

Overview of Intelligent Transportation Systems Deployment and Future Development in New Zealand

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Abstract

Intelligent Transportation System (ITS) combine information and communication technologies in the field of transportation, to create an efficient, effective, safe and resilient transport infrastructure. ITS enables a more intelligent use of available transportation infrastructure and vehicles by allowing real time information and data flow between service providers and users. The New Zealand Government aims for a transportation network that exhibits the above mentioned features. As mentioned in the National Land Transport Programme (2015-2018), the New Zealand Government is planning to invest \$3.2 billion NZD in the transport network over the next three years. The government is investing in building and maintaining transport infrastructure alongside research and development in ITS. This paper reviews the development of ITS in New Zealand, including its historic development histories and applications. The ITS technologies are grouped into seven categories based on their functionalities. A thorough literature review of the deployed ITS technologies is carried out and presented for each of the categories. The final section discusses the future of ITS technologies in New Zealand.

Introduction

The New Zealand government's overall objective for its transport sector is to create and provide a transport infrastructure that is efficient, effective, safe, secure, accessible and resilient and can support the economic and environmental long term strategies. The government has adopted a business growth agenda target to lift exports from 30 to 40 percent of gross domestic product by 2025 (NZTA, 2014). Since New Zealand's economy is reliant on services and trade of goods (such as tourism), we require an effective and efficient transport infrastructure to achieve these business agendas.

An effective transport network enables movement of people and freight to their destination in a timely manner, while providing a safe infrastructure with best available services possible. The nation's transport infrastructure must be sustainable and resilient to meet current needs as well as future demands while enduring and being able to recover from any shocks (NZTA, 2014). In 2015, Auckland's congested roads cost NZ economy over \$1.25 billion NZD in lost productivity (OECD, 2015). Congestion also had and continues to have a negative impact on the environment, waste non-renewable resources, and affects safety and quality of life in general.

Besides traffic congestion, safety of commuters is another critical issue that New Zealand transport sector is facing. Road crashes in the country cost about three times as much as traffic congestion, which is \$3.1 billion NZD annually (NZTA, 2014). This is excluding the trauma and personal tragedy experienced by those involved in the crash, since it cannot be evaluated financially. The government aims to implement safer journey strategy to improve road safety and is working in conjunction with vehicle manufactures to research and develop driver assistant systems (NZTA, 2014).

New Zealand's Greenhouse Gas (GHG) emissions have significantly increased since 1991. The GHG emissions in 2013 were 21% higher than those observed in 1991 (OECD, 2015). Transport, electricity generation and agriculture are the three sectors that have seen the maximum increase in GHG emission. On average, a New Zealander's GHG emission is nearly twice as that of someone in the UK and nearly seven times as that of someone in India (OECD, 2015). The NZ energy efficiency and conservation strategy has a target for making vehicles fuel efficient and in parallel to reduce the GHG emissions by five percent by 2020, and by 50 percent by 2050 (NZTA, 2014).

To achieve these goals, huge investment in the transport sector is necessary along with research and development in the field of Intelligent Transportation Systems (ITS). The transport system has many interlinked and interacting parts, such as moving people and freight between destinations, safer vehicles, efficient traffic management, real time flow of information and many more. Intelligent transportation systems have the potential to support these objectives by achieving transformational change in the way the system operates.

Intelligent Transportation Systems

Intelligent Transportation Systems involve the application of information technology, sensors and communication in the field of surface transport (OECD, 2015). They allow better use of the existing traffic infrastructure through the use of a broad range of technologies. ITS applications take the benefit of combining information, data processing, communication and sensor technology and apply them to vehicles and traffic infrastructure and management software, to provide a more efficient transport network. In ITS, disciplines such as transportation, engineering, telecommunication, computer science, finance, electronic commerce and automotive manufacturing are integrated together (GSMA, 2015). With the wide range of communication technologies available (such as wireless/radio mobile communication), ITS is now being seen as the key in creating interfaces and integration of real time information across all modes of transport (GSMA, 2015).

Overview of ITS in New Zealand

NZTA (New Zealand Transport Agency), in association with local authorities, manages the traffic on New Zealand roads. NZTA has three Joint Traffic Operation Centres (JTOC), located in Auckland, Wellington and Christchurch, that play a vital role in enhancing a road user's everyday travel experience by employing a wide range of ITS technologies. Hamilton and Tauranga also have their own traffic management centres where Tauranga, in particular, has an extensive ITS monitoring network.

In Auckland, JTOC works closely with Auckland Transport (AT) to reduce congestion on Auckland motorways and arterial roads by integrating area wide traffic management technologies. JTOC works closely with NZTA to provide accurate real time traffic information to the transport users. These data are gathered using the extensive network of sensors deployed across motorways and arterial roads. These technologies will be discussed in detail in later section of this paper.

The ITS technologies in NZ are provided and managed by either central and local governments, the private sector, or are driven by user innovation (such as crowd sourcing of information, open data and user generated data). For the purpose of this paper, ITS systems are grouped into seven categories, based on their functionalities (Giannopoulos.G.A, 2012). These categories include:

- Advanced Traveller Information Systems
- ITS for Traffic and Public Transport Management
- Charging and Payment Technologies
- ITS for Safety and Security
- ITS for Freight Transport and Logistics
- Navigation Services
- Intelligent mobility and co-mobility services

Advanced Traveller Information Systems

Advanced Traveller Information Systems (ATIS) are aimed at providing transport users traffic information which they can utilize efficiently plan their journeys. The topicality of the provided data ranges from static information about various means of transport to dynamic and real time information gathered from sensors deployed across traffic network (Dimitra Alexandri, 2015). Travelers can use this information to select the mode of transport, route of their journey to avoid congestion or utilize real-time journey time prediