (VMS) have been used both internationally and in New Zealand, and there are examples of success in both cases. In New Zealand, savings have been achieved as a result of the Auckland ATMS Stage II Project on the Northern Motorway. The project had congestion reduction benefits and crash reduction benefits totalling NZ$14 million (James 2006).

Overseas, in 2001 the University of Wisconsin surveyed drivers to assess the impacts of traveller information made available on a motorway VMS system, with 68% of respondents reporting that they adjusted their travel routes based on information supplied by the system. However, a study undertaken in Detroit found that VMS proved no benefit to facility operation in terms of flow or speed, except when there were incidents. During the 2002 Winter Olympic games, a new TOC and extensive use of ITS equipment (including VMS) helped reduce the traffic in Salt Lake City by up to 30% to 40% from background flows. A report on crash statistics in San Antonio claimed that the installation of a VMS system reduced overall crashes by 41%. 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 crashes when incidents occur (James 2006).

The cost to install (over US$30,000) and maintain VMS signs is high (Persad 2006). The WDOT operates 145 VMS signs with purchase and installation costs between US$75,000 and US$125,000 per sign (Kristof et al 2005).

In a rural environment the main benefit of VMS is providing drivers with real-time information on incidents. This allows improved selection of alternative routes and reducing the risk of secondary crashes when incidents occur. In a rural environment, VMS are generally smaller roadside devices using LED technology. The cost of units suitable for rural application is relatively high and there is some evidence that, where a range of alternative information sources is available, the tangible benefits are limited (Maccubbin et al 2008).

It is claimed that VMS can reduce CO_2 emissions through more efficient traffic flow and reduction of stop-start traffic (Highways Agency 2012). As with travel time signage, capital and maintenance costs vary widely for VMS depending on size and capability (USDOT 2010).

Other travel time signs are increasingly being used both in New Zealand and overseas, and have had some success. It is claimed that travel time signs can reduce congestion and increase safety by maintaining traffic at the capacity a highway was designed to carry, thus distributing traffic evenly during rush hour periods (Charlebois 2013). Travel time signs can also influence traveller behaviour. Changeable message signs in the Bay Area of San Francisco, which displayed highway and transit trip times and departure times for the next train, influenced motorists to switch to transit when there were time savings to be found, with the uptake depending on the amount of time saved (Mortazavi et al 2009).

Evaluation data has shown that passengers who use real-time bus or tram departure information signs find them useful. At the Acadia National Park in Maine, 90% of visitors using the signs said they made travel easier (Pincus 2011). An evaluation of a real-time bus and tram TIS in Finland found that 66% of tram passengers and 78% of bus passengers interviewed regarded the displays as useful, with the most desirable aspects being:

- information on remaining wait time
- option to choose another route
- understanding the ability of the display (the comprehension of the message given)
- knowing if the vehicle they were waiting for had already passed.

An additional survey found that 95% of travellers who noticed the displays regarded them as useful (James 2006).

Real-time 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. 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 (Maccubbin et al 2008).

Capital and maintenance costs vary widely for travel time signage depending on size and capability (USDOT 2010).

A report by the UK Cabinet Office (2009) states that a number of studies have reported values of £0.04-0.09 (US$0.06 to US$0.13) per journey for real-time information at bus stops and the studies consistently show that real-time information is valued higher than other potential TIS improvements.

5.1.7 Vehicle information communication system (VICS) and vehicle to vehicle (V2V) communications

Vehicle to vehicle (V2V) is an emerging technology which is currently being developed by private motor companies such as the BMW Motor Company and is also being trialled by the US DOT through its Connected Vehicle Research Program. The project has recognised that V2V technology provides significant opportunities to improve safety and situational awareness via wireless transmission of valuable data and information between compatible vehicles located within in close proximity (Pincus 2011). According to the US DOT a fully functioning V2V infrastructure communications system could halve the 43,000 annual US traffic deaths (Persad et al 2006).

V2V systems similar to those found in some recently released BMW vehicles can transmit information on dangerous road conditions and traffic conditions (BMW 2013).

Vehicle information communication systems (VICs) in Japan transmit road traffic information to car navigations screens via FM multiplex broadcasting. The system is widely used in Japan with an estimated 35 million users and is administered by the Ministry of Land, Infrastructure, Transport and Tourism. In 2009, the VICS system achieved an annual 2.4 million tonne reduction in CO_2 emissions across Japan (MLIT 2012).

A report by the Economic and Industry Analysis Division of the US DOT (2008) outlines the Vehicle-Infrastructure Integration (VII) initiative. The report presents a framework for assessing and calculating the benefits and costs of VII, including the establishment of the core economic variables to be used in converting impacts into monetary terms. The aim of the initiative was to obtain significant improvements in highway safety and trip times via a nationwide network of communications between vehicles and the roads they were travelling on as well as among vehicles themselves. The communication capabilities would be used to exchange safety messages and improve traffic flow. The study identified a number of tangible benefits with regard to travel time savings, safety, crashes, fuel savings, carbon emissions resulting from VICS and V2V technology. The tangible benefits from this study are outlined in detail in the benefit tables in chapter 6: Benefits and costs. The report also outlines capital and operational costs of existing technology, ie VMS and outlines the monetary benefit of VII compared with the existing roadside technology.

5.1.8 GPS/navigation

GPS technology has been successfully used to disseminate information to travellers in TIS applications. The technology transmits information to in-car systems and increasingly commonly to hand-held mobile devices such as mobile phones (Deeter 2009).

GPS systems are frequently used to calculate the shortest/fastest possible route between two points. As technology has improved, live traffic and road information can be transmitted to devices via cellular network, FM radio or satellite broadcast (James 2006). Premium subscriptions in combination with appropriate equipment within the vehicle can automatically re-route the traveller should the original route show difficulties. Information can be displayed on the navigation display allowing users to make informed decisions while en route. Travel time cost savings can be achieved by selecting shorter routes and/or less congested routes. Studies have found that travel times can be reduced by 4% to 10% under normal traffic conditions or recurring congestion when using an in-vehicle GPS navigation system. Shorter travel distances and more efficient travel can also reduce vehicle emissions (Maccubbin et al 2008).

GPS technology was also found to influence pre-journey behaviour and allow for reduction in vehicle emissions. One investigation in Japan provided commuters with a travel plan system using GPS-enabled and internet-ready cell phones to allow commuters to make more environmentally friendly travel choices in terms of mode and route. The investigation suggested that the system influenced pre-journey behaviour and resulted in a 20% reduction in carbon dioxide emission (Pincus 2011).

GPS technology has been used to reduce the costs of crashes and the secondary effects, and to improve response and recovery to vehicle crashes. Advanced automatic crash notification systems employ GPS technology, in-vehicle crash sensors, and wireless communication systems in combination to pinpoint the location of the vehicle. This information is then communicated to emergency responders to allow rapid and streamlined response. A survey conducted of 166 key professionals in five US states (Kentucky, Georgia, Tennessee, North Carolina and South Carolina) found that GPS (automatic vehicle location) technology had one of the highest potentials among ITS technologies to benefit emergency transport operations (Maccubbin et al 2008). The report does not define the nature of the ‘key professionals’ but the article implies that these are from public bodies.

Another observed benefit of GPS technology is an improvement of driver safety. A simulation study of GPS navigation systems conducted in Florida found that drivers reduced their crash risk by up to 4% when using a GPS navigation system. The reduction was attributed to better wrong-turn performance and the GPS navigation system selecting routes with improved (normally safer) facilities (Maccubbin et al 2008).

The cost of GPS technology is dependent on the level of function the system is able to deliver. A sophisticated in-car GPS navigation unit costs between US$1,300 and US$1,500 and an additional US$15 per month subscription if satellite services are required. GPS systems for vehicle location cost between US$500 and US$2,000 (Maccubbin et al 2008). However, in the recent past for the simpler and commonly used units, purchase costs can now be as little as US$200. The costs of such systems are nearly always borne by the traveller themselves in the expectation that with better information than others, their own individual journey will always be shorter or faster.

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. These systems are likely to be best used in an area where traffic patterns are unpredictable. They will allow drivers to plan their trips beforehand and change their plans en route with the help of real-time traffic information (James 2006).

Other research has identified that travellers can monitor and make informed decisions on travel choices in real time (Pincus 2011) and there are indications that cellphone and GPS data is being pursued in California to augment performance monitoring and therefore improve traveller information (Deeter 2009).

5.1.9 Operation

The following best practices have been identified for business models for the operation of traveller information delivery systems (Kim et al 2004):

- Avoid technology changes without a clearly defined need for change.
- Take advantage of technology changes that introduce large cost savings.
- Seek committed annual operations budgets.
- Minimise public sector operation costs as much as possible.
- Choose services offered by public agencies wisely and seek private partners for the remainder of services.
- Make as much information available to private sector information providers as possible.

According to ITS-America, the key challenge to successfully implementing TIS is establishing the roles, responsibilities and relationships of the public and private sectors. A business plan should address five issues (Persad et al 2006):

1. Define the target market.
2. Define the data to be collected.
3. Determine how to disseminate the consolidated information.
4. Demonstrate where the funding will come from and how it will be used.
5. Estimate business costs.

6 Benefits and costs

6.1 TIS benefits

As detailed in section 3.2, the literature review was categorised into urban, rural, pre-trip and en-route TIS.

There are a wide range of benefits applicable to TIS (eg see http:its-toolkit.eu/2decide/node/44). This range is reduced to five key benefits which are addressed in this chapter. The EEM often refers to three metrics:

- travel time savings
- vehicle operating costs
- crash cost savings.

These metrics are retained as the focus of this study to demonstrate the strengths of the various TIS and to ensure alignment with current New Zealand practice. Two further benefit measures are also included in the study.

- vehicle emission reduction
- customer satisfaction.

Customer satisfaction is a useful consideration when comparing different TIS; however, no literature was found that included it in a cost–benefit analysis.

Ben-Elia et al (2013) found that the reliability of information provided by the TIS affected whether the traveller would pay attention to the advice. This is supported by a study undertaken in the Minnesota metropolitan area which noted that travellers' responses to TIS information was dependent on properties of the information provided including the quality, accuracy, usefulness, timeliness, cost and the manner in which the information was provided (Zhang and Levison 2008). This is an important consideration in determining the scale of benefits that may be realised.

Kristof et al (2005) reviewed a study undertaken by the Washington State Transportation Center in collaboration with the US DOT. The study describes an evaluation method called the ITS Deployment Analysis System (IDAS). The system is a planning tool designed to evaluate a number of benefits relating to ITS factors such as efficiency, mobility, safety and environmental costs. The benefits are determined by calculating changes to indicators following the deployment of ITS. The indicators include vehicle miles travelled, vehicle hours travelled (VHT), volume-capacity ratios, and vehicle speeds throughout a given network. The study was based on a number of assumptions that were used in the calculations to determine costs and benefits (Kristof et al 2005). The report reviews a number of existing methodologies that aim to evaluate the benefits of deploying advanced traveller information systems and summarises that IDAS is currently the recommended evaluation method (Kristof, 2005). A description of how the benefits are calculated by IDAS (using HARs as an example) is provided. The *impact* would be a reduction in VHT, the *benefit* would be the increase in US$ saved by the traveller and society in general by reducing VHT and the *cost* would be the increase in US$ spent by the road agency per HAR unit employed (Kristof et al 2005). Some of the simulated benefits/impacts identified in the study for different types of TIS regarding travel time savings are discussed further in table 6.2.

An indication of the importance of each type of benefit for each TIS category is summarised in table 6.1. Further information regarding how each benefit is achieved is provided in appendix C. Evidence of how benefits are achieved by TIS is further detailed below.

Table 6.1 TIS benefit summary

Journey type		Direct benefits		Indirect benefits		
		Travel time cost savings	**Vehicle operating cost savings**	**Crash cost savings**	**Vehicle emission reduction**	**Customer satisfaction**
Pre-trip	Urban	Reduces early and late arrivals. Allows better departure time decisions. Allows informed mode choice decisions.	Allows users to minimise travel distance/ time spent in congestion.	Allows hazards to be avoided	Encourage mode shift to PT Reduces distances travelled and stop start traffic	The uptake experienced by existing TIS shows that users perceive value in the provision of these services.
	Rural		Shorter routes taken	Especially when TIS is a weather warning system	Reduces distances travelled	
En route	Urban	Congestion relief through high proportion of travellers changing route.	Congestion relief	Allows hazards to be avoided. Reduces congestion and associated crashes.	Reduces distances travelled and stop start traffic	
	Rural		Shorter routes taken	Especially when TIS is a weather warning system		

6.1.1 Travel time cost savings

Travel time cost is the cost of time spent on transport. For a business, this cost includes the time that employees and vehicles spend on travel. The travel time cost savings are the benefits felt due to reduced travel time costs from a do-minimum approach. Recent studies indicate that traveller information can be very effective during periods of non-recurring congestion caused by unexpected events such as incidents. Benefit–cost ratios range from 16:1 to 25:1 (Pincus 2011).

Studies show that drivers who use route specific travel time information instead of area-wide traffic advisories can improve on-time performance by 5% to 13% (James 2006).

Table 6.2 Travel time cost savings benefit

Delivery mechanism	Travel time cost savings (direct)
Freephone service/ website/RSS web feeds/radio	• A simulation study in Washington DC found that regular users of pre-trip traveller information reduced traveller frequency of early arrivals by 56% and late arrivals by 52%. Information was disseminated through website, wireless devices, a freephone service and by radio (Maccubbin et al 2008). • SmarTraveler project in Eastern Massachusetts, started in 1993, had travellers receiving information through freephone, an internet map, and television and radio. Information included traffic conditions as well as construction and event information (Ullman et al 2000).
Social media	• No objective evidential references could be found.
Travel time signs	• Variable message signs in the Bay Area of San Francisco displaying travel times and departure times of trains, influenced 1.6% of motorists to switch to transit when the time saving was less than 15 minutes, and 7.9% of motorists switched when the time savings were greater than 20 minutes (Mortazavio et al 2009). • Recent work for London has estimated that the provision of electronic displays and real-time information is worth between £0.04 and £0.09 (US$0.06–US$0.13) per journey in travel time savings (Cabinet Office, UK 2009). • The IDAS assessment calculates simulated average travel time savings per traveller as a result of travel information signs based on previous studies. The IDAS study area contains 42 rest area kiosks with highway information. Based on adjustments, an average travel time saving of two minutes has been calculated, based on the assumption that 30% of kiosk users will save time as a result of the kiosk travel information signs (Kristof et al 2005).
VMS	• Application of VMS to the Auckland ATMS II project resulted in a reduction of non-recurrent and recurrent congestion of an estimated value of US$3.9 million and US$1.6 million respectively (James 2006). • Extensive use of VMS and web-based traffic information dissemination as part of the Olympic transportation plan in Salt Lake City led to a reduction of 30% to 40% reduction in traffic from background flows (James 2006). • A study completed in 2004 by CUBRC/University at Buffalo, examined a number of VMS deployments on arterial routes. Travel time was 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 jumped to 43.6% for a diversion rate of 27% (James 2006). • In Houston, real-time travel time information posted on DMS influenced drivers' route choice. 85% of respondents indicated that they changed their route based on the information provided. Of these respondents, 66% said that they saved travel time as a result of the route change, 29% were not sure. Overall, drivers were primarily interested in seeing incident and travel time information. • Metropolitan areas that deploy ITS infrastructure, including DMS to manage freeway and arterial traffic, and integrate traveller information with incident management systems can increase peak period freeway speeds by 8% to 13%, improve travel time, and according to simulation studies, reduce crash rates and improve trip time reliability with delay reductions ranging from 1% to 22%. • The IDAS assessment calculates simulated average travel time savings per traveller as a result of VMS based on previous studies. The IDAS study area contains 145 permanent VMS and default impact values were adjusted according to the frequency of incidents along the route. Based on adjustments, an average travel time saving of 5 to 20 minutes has been calculated, based on the assumption that 4% of vehicles will save time as a result of VMS (Kristof et al 2005).

Delivery mechanism	Travel time cost savings (direct)
VIC and V2V	• Travel time saved through VII applications is valued in the cost–benefit analysis at US$11.20 per person-hour for local travel and US$15.60 per person-hour for intercity travel. These values come from policy guidance issued by the Office of the Secretary of Transportation and are based on the idea that users of transportation infrastructure are willing to pay a certain amount of money in order to avoid traffic delays (US DOT 2008).
GPS service	• Simulation in Florida found that with a market penetration of 30%, dynamic route guidance would allow the road network to handle a 10% increase in vehicle volumes (Maccubbin et al 2008). • In-vehicle navigation/route guidance devices can reduce travel times by 4% to 10% under normal traffic conditions or recurring traffic congestion (Maccubbin et al 2008). • 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. The TravTek system was found to improve the efficiency of trips over those 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. (James 2006).

6.1.2 Vehicle operating cost savings

The benefits in costs of vehicle operating savings can range from fuel cost savings due to shorter journeys to time saved travelling. This in term can reduce maintenance and repair costs.

Table 6.3 Vehicle operating cost savings benefit

Delivery mechanism	Vehicle operating cost savings (direct)
Freephone service	No objective evidential references could be found
Website/RSS web feeds	No objective evidential references could be found
Radio	In the Grand Canyon National Park, the park dynamic message signs and HAR, installed as part of a pilot shuttle bus programme in 2008, were estimated to result in a reduction of between 66,000 and 99,000 vehicle-miles driven and a fuel savings of between 2600 and 2800 (US) gallons (Pincus 2011).
Social media	No objective evidential references could be found
Travel time signs	No objective evidential references could be found
VMS	No objective evidential references could be found
VIC and V2V	No objective evidential references could be found
GPS service	No objective evidential references could be found

6.1.3 Crash cost savings

Less congestion on the network, informed choices and improved driver decisions can lead to increased safety and therefore provide crash cost savings. It is considered that the widespread deployment of TIS, as part of a larger ITS system which can detect incidents, support traffic supervision and provide information to users in real time, improves road safety considerably. Accurate and widely available road safety-related traffic information that warns motorists and allows them to better anticipate and avoid unexpected and dangerous situations has the potential to significantly reduce the number of traffic crashes resulting in crash cost savings (European Commission 2013).

In Europe, the overall effect of road safety-related traffic information is estimated to be an average of 2.7%[1] in fatalities and 1.8%[1] in injuries (figures based on an extensive range of literature including a review of the European Union's vehicle technology projects CODIA, Eimpact, PROSPER, Easyway, Road operator reports and CARE database). In monetary terms the reduction in fatalities and injuries equates to the following costs savings (European Commission 2013):

- US$1,868,332 for fatalities
- US$293,817 for serious injuries
- US$22,547 for less severe injuries
- overall weighted average of US$58,354.

The US DOT (2008) study states that the safety benefits of VII applications are generally expressed in terms of crashes avoided and the associated reductions in injuries and fatalities. To translate these figures into monetary terms, the VII initiative cost–benefit analysis uses the 'comprehensive' or 'willingness-to-pay' approach, which reflects the premise that crash reduction benefits are ultimately defined in terms of what society and individuals are willing to pay to reduce, by given magnitudes, the probability of injuries or fatalities. This is in contrast to approaches based only on the direct financial costs of the crash. The comprehensive costs follow US DOT guidance. The comprehensive cost values reflect the societal costs of crashes, including property damage, medical and legal costs, time lost due to the travel delays associated with the crash, and other direct costs, as well as the intangible costs of injuries, such as pain and suffering. In 2007 the recommended economic value for the prevention of a transportation fatality was US$3.2 million. Recently, the figure has been revised to US$5.8 million with a recommended range of sensitivity testing from US$3.2 million to US$8.4 million.

Delays caused by crashes will decrease as a direct result of crash reduction with the following cost savings:

- US$51,469 for a fatal crash
- US$14,068 for an injury.

No further measured or estimated values for crash cost savings benefits were found for any of the TIS methodologies.

6.1.4 Vehicle emission reduction benefit

Reduction in congestion would lead to a reduction in vehicle emissions. Reduction in CO_2, noise and greenhouse gas emissions would create vehicle emission reduction benefits. TIS systems can enhance network traffic distribution, modestly improving effective capacity and reducing fuel consumption and related emissions.

[1] In the literature, these benefits are taken per annum as this is implied rather than stated, but it is unclear from the reference research whether this is an absolutely correct assertion

Table 6.4 Vehicle emissions reduction benefits

Delivery mechanism	Vehicle emission reduction benefits (indirect)
Freephone service/ website/radio	Simulation study found that, with improved traveller information, emissions could be reduced. Includes 25% reduction in organic compounds, 1.5% reduction in nitrogen oxide, and 33% reduction in carbon monoxide. Methods of information dissemination included website, wireless devices, freephone and radio (Maccubbin et al 2008).
Social media	No objective evidential references could be found
Travel time signs	No objective evidential references could be found
VMS	Little or no impact (James 2006).
VIC and V2V	• In Japan, the government administered VICS achieved a 2.4 million tonne reduction in CO_2 emissions (MLIT 2012). • The US DOT report (2008) states that a value of US$2.30 per (US) gallon is used for any projected fuel savings for the VII initiative. Current emissions of nitrogen oxides (NOx) by light vehicle are estimated at 8.25 million short tons, with potential reductions in emissions valued in a range from US$1500 to US$9500[a] per ton. Particulate matter emissions are assumed to be 220,000 short tons, with valuations ranging between US$10,000 and US$108,000 per ton. Valuation of hydrocarbons is estimated at US$650 to US$2,900 per ton. Valuation of sulphur dioxide is estimated at US$2,260 to US$15,100 per ton. The volume of carbon monoxide emissions is assumed at 511.2 million short tons and volumes of volatile organic compounds at 4.87 million short tons. A value of US$2 per metric ton of carbon is used in this report, reflecting the lower end of current prices in 'cap and trade' futures markets for carbon emissions and offsets (a {US} gallon of gasoline produces 19.564 pounds of carbon dioxide, of which the carbon content is 12/44ths (0.273). There are 2,204.6 pounds per metric ton).
GPS service	• In Japan, GPS-equipped cellphones helped commuters to analyse and modify their daily travel behaviour. Survey data indicated a 20% reduction in carbon dioxide emissions (Pincus 2011).

[a] There is no explanation within the report why the range is so large.

6.1.5 Customer satisfaction

Customer satisfaction is a useful consideration when comparing different TIS; however, customer satisfaction is not easily quantifiable and therefore cannot be included in a cost–benefit analysis in its direct form. A number of the articles discuss travellers' 'willingness to pay' for TIS as a benefit. There are links between customer satisfaction and willingness to pay for travel information, eg a driver may experience journey time savings or other benefits by using free pre-trip or en-route travel information. If the driver was then required to pay for the same service, their willingness to pay would depend on how satisfied they were with the service. The contingent valuation method which uses a survey to ask people how much they would be willing to pay for a specific service would be a method for measuring customer satisfaction for TIS.

Customer satisfaction is relatively new concept and is not currently included as a benefit in the EEM. However, it is one of the 'goals' within the RITA ITS database and the reference is relevant to this study. As noted above, a value could be assigned for customer satisfaction in EEM by identifying travellers' 'willingness to pay' for TIS.

TIS are often associated with high customer satisfaction benefits which enhance the success of these applications.

Table 6.5 Customer satisfaction benefits

Delivery mechanism	**Customer satisfaction (indirect)**
Freephone service	• Survey responses from state and local agency professionals in the USA indicated that enhanced 911, interoperable radio communication, dynamic message signs and GPS could all benefit emergency transport operations (Pincus 2011). • 2003 Montana traveller information survey indicated that the majority of Montana travellers were quite satisfied with their 511 telephone service (Pincus 2011). • A review of user feedback and case studies suggested that 511 systems play a critical role in travel information, and travellers find the information useful (Deeter 2009). • Customer satisfaction with regional 511 deployments ranged from 68% to 92%. (Pincus 2011).
Website	• An evaluation of the SmartBus ITS programme found that two thirds of bus tracking website users said that they used transit more frequently because of the availability of real-time information (Pincus 2011). • Data shows that 80% to 94% of motorists who use traveller information websites think road weather information is useful and enhances their safety (Pincus 2011). • 83% of respondents considered traffic and weather information to be important (James 2006). • A UK travel time information website generated 50,000 hits per month in the first 10 months from its inception (Gillies et al 2004). • In Pittsburgh and Philadelphia, a significant majority of users changed their travel route and time of travel as a result of traveller information found online (Deeter 2009).
Radio	• See first bullet point of freephone service above.
Social media	• Study at University of Texas found that seven out of nine participants would like to check their social media while travelling, if it is accessible. Participants showed willingness to use a Facebook page as a portal for transportation information (Qiao et al 2011).
Travel time signage	• 90% of visitors to Acadia National Park in Maine said they made travel easier (Pincus 2011). • Helsinki; Finland. A significant majority of tram and bus passengers regard travel time displays as useful. 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 (James 2006).
VMS	• Claimed to be among the top five ITS systems for benefiting emergency transportation operations (Pincus 2011). • VMS can possibly be used to display information on events or other highway information (non-instructive and non-directive). Traveller care may be increased by such improvement (Highways Agency 2012).
VICS and V2V	• No objective evidential references could be found
GPS Service	• Survey responses from state and local agency professionals in the USA indicated that enhanced 911, interoperable radio communication, dynamic message signs and GPS could all benefit emergency transport operations (Pincus 2011). • In San Antonio, Texas, 60% of drivers of para transit vehicles equipped with navigation devices reported they saved time and felt safer than when they used paper maps.

6.2 Traveller information services costs

The common form of measuring costs found in the literature investigated is consistent with the EEM:

- capital cost of the TIS
- operations and maintenance costs associated with keeping the system running.

6.2.1 Capital costs

Capital costs are the cost of the physical infrastructure necessary to implement a system or project (costs in USD).

Table 6.6 Capital costs

Delivery mechanism	Capital costs
Freephone service	• US$4,000 to US$6,800 for call box and installation (US DOT 2010). • US$1,000 to US$7,000 cost per box from knock downs; high variation (Button et al 2001).
Website/RSS web feeds	• US$18,000 to US$22,000 depending on the level of service the website is to accommodate (US DOT 2010).
Radio	• US$15,000 to US$30,000. The figures are taken from the US DOT ITS Joint Program Office, 2006. The capital cost is for a 10 watt HAR which includes processor, antenna, transmitters, battery backup, cabinet, rack mounting, lighting, mounts, connectors, cable and license fee. The life expectancy of the equipment is 20 years (Persad et al 2006).
Social media	• No objective evidential references could be found in the literature. • Varies depending on extent of social media involvement (720MEDIA 2009). • A general quote from a social media company is US$800 to US$2,000 per month for management and promotion services (WebpageFX 2013).[a]
Travel time signage	• Varies extensively depending on type, number, size and capability of signage (US DOT 2010). • US$120,000 to US$150,000 for real time, traffic adaptive signal control system (URS work on traveller information systems in the UK).
VMS	• US$47,000 to US$117,000. The figures are taken from the US DOT ITS Joint Program Office 2006. The lower cost is for smaller VMS installed along arterial roads. The higher capital cost is for full matrix, LED, 3-line, walk-in VMS installed on a highway/motorway. The equipment has an estimated 10-year lifespan (Persad et al 2006). • The task force members from state DOTs for the VII initiative stated upfront costs of US$272,500 per VMS unit (US DOT 2008).
VIC and V2V	• It is estimated that the initial infrastructure costs for the VII initiative will be approximately US$5 billion, mostly spent in a five-year period. Installing VII equipment and systems on all vehicles sold in the US will cost over US$1 billion per year at full deployment, simply because so many vehicles are involved. The report states that the decision to go forward with the VII initiative must consider whether expected benefits – in the form of reductions in crashes and injuries, travel time savings, and environmental and other benefits, justify the costs (US DOT 2008).
GPS service	• US$500 to US$2,000 for a global positioning system (Maccubbin et al 2008). • Handheld device US$200 to US$1000 (US DOT 2010). • US$200 to US$400 for GPS/differential GPS. The figures are taken from the US DOT ITS Joint Program Office (2006). The equipment has an estimated seven-year lifespan (Persad et al 2006).

[a] It is acknowledged that approaching a specific social media company for an idea of costs is not completely scientific, but in the absence of other data, it was thought that this approach would be better than disregarding this medium. This is an operating cost rather than an upfront payment for creating a web page.

6.2.2 Operation and maintenance costs

The operational and maintenance costs are the costs required to maintain and operate the system to a proposed level of service (costs in USD).

Table 6.7 Operations and maintenance costs

Delivery mechanism	Operation/maintenance costs
Freephone service	• US$250 to US$580 per year for service maintenance and cellular service fees (US DOT 2010). • US$150 to US$500 per year; maintenance costs per box vary significantly (Button et al 2001). • US$0.50 to US$2.50 per call (Maccubbin et al 2008). • The operation and maintenance costs of WS DOT system were about US$300,000 per year for all components of the system (Kristof et al 2005).
Website	• US$18,000 to US$22,000 per year, depending on level of service the website must accommodate (US DOT 2010).
Radio	• US$600 to US$1,800 per year depending on capabilities of system (US DOT 2010). • US$600 to US$1,000. The figures are taken from the US DOT ITS Joint Program Office (2006). The capital cost is for a 10 watt HAR which includes processor, antenna, transmitters, battery backup, cabinet, rack mounting, lighting, mounts, connectors, cable and licence fee. The life expectancy of the equipment is 20 years (Persad et al 2006).
Social media	• No objective evidential references could be found in the literature. • Varies depending on extent of social media involvement (720Media 2009). • A general quote from a social media company is US$800 to US$2,000 per month for management and promotion services (WebpageFX 2013).
Travel time signs	• Roadside information US$48,000 to US$119,000 (Maccubbin et al 2008). • US$20,000/year for real-time traffic adaptive signal control system (US DOT 2010). • US$4,500/year for incident detectors (US DOT 2010).
VMS	• US$2,000 to US$6,000 (US DOT 2010). • The WS DOT operates 145 VMS signs with purchase and installation costs between US$75,000 and US$125,000 per sign (Kristof et al 2005). • US$2,400 to US$6,000. The figures are taken from the USDOT ITS Joint Program Office, 2006. The lower cost is for smaller VMS installed along arterial roads. The higher capital cost is for full matrix, LED, 3-line, walk-in VMS installed on a highway/motorway. The equipment has an estimated 10-year lifespan (Persad et al 2006). • The task force members from state DOTs for the VII initiative stated annual maintenance costs of US$11,600 per unit and a useable lifespan of 10 years (US DOT 2008).
VIC and V2V	• Very low (US$13/year) for operating and maintenance once installed (US DOT 2010).
GPS Service	• Low (US$12/year) for operating and maintenance once installed (US DOT 2010). • US$4 to US$10 for the maintenance of GPS/differential GPS. The figures are taken from the USDOT ITS Joint Program Office 2006. The equipment has an estimated seven year lifespan (Persad et al 2006).

A summary of the above tables is included in appendix C.

6.3 Traveller information service disbenefits

Road hierarchies are commonly used by road controlling authorities in New Zealand as a means to target investment and ensure that only activities appropriate for the road environment in a given area are allowed to occur. The potential re-routing of vehicles through residential areas could create negative effects through the creation of additional noise and vehicle emissions. These types of effects are difficult to quantify; however, they should be considered and mitigated or minimised when implementing new TIS services.

Audio and cognitive in-vehicle distractions are shown by Östlund et al (2004) to increase the amount of time that a driver focuses on the centre of the road and decrease the time spent scanning the wider road environment. In-vehicle TIS could therefore have safety disbenefits if used by a driver while driving.

6.4 Pre-trip and en-route TIS benefits

En-route and pre-trip information services are best applied in areas where traffic patterns are not regular and are frequently affected by congestion. They allow drivers to plan their trips beforehand and change their plans while en route with the help of real-time information (James 2006). Best practice information regarding en-route and pre-trip information, websites, freephone and GPS services is detailed below:

6.4.1 En-route information

The prevailing media for disseminating en-route information are DMS and HAR. The most common types of messages are incident information, maintenance and construction information and amber alerts. Next in popularity are congestion, diversions and weather alerts. The less common are travel time, public services and special events (Maccubbin et al 2008).

En-route information related to current road conditions (for example, travel time, weather status/ warnings) should have a positive impact on network efficiency as drivers/haulers should use this information to make more effective travel decisions. In future it may be possible for well-informed travellers who improve their choice of mode, route and departure time to contribute to a more even spread of traffic throughout the day. With predictive and real-time information about the traffic condition, the network efficiency can be influenced positively. The information can be used for recommendations so that the traffic load can be diverted inside the road network or shifted to public transport (www.its-toolkit.eu/2decide/node/44).

Potential benefits of en-route information could derive from travel efficiency and environmental impacts (the level of this impact is expected to be low). The eSafety project refers to real-time information and provides a benefit–cost ratio which ranges from 1 to 2.5 for event information and 2 to 6 range for traffic condition (www.its-toolkit.eu/2decide/node/44).

6.4.2 Pre-trip Information

The most common medium for disseminating pre-trip information is the internet and the next in popularity is TV and radio. A 511 telephone information service for pre-trip information is in use by freeway and arterial agencies (Maccubbin et al 2008).

The ITS toolkit at www.its-toolkit.eu/2decide/node/44 (AustriaTech project '2DECIDE' 2013) brings together evidence from TIS implemented throughout Europe as shown in table 6.8. It should be noted that this database is self-populated by its-toolkit users and therefore the evidence has not undergone peer review.

Table 6.8 TIS benefits summary (reproduced from www.its-toolkit.eu/2decide/node/44)

Service assessment parameter	Expert summary of impacts or feasibility
Improve travel efficiency	Pre-trip information may affect the choice of mode, route or departure time and in some cases even the decision whether to make the trip or not. In general, travellers and other users of the transport system can make better decisions from their own point of view when they have more complete information on the available options. The impact of pre-trip information on travel efficiency depends on the type of information provided to the traveller. For example, warnings of slippery road surface or crashes may affect the choice of driving speed and reduce the average speed of traffic flow which leads to increased travel times. On the other hand, information affecting the choice of route usually leads to shorter travel time. Information about the available transport modes has a potential to support better utilisation of existing capacity in the transport system. En-route information can also have an impact on travel efficiency by affecting the choice of route, or even the mode (in case eg park-and-ride is available). A study on radio data systems – traffic message channels (RDS–TMC) indicates a change of route by 45% of drivers due to en-route RDS–TMC messages at least once. On the basis of information received before the trip, 23% of the drivers had changed their plans sometimes. The effects during all journeys are much smaller, 1% to 2% at most.
Improve road safety	Safety effects of pre-trip information were estimated in the Easyway annual forum (2009). 'Pre-trip information and predicted travel time information reduce on one hand, crash risks by making drivers aware of the problems, but increase the risks on the other hand by transferring traffic onto roads with higher average crash rates. Co-modal information is beneficial to safety by encouraging modal shift to public transport, where the fatality risks are considerably lower than for the private car, but unfortunately the information services have not been extremely efficient.' However, the magnitude of the effect in fatalities was estimated to be negligible. En-route information has the potential to affect traffic safety positively, especially when drivers get support on the appropriate choice of speed. Real-time information on slipperiness and other road weather related problems has been estimated to reduce the risk of injury crashes in adverse conditions by 8% on main roads and 5% on minor roads in Nordic conditions. In addition, by getting incident-related information en route, drivers can change their route and avoid the affected area (and therefore reduce the risk of secondary crashes).
Improve public transport service	A passenger, who is at a bus or light railway stop, is foremost interested in knowing when the next bus or train will arrive. The perception of how long the wait time is depends on whether the time is known beforehand or not. If the traveller does not know how long the wait time will be, the time is perceived as much longer. The wait time is perceived as much shorter if the time is known beforehand, eg shown on a real-time display, provided that the information is accurate and reliable. By providing passenger information displays, customer satisfaction and the image of public transport is improved. In surveys 80% of passengers have evaluated such intelligent transportation systems as useful. Research has also shown that 20% of bus passengers say they have travelled by public transport more often because of on-stop displays. Actual bus passenger volumes have increased by 10% to 12% after installing digital countdown signs. In-vehicle en-route information is not yet widespread, but is helpful to passengers by communicating information about delays and possible alternative routes. The most helpful passenger information systems incorporate information

Service assessment parameter	Expert summary of impacts or feasibility
	from adjacent public transportation systems and other transport modes. Informed passengers are more satisfied because they perceive waiting and travel time as shorter and experience public transit as on-time and reliable. This service thus helps to improve the image of public transport.
Improve freight management	A variety of new technologies can be used to improve freight system efficiency, including driver information systems, on-board diagnostic equipment, computerised logistics for vehicle routing, and improved location and distribution planning. This could improve overall productivity in addition to energy savings. These are predicted to have the following energy conservation impacts: • 5% for vehicle technical improvements and purchasing practices • 5% to 10% for driver training and monitoring • more than 10% for fleet management and logistics measures • companies that take a comprehensive approach could improve fuel efficiency up to 20%.
Improve freight fleet management	The information generated by this service could contribute to improved routing and scheduling of freight fleet vehicles which can potentially result in a reduction of transport cost and time.
Enhance security	Pre-trip information services assist the traveller in optimising their journey before the trip. Knowing what the travel conditions are in advance (special events, difficult weather, incidents and security issues) makes trips easier, comfortable and less stressful. Hence, pre-trip information services have a direct and positive impact on the user's feeling of security and travel comfort. En-route information services also assist the traveller during the trip in taking more effective and well-informed travel decisions. Hence, en-route information services have a direct and positive impact on the user’s feeling of security and travel comfort. Moreover, en-route traveller information can have significant benefits for passengers with mobility difficulties, for example by improving access to public transport and providing travel information in many formats (sound, visual signs).
Reduce environmental impacts	Studies have shown that pre-trip information has indirect but, at the same time, important results on the environment. This is due to the fact that by being aware the traveller can choose the route they consider to be less time and budget (including fuel) consuming. Hence, it is expected that the traveller tries to find the shortest route (according to the pre-trip information) consuming less fuel or using public transport, again leading to less overall fuel consumption. For freight transport, pre-trip information is important in defining congestion spots, shortest routes, making the trip more sustainable. Depending on the system type (how personalised the system is), car usage may decrease substantially (up to ca. 20%) and travelling by walking and/or cycling may increase as well as the use of public transport. As a result, this has a positive impact on emission levels (including NOx by 1% to 2%, CO_2 by more than 1%, and particulate matter). Here, reference is specifically made to eco-driving already implemented in Finland and Sweden, which attempts to ensure the driver maintains a regular speed as studies have shown that very slow, very fast and irregular driving patterns lead to excessive fuel consumption. For freight transport, en-route information is important in defining congestion spots/ shortest routes (real time), making the trip more sustainable. Simulation studies have indicated that integrating traveller information with traffic and incident management systems in Seattle, Washington could reduce emissions by 1% to 3 % (NOx by 1.3%), lower fuel consumption by 0.8 % and improve fuel economy by 1.3 %. Studies have also found that eco-driving with dynamic speed recommendations can reduce fuel

Service assessment parameter	Expert summary of impacts or feasibility
	consumption by 10% to 20% and lower carbon dioxide emissions without drastically increasing freeway travel times. The author noted that the benefits are dependent on level of service. Under free-flow conditions benefits would be minimal; however, under severe congestion benefits would be considerable.
Improve road traffic planning, operations	Supporting increased modal shift toward public transport requires good quality pre-trip and co-modal traveller information to allow for more efficient pre-trip routing decisions and/or departure times, thus increasing network efficiency and potentially delaying the need for asset investment. En-route information related to current road conditions (for example, travel time, weather status/ warnings) should have a positive impact on network efficiency as drivers/haulers should use this information to make more effective travel decisions. In future it may be possible for well-informed travellers who improve their choice of mode, route and departure time to contribute to a more even spread of traffic throughout the day. With predictive and real-time information about the traffic condition the network efficiency can be influenced positively. The information can be used for recommendations so that the traffic load can be diverted inside the road network or shifted to public transport.
Improve revenue generation	Some income can potentially be made if premium rate telephone numbers are used. However most information providers are transport operators or public authorities which aim to maximise information dissemination, so the norm is to use standard telephone numbers (no revenue generation) or low-rate or free numbers (which cost the provider money). Pre-tip information provided on websites can be partially funded by advertising on the website. For public transport operators, the main revenue generation element is that better availability of information can increase the number of fare-paying users of the public transport services. Certain income from charges for real-time services (for information on traffic conditions), eg from subscriptions, can be made.
Decrease traffic violations	Pre-trip information can have an impact on traffic violations. Information about enforcement may have an impact on speed compliance. In addition, by having more predictable travel/driving time, based on real-time information and forecasts, the drivers are able to reserve more time, and therefore decrease the need for speeding. Real-time weather-related information has an impact on driving speeds and headways. In addition, en-route information about enforcement may have an effect on driving speeds. Hence, violations are expected to decrease to a small extent.
User acceptance	User acceptance for pre-trip and en-route information is rather high on average. A significant number of end users see the usefulness of that kind of ITS service. Usage rates are high and end users tend to change their travel mode accordingly.
Cost benefit	The potential benefits from pre-trip services include less congestion, less vehicle use and environmental benefits (as mentioned in the environmental assessment). Analysis conducted by eSafety mentions real-time information on events and traffic condition, which could also be a part of pre-trip information. In regards to real-time event information the benefit–cost ratio ranges from 1–2.5 and for real-time traffic condition information it ranges from 2–6.

7 Discussion

The provision of real-time information on a variety of topics, eg sport, news and financial markets, is expected in many walks of life. As such, travellers now seek the most appropriate route, according to their preferences, and use the most accurate and up-to-date information available regarding the travel conditions along that route before and en route. In countries that have mature transport systems, the provision of timely information is an expectation rather than a desire.

Public and private agencies that collect, process and broadcast traveller information can help travellers make more informed decisions regarding departure times, route choices and mode of travel. With timely traveller information, travellers can defer or delay trips, select alternative routes or use transit services to help reduce congestion (Pincus 2011).

The end user derives most of the benefits of TIS. However, many of the costs of implementation are borne by the network operator, especially in the information collection and primary operational system stages/elements. Network operators can also realise benefits if levels of network saturation can be evened out by allowing individuals to choose the most appropriate route for their journey, no matter the circumstance.

Japan has deployed numerous TIS and may be referenced as a template as a way forward for New Zealand's TIS development. Japan has focused efforts over the past few years into making their vehicle fleet increasingly GPS enabled and the government has a long-term goal of a fully in-vehicle device enabled fleet. This would provide unparalleled data gathering power, and would also provide a near nationwide pubic audience for the traffic information they wish to disseminate. They are also developing technology in V2V communications.

Consider the scenario where advances in in-vehicle communication and information systems provide road users with access to essential real-time data about an incident and about transport conditions on all routes (Maccubbin et al 2008). In-vehicle units can report vehicle locations to the road agency traffic management centre which can combine this data into useful information, such as levels of congestion for each route. The congestion level information can then be provided to other users so that the traveller or motorist can make an informed route or travel decision based on the current conditions. This scenario will be slightly different for public transport users, but as the public transport vehicle location is correlated with traffic conditions and the published timetable, public transport users are allowed real-time journey planning during the journey.

Should it be decided that potential merit exists in the provision of TIS in New Zealand, some specific exploratory work needs to take place and perhaps a pilot site could be chosen with a rigorous assessment of the actual benefits so that a benchmark can be established for potential investment decisions. All TIS projects could also include a formal evaluation component to decide what will be used to measure its effectiveness.

The evaluations of TIS show that these systems are well received by those that use them. Benefits are found in the form of improved on-time reliability, better trip planning and reduced early and late arrivals (Maccubbin et al 2008). Accurate TIS costs are relatively easy to define while benefits are not.

7.1 Limitations of study

A significant gap identified in the literature review is the lack of information relating to rural TIS. This is most likely due to the fact that there very few TIS services are used in a rural environment. The reason for this can be traced to the advent of TIS, where it was largely developed to allow better utilisation of the existing transport network. In a rural setting, the transport network is rarely under pressure from factors such as congestion; hence the traditional applications of TIS which help to alleviate congestion through the full utilisation of the transport network are not as prevalent. The main types of TIS that are used in rural environments are normally weather and incident detection systems, as the main problem on rural roads is not congestion but crashes and isolation due to adverse weather conditions.

7.1.1 Limitations of the literature review

The literature review was limited by the systematic approach applied and by using a selection criteria for the inclusion and exclusion of literature. Although the selection criteria imposed a limitation on the range of literature reviewed, this was required to ensure that only the most recent and pertinent literature was considered in the first instance. TIS is constantly changing with new technology emerging from advances in society as a whole which supplements the more established methods, therefore it was important to consider the latest information where possible rather than rely on research that has been significantly overtaken by events. Nevertheless, where gaps were identified due to minimal or no literature regarding the costs and benefits of specific TIS, older/more general TIS and ITS literature were identified to supplement the review.

During the literature review process it was also observed there is relatively little information on social media TIS. The main reason for this is that the use of social media to provide traveller information is an emerging practice. The popularity of conveying traveller information in this manner has not picked up until recently, limiting the amount of research undertaken on the subject.

There is little information available on TIS from New Zealand. The main reason for this is that the TIS landscape in New Zealand is still in its early stages of development, hence not much literature has yet been published. As the TIS in New Zealand advances and the consumption of the systems increases, more literature will become available.

Expanding on the gap in literature found by geographic location, an overwhelming portion of the research found was related to American TIS systems. The main reason for this is that the institutions which collected and distributed the literature were primarily American journal publishers. Most literature works accessed from these publishers related to research on American systems. It was also difficult to access research from non-English speaking countries.

A recurring theme in the research was that it is difficult to isolate and quantify the direct benefits obtained from TIS. Desired traveller actions from provision of TIS information include changing routes, mode of travel, and/or timing of travel. Departures from the norm in travel patterns are difficult to attribute to the uses of TIS as there is a broad range of reasons for the change in travel patterns. It can become nearly impossible to gauge the benefits of any one system, particularly so when associated benefits can be relatively small per individual person and/or vehicle. Such a situation may partially explain why there is so little tangible objective research leading to the derivation of financial benefits for TIS.

It was difficult to find quantitative research and to find a common scope when considering the cost and benefits of the systems evaluated. Each project is unique and often the benefits from two separate projects are difficult to compare.

As noted earlier, the majority of the literature found was from the USA. The applicability of this research (and research from other countries) did not correlate completely to the transportation systems and geography in New Zealand as a whole. This was mainly due to the size of New Zealand, the population and the extent of rural areas. Larger urban areas such as Auckland and Wellington correlated more to the literature reviewed. Rural information was very limited, probably due to the fact that the majority of TIS are used in urban areas where there is the demand/audience and the most congestion occurs, so TIS can have a proportionately higher benefit.

7.2 Research findings strengths

Many of the resources are less than five years old. This means that the information gathered from the literature review can be considered to be current and up to date. For any business case, costs (and benefits) will need to be adjusted for inflation and changes in the cost of technology, but can be considered a relatively accurate representation of the cost of TIS.

Large amounts of information found were project or actual case-based research. This means that the results are real and have been tangibly extracted. Some research papers describe theoretical models addressing the impacts of TIS (traffic diversion). The research therefore covered both the practical and theoretical benefits that could be drawn from the use of TIS. A large number of the research reports included in the literature review were produced by government organisations. These governing bodies have reliable access to road network information. Some credibility into the findings of these reports is assumed as investment decisions and project plans are usually based upon such TIS research. As with all research, especially when benefits are difficult to strip out from other variables, any findings are best treated with some caution, particularly when they are applied for purposes other than the original intention.

Freephone services are a TIS delivery mechanism that is well documented. This is due to the large number of years it has been in use and its almost nation-wide use in the USA (eg 511). Freephone services were implemented in the USA in the year 2000 and by 2008 were being used in 33 states by 47% of the population. Benefits of freephone services are primarily determined from customer satisfaction studies.

Over the last decade, websites have become an increasingly popular means of delivering traveller information. This has occurred with the rise in access to high-speed internet. High-speed internet has allowed websites to display more dynamic, detailed and useful information. For example current fixtures of traveller information websites are dynamically zooming maps. A dynamic zoom has only been made possible with the increase in internet speeds. The increased utility of websites has helped them to continue to grow in popularity, increasing the number of hits by 1 million plus users each year between 2004 and 2007. During this time, consumption of other forms of TIS remained largely static. Benefit information is normally obtained in the form of customer satisfaction surveys. Another common measure is how closely the user arrived at their destination to the estimated time. Websites are a low-cost way to disseminate information to the public compared with other methods. The main problem with implementing travel time websites is ensuring that trust is built and maintained in the information that is delivered to the public.

8 Conclusions and recommendations

8.1 Areas for future investigation/consideration

8.1.1 Journey time reliability

Journey time reliability is important to travellers and can be influenced by TIS. The requirement to build additional time into journeys to account for possible delays can result in significant periods of unproductive time, eg when a destination is reached earlier than necessary.

Journey time reliability is not often quantified in cost-benefit analysis as very few methods exist to achieve this. Existing methods of quantifying journey time reliability are generally related to changes in mean travel time. These methods are not applicable to TIS, where reducing mean travel time is usually not the key outcome of the project (Peer et al 2012).

8.1.1.1 Recommendations

Further research is needed to develop a method to quantify the benefits of increased journey time reliability due to TIS when travel times remain unchanged.

A pilot site could be chosen with an assessment of the actual benefits so that a benchmark can be established for potential investment decisions.

All TIS projects should include a formal evaluation component to measure their effectiveness.

8.1.2 Vehicle to vehicle and vehicle to infrastructure communication

V2V communication is an emerging technology being implemented by vehicle manufacturers. For example new BMW technology allows BMWs to communicate with other BMWs to warn drivers of events ahead such as traffic jams, poor weather or icy roads (www.BMW.com). Similar vehicle to infrastructure and infrastructure to vehicle technologies are also conceptualised.

The implementation of these services could have a significant impact on the delivery of TIS, but is likely to be very costly for the network operator and will only be beneficial once a significant proportion of the vehicle fleet is equipped with appropriate communication technology.

Further research should be undertaken to understand what the impact of these technologies on the New Zealand transport sector might be and when these impacts might likely occur.

8.1.3 Project benefit assessment

Although each potential project must be assessed as a separate entity, the work undertaken within this study should be used to provide the basis for some of the numerical assessments, perhaps supplemented with some of the subjective assertions as to the benefit of TIS.

8.2 Implementation

As many governmental bodies around the world in towns and cities have had the confidence to invest in TIS, it would be expected that there are many potential schemes in New Zealand capable of delivering good value to travellers with a reasonable cost-benefit ratio.

TIS are likely to be relevant to many transport networks in New Zealand in both rural and urban applications. The cost and benefit models may differ markedly which is why specific studies for potential applications will be required. The objective financial benefits will be supplemented by the features of TIS that may match transportation policy, such as social inclusion and the use of public transport in appropriate locations. The technology that lies behind TIS will continue to develop and some TIS will be provided by private operators as evidenced by the roll-out of in-vehicle technology in Japan and elsewhere. This is a significant indicator that the travelling public values information, particularly when in-journey. Such indicators provide a very positive inference that TIS is a technology waiting to be applied in the appropriate circumstances in New Zealand. The Transport Agency is not alone in having identified a lack of data regarding the value of traveller benefits from TIS; it is a worldwide situation

Technology, by the very nature of the industry, will continue to evolve. Computer technology is advancing quickly with processing power doubling every two years. The advances and distribution of wireless communication systems allow travellers and travel data to be gathered and disseminated faster, more reliably and at less expensive than ever before. TIS are one of the many sectors within the technology field that have benefited from and will continue to benefit from the rapid growth in the IT sector.

9 Bibliography

The following list contains a comprehensive list of references. Some do not contain numerical data and others may include subjective views and non-substantiated statements as to the value or costs of TIS. To allow the reader to gain a full view of the quality and content of the limited number of research and published papers on TIS, the full list has been retained rather than filtering out the less useful papers.

720MEDIA (2013) [online] www.720media.com/average-cost-to-be-setup-social-media-facebook-twitter-website-design/ (24/4/2014)

AustriaTech project 2DECIDE (2013) *Welcome ITS toolkit*. Accessed 29 March 2013. www.its-toolkit.eu/2decide//node/44.

Ben-Elia, E, R Di Pace, GN Bifulco, and Y Shiftan (2013) The impact of travel information's accuracy on route-choice. *Transportation Research Part C: Emerging Technologies 26*: 146–159.

BMW (2013) [online] www.bmw.com/en.insights/technology_guide/articles/cartocar_communication.html Car-to-car communication [since the compilation of the original draft of this research, this web site has been removed by the provider]

Button, K (2001) Final report of ITS Center project: callbox evaluation. *US DOT University Transportation Research.*

Cabinet Office (UK) (2009) *An analysis of urban transport*. Accessed 29 March 2014. http://webarchive.nationalarchives.gov.uk/+/http:/www.cabinetoffice.gov.uk/media/308292/urbantransportanalysis.pdf

Crawford, D (2011) Social media a one-stop shop for travel information. ITS International [online]. Accessed 29 March 2014. www.itsinternational.com/sections/transmart/features/social-media-a-one-stop-shop-for-travel-information/

Charlebois J and A Johnson (2011 and updates, notably 2013) *Lake Washington travel time signs project*. Washington State Department of Transport. Accessed 9 May 2014. www.wsdot.wa.gov/projects/lkwamgt/traveltime/

Deeter, D (2009) Real-time traveler information systems, *National Cooperative Highway Research Program.* Washington DC: Transportation Research Board.

EasyWay Annual Forum (2009) *European perspective/ DG TREN.* Presentation 09Nov17_EW-Forum_ET_2.pdf. Accessed 9 May 2014. www.easyway-its.eu/download/380/1215/

European Commission (nd) *Digital agenda for Europe: a Europe 2020 initiative*. (The European Union's strategy to help digital technologies, including the internet, to deliver sustainable economic growth). Accessed 9 May 2014. http://ec.europa.eu/digital-agenda/

European Commission (2013) Commission staff working document, cost-benefit analysis. Accessed 9 May 2014. http://ec.europa.eu/transport/themes/its/news/doc/swd%282013%290170.pdf

Gillies, R, J Glen and G Gates (2004) A year in the life of a journey time website. In *Proceedings of Road Transport Information and Control, 12th IEE International Conference:* 56–59.

Highways Agency (2012) *Interim advice note 160/12: Appraisal of technology schemes*. Accessed 9 May 2014. www.dft.gov.uk/ha/standards/ians/pdfs/ian160.pdf

James, R (2006) Intelligent transport systems: what contributes best to the NZTS objectives?. *Land Transport NZ research report 302.*

Kim, S, ME Lewis and CC White III (2004). Optimal vehicle routing with real-time traffic information, *IEEE Intelligent Transportation Systems Society 6*, no.2: 1–29.

Kristof, T, M Lowry and SG Rutherford (2005) Assessing the benefits of traveller and transportation information systems. *Washington State Transport Center research report.*

Maccubbin, RP, BL Staples, F Kabir, CF Lowrance, MR Mercer, BH Phillips, and SR Gordon (2008) *Intelligent transportation systems, benefits, costs, deployment, and lessons learned: 2008 and 2011 update.* Federal Highways Authority document reference FHWA-JPO-11-139

Ministry of Land, Infrastructure, Transport and Tourism (MLIT) (2012) *VICS (vehicle information and communication system).* Published within the MLIT website www.mlit.go.jp/en/index.html

Mortazavi A, X Pan, E Jin, M Odioso and Z Sun (2009) *Travel times on changeable message signs. Volume II – evaluation of transit signs.* Berkeley: University of California.

Nunes, AA, T Galvao, I Falcao, J Cunha and JV Pitt (2011) Using social networks for exchanging valuable real time public transport information among travellers. In proceedings of *2011 IEEE Conference on Commerce and Enterprise Computing:* 365–370.

New Zealand Transport Agency (2011) *How the NZ Transport Agency keeps you moving*. Wellington.

New Zealand Transport Agency (2013) *Economic evaluation manual* (EEM). Accessed 29 March 2013. *www.nzta.govt.nz/resources/economic-evaluation-manual/economic-evaluation-manual/index.html*

Östlund J, L Nilsson and A Kircher (2004) Using mobile telephones: cognitive workload and attention resource allocation. *Accident Analysis & Prevention Science Direct Journal 36,* no.3.

Peer, S, C Koopmans and E Verhoef (2012) Prediction of travel time variability for cost-benefit analysis. *Transportation research part A: Policy and practice 46*: 79–90.

Persad, K, MC Walton and Z Wang (2006) *Implementation issues and strategies for deployment of traveller information systems in Texas*. Accessed 29 March 2014. www.utexas.edu/research/ctr/pdf_reports/0_5079_P3.pdf

Pincus, M (2011) *Intelligent transportation systems benefits, costs, deployment, and lessons learned desk reference: 2011 update*. Accessed 29 March 2014. www.itsknowledgeresources.its.dot.gov/its/benecost.nsf/files/bclldepl2011update/$file/ben_cost_less_depl_2011%20update.pdf

Qiao, F, Q Zhu and L Yu (2011) Social media applications to publish dynamic transportation information on campus. *ICCTP 2011*: 4318–4329.

Ullman, G, W Eisele and G Daniels (2000) *Future ATIS development in Houston: issues and alternatives, developing an advanced traveler information system plan for Houston*. Texas Department of Transportation.

US Department of Transportation (US DOT) (2008) *Vehicle-infrastructure integration (VII) initiative, benefit–cost analysis.* Version 2.3 (draft). Accessed 29 March 2014. www.its.dot.gov/research_docs/pdf/7vii-benefit-cost-analysis.pdf

US Department of Transportation (US DOT) (2010) *ITS unit costs database (as of 30 October 2010).* Accessed 29 March 2014. www.itscosts.its.dot.gov/its/benecost.nsf/Images/Reports/$File/CostElements%202010-10-30.pdf.

US Department of Transportation (US DOT) (2014) ITS Joint Program Office. Accessed 9 May 2014. www.its.dot.gov/its_jpo.htm

WebpageFX (2013) *Social media pricing*. Accessed 29 March 2014. www.webpagefx.com/Social-Media-Pricing.html

Whyte, D (2009) InfoConnect delivers accurate travel information on all levels. Accessed 9 may 2014. *www.itsinternational.com/categories/detection-monitoring-machine-vision/features/infoconnect-delivers-accurate-travel-information-on-all-levels/*

Zhang, L and D Levison (2008) Determinants of route choice and value of traveller information. *Transportation Research Record: Journal of Transportation Research:* 81–92.

Appendix A: Documents included in the review

Ref no.	Title/description	Author	Comments, relevance and best practice
1	720 media – social media	720Media (2013	Website contains information about the cost of setting up website – relevant.
2	The impact of travel information's accuracy on route-choice	Ben-Elia et al (2013)	Has relevance to TIS.
3	Car-to-car communication	BMW (2012)	Information on BMW developments in the field of car-to-car communication.
4	Final report of ITS Center project: callbox evaluation	Button et al (2001)	Evaluates travellers' reactions to the installation of callboxes on a stretch of road.
5	An analysis of urban transport	Cabinet Office (UK) (2009)	Provides some value-of-benefits information relevant to TIS.
6	Lake Washington travel time signage	Charlebois and Johnson (2011)	Study of a programme which utilised travel time signs.
7	Social media a one-stop shop for travel information, ITS International	Crawford (2013)	Provides useful information regarding the growth of social media and application for transport.
8	Real-time traveler information systems. A synthesis of highway practice	Deeter (2009)	State of the practice on real time traveller information systems. Contains 1) a literature review of previous studies, evaluations and research activities; 2) survey findings; 3) observation and testing of as many systems as possible; and 4) interviews – via telephone and face-to-face.
10	Commission staff working document, cost benefit analysis	European Commission (2013)	Provides useful information regarding crash cost savings.
11	A year in the life of a journey time website	Gillies et al (2004)	Contains information on journey time websites.
12	Interim advice note 160/12: Appraisal of technology schemes	Highways Agency (2012)	Comprehensive discussion relating to major highway technology benefits. Some numerical analysis, but mainly subjective unquantified analysis. Some differentiation of benefits by technology type. No discussion relating to public transport.
13	Intelligent transport systems: what contributes best to the NZTS objectives?	James (2006)	This paper documents international experience of where the greatest benefits have been gained from the implementation of intelligent transport systems. Information is relevant and useful.

Ref no.	Title/description	Author	Comments, relevance and best practice
14	Optimal vehicle routing with real-time traffic information	Kim et al (2004)	Investigation of the vehicle routing.
15	Assessing the benefits of traveller and transportation information systems	Kristof et al (2005)	Provides review of an evaluation tool called IDAS for assessing benefits of various types of TIS. Very useful for the research.
16	Intelligent transportation systems benefits, costs, deployment and lessons learned	Maccubbin et al (2008)	Comprehensive article with a lot of depth. Will be very useful for the research projects. Provides a lot of information regarding the cost and benefits of ITS.
17	VICS	MLIT (2012)	A diagrammatic explanation of MLIT's success with VICS technology.
18	Travel times on changeable message signs	Mortazavi et al (2009)	Evaluation of the effectiveness of VMS sign and the technology behind it.
19	Using social networks for exchanging valuable real time public transport information among travellers	Nunes et al (2011)	Discusses a reward based information exchange system using social networks.
20	How the NZ Transport Agency keeps you moving	NZ Transport Agency (2011)	Overview document of the TIS services the NZ Transport Agency provides.
21	Economic evaluation manual (EEM)	NZ Transport Agency (2013)	Industry's standard for the economic evaluation of transport activities in New Zealand.
22	Prediction of travel time variability for cost benefit analysis	Peer et al (2012)	Provides useful information regarding journey time reliability.
23	Implementation issues and strategies for deployment of traveller information systems in Texas	Persad et al (2006)	Useful information regarding the costs of various types of TIS.
24	Intelligent transportation systems benefits, costs, deployment and lessons learned desk reference: 2011 update	Pincus (2011)	Comprehensive article that has a lot of depth. Will be very useful for the research projects. Provides a lot of information regarding the cost and benefits of ITS.
25	Social media applications to publish dynamic transportation information on campus	Qiao et al (2011)	Investigates the potential to use social media websites to disseminate transportation information.
27	Future ATIS development In Houston: issues and alternatives	Ullman et al (2000)	Dated, but traveller information business model guidance (and analysis procedure) is useful.
28	ITS toolkit	Unknown (2013)	Highly detailed explanation of the benefits of ITS.
9	Vehicle-infrastructure integration (VII) initiative, benefit-cost analysis, Version 2.3 (draft)	US Department of Transportation (2008)	Very relevant document providing values of benefits for V2V and VICS.

Ref no.	Title/description	Author	Comments, relevance and best practice
26	ITS unit costs database	US Department of Transportation (2010)	Detailed information on capital and O/M costs for a wide range of TIS
29	The economic value of InfoConnect	Whyte (2009)	General description of InfoConnect – looking at the ‘big picture’
30	Social media pricing	WebpageFX (2013)	Website contains information about the cost of setting up website
31	Determinants of route choice and value of traveller information	Zhang and Levison (2008)	

Appendix B: Documents considered but not included in the review

Key Pre - 2002 (excl. 2002) [green]; 2002 – 2007 [red]

Ref no.	Title/description	Country	Year	Comments, relevance and best practice
A1	NCHRP synthesis 399 real-time traveller information systems– a synthesis of highway practice (http://onlinepubs.trb.org/onlinepubs/nchrp/nchrp_syn_399.pdf)	USA	2009	State of the practice on real-time traveller information systems. Contains 1) a literature review of previous studies, evaluations, and research activities; 2) survey findings; 3) observation and testing of as many systems as possible; and 4) interviews - via telephone and face-to-face
A2	ATIS FOT analysis report (http://ntl.bts.gov/lib/jpodocs/repts_te/6323.pdf)	USA	1998	Compares a number of field operational tests
A3	Florida model deployment final evaluation report (http://ops.fhwa.dot.gov/publications/fhwahop08050/index.htm)	USA	2009	In-depth analysis into software procurement and roll-out aspects of a traveller information project.
A4	Final report – model deployment of a regional, multi-modal 511* traveller information system (http://ntl.bts.gov/lib/jpodocs/repts_te/14248.htm)	USA	2005	Covers a wide region , includes pre-trip, en-route and travel information
A5	FHWA Office of Operations – 511* Travel information telephone service website (http://www.ops.fhwa.dot.gov/511/index.htm)	USA	Current	Contains links to all state 511 programs (includes cost–benefit information)
A6	511* Coalition evaluation reports (www.deploy511.org/index.php/2011-11-28-15- 47-03/16-library/program-documents/46-usage-statistics-documents)	USA	2008	Seems to contain all evaluation reports for 511 on a case-by-case basis
A7	FHWA Office of Operations - 511* Travel Information Telephone Service Publications and Presentations (http://ops.fhwa.dot.gov/511/resources/publications/ publications.htm)	USA	Current	Website/resource that includes: 'Implementation and operational guidelines for 511 services'; A series of deployment assistance reports, market-ready technologies and more
A8	City of Seattle Washington travel information (www.ite.org/annualmeeting/compendium10/p df/AB10H2102.pdf)	USA	2010	Provides plenty of information; however, no benefit–cost information.
A9	AASHTO social media survey results and analysis	USA	2012	The document has enough references to ATIS to be relevant to the study. Need to review in detail to determine traveller info-only components of the overall survey.

Ref no.	Title/description	Country	Year	Comments, relevance and best practice
A10	ATIS US business models review (www.ops.fhwa.dot.gov/travelinfo/resources/atis_bm.htm)	USA	2001	Guidance document.
A11	Real time travel information services business models – state of the practice review (http://ops.fhwa.dot.gov/publications/rtis_busmodels/rtis_busmodels.pdf)	USA	2007	Includes international/European experiences as well as USA. Guidance document.
A12	AMBER, emergency, and travel time messaging guidance for transportation agencies (http://ops.fhwa.dot.gov/travelinfo/resources/cms_rept/cmspractices.htm)	USA	2004	Provides analysis of VMS as a traveller information tool. Useful information.
A13	ITS for traveller information (http://ntl.bts.gov/lib/jpodocs/brochure/14319_files/1 4319.pdf)	USA	2007	Includes deployment benefits and lessons learned for ATIS, travel time, VMS messages, US 511 and more. Also includes places to look for more info and provides references.
A14	Understanding and predicting traveller response to information: a literature review (http://ntl.bts.gov/lib/jpodocs/repts_te/13953.html)	USA	2001	Vital findings likely contained in 399.

Appendix C: Summary of benefits achieved

Delivery mechanism	Journey type	Direct benefits		Indirect benefits			Direct costs	Indirect costs
		Travel time cost savings	Vehicle operating cost savings	Crash cost savings	Vehicle emission reduction benefit	Customer satisfaction	Capital (US$)	O/M (US$)
Free phone services	Urban/pre-Journey	Reduced travellers' frequency of early and late arrivals by 56% and 52%. 59% of people using the phone service reported they saved time. SmarTraveler project in Eastern Massachusetts had travellers receiving info on traffic conditions, construction and other events.		63% of users of the phone service reported avoiding traffic problems because of the information provided.	25% reduction in organic compound emission.	Claimed to be the top 5 ITS systems to be adopted. People who used the system were satisfied with its performance. Users of the system found the information to be useful. Depending on the region between 68%–99% of people who called said they would use the system again.	$4000–$6800 $1000–$7000	$250–$580/yr $150–$500/yr $0.50–$2.50/call $300,000/yr
	Urban/en route					Customer satisfaction range from 68% to 99% Claimed to be the top 5 ITS systems to be adopted.	$4000–$6800 $1000–$7000	$250–$580/yr $150–$500/yr $0.50–$2.50/call $300,000/yr
	Rural/pre journey				25% reduction in organic compound emission.		$4000–$6800 $1000–$7000	$250–$580/yr $150–$500/yr
	Rural/en-route						$4000–$6800 $1000–$7000	$250–$580/yr $150–$500/yr

Delivery mechanism	Journey type	Direct benefits		Indirect benefits			Direct costs	Indirect costs
		Travel time cost savings	**Vehicle operating cost savings**	**Crash cost savings**	**Vehicle emission reduction benefit**	**Customer satisfaction**	**Capital (US$)**	**O/M (US$)**
Website/RSS web feeds	Urban/pre-journey	Reduced traveller's frequency of early and late arrivals by 56% and 52%		20% of smartphone users will have access to road safety related traffic information	25% reduction in organic compound emission	66% use transits more frequently due to real-time information 80%–94% of drivers think road weather information enhances safety 83% of web user found the information helpful Positive feedback from website users Washington State, 94% agreed or strongly agreed that the website displaying road weather information better prepared travellers for their trips	$18000–$22000	$240–$1200
Radio	Urban/pre-journey	Reduced traveller's frequency of early and late arrivals by 56% and 52 %	Reduction of 66,000 to 99,000 vehicle miles due to radio and VMS signs.	Drivers have easy access to traffic information regarding accidents, road works, traffic jams and weather report updates via FM radio	25% reduction in organic compound emission	Claimed to be the top 5 ITS systems to be adopted	$15000–$35000 $15000–$30000	$600–$1800/yr $600–$1000/yr
	Urban/en-route					Claimed to be the top 5 ITS systems to be adopted	$15000–$35000	$600–$1800/yr

Delivery mechanism	Journey type	Direct benefits		Indirect benefits			Direct costs	Indirect costs
		Travel time cost savings	Vehicle operating cost savings	Crash cost savings	Vehicle emission reduction benefit	Customer satisfaction	Capital (US$)	O/M (US$)
	Rural/pre journey		Fuel saving 2600 – 2800 gallons				$15000–$35000	$600–$1800/yr
	Rural/en-route		Fuel saving 2600 – 2800 gallons		25% reduction in organic compound emission		$15000–$35000	$600–$1800/yr
Travel time signs	Urban/en-route	Passengers felt that they would also use the bus more if they had travel time signs available. 1.6% of motorists chose transit when travel time savings was 15 minutes or less, and 7.9% chose transit when the time savings was greater than 20 minutes.	Relieves congestion. Claimed to help evenly distribute traffic during rush hour.	Claimed to make highways safer by reducing congestion-causing collisions.		Passengers felt they waited a shorter time because of the signs being in place. 90% thought the signs made travel easier. 95% said information displays were useful.	$685,000 Roadside information $48,000–$119,000	
Variable message sign	Urban/en-route	$3.9 million reduction in non-recurrent and $1.9 million in recurrent congestions. Travel time reduction of 0.2% for VMS induced diversion rate of 3%; overall reduction jumps to 43.6% for a diversion rate of 27%. 85% of respondents claimed the changed route based on VMS sign. 66% claimed saved travel time as a result.	$4.8 million	$5.2 million Reduced overall accidents by 41%.	Little impact	Claimed to be the top 5 ITS systems to be adopted. Increase in traveller care.	$47,000–$119,000 $47,000–$117,000	$2300–$6000/yr $2400–$6,000/yr $75,000–$125,000/sign

Delivery mechanism	Journey type	Direct benefits		Indirect benefits			Direct costs	Indirect costs
		Travel time cost savings	Vehicle operating cost savings	Crash cost savings	Vehicle emission reduction benefit	Customer satisfaction	Capital (US$)	O/M (US$)
		Metropolitan areas increased vehicle speeds by 8% to 13%. Increased route adjustments by 68%–72%. No benefit to facility operation. Decreased traffic flows to hotspots by 20%–40%. Reduce traffic by 30%–40%.						
	Rural/en-route		Fuel saving 2600 – 2800 gallons			No benefit for flow or speed	$47,000–$119,000	$2300–$6000/yr
VICS and V2V	Urban/en-route			The US DOT's Connected Vehicle Research Program identified V2V technology as could halve the annual US traffic deaths.	Reduced annual CO_2 emissions by 2.4 million tons in 2009.			
Social media	Urban/en-route	Facebook service based Metro do Porto, Portugal, provides information to users. Facebook service based Lisbon, Portugal provides information to users.		38% participants who are willing to share incident information to		63% of users showed a willingness to add this Facebook page as a portal to transportation information. Seven out of the nine participants would like to check	$100–$500	$800–$2000/month

Delivery mechanism	Journey type	Direct benefits		Indirect benefits			Direct costs	Indirect costs
		Travel time cost savings	Vehicle operating cost savings	Crash cost savings	Vehicle emission reduction benefit	Customer satisfaction	Capital (US$)	O/M (US$)
				their social media group.		their social media when they are travelling on route. As long as they are accessible.		
GPS/ navigation	Urban/pre-Journey	Travellers can now monitor and make informed decisions on travel choices in real time using GPS-equipped personal communication devices and multi-modal route guidance tools available on the internet or mobile devices.				A study conducted in Japan found that the GPS information on phones influenced traveller pre-journey behaviour, in particular transport mode selection. The study found that the GPS information reduced carbon dioxide emissions by 20%.	\$200–\$400/yr	\$4–\$10/yr
	Urban/en-route	GPS navigation systems can determine the shortest route to a destination, so devices are enabled to receive life traffic data which can be factored in when selecting a route. Market penetration of 30% would allow 10% increase in vehicle volume. In vehicle navigation can reduce travel time by 4% to 10% in normal traffic conditions. Tourists were able to plan trips in unfamiliar area in 75% less time.	GPS systems can be used to administer RUCs based on the actual distance travelled as well as reducing overall distance travelled. GPS devices help navigate traffic efficiently therefore less time.	Advanced automatic collision notification systems can quickly dispatch emergency services after a crash. Advanced systems can supply call centres with crash info.	60% of drivers reported saving time and feeling safer when using GPS systems compared with using paper maps	\$0.5–\$2K global positioning system. Handheld device \$200–\$1000 \$200–\$400/yr	2% of capital cost for maintenance \$4–\$10/yr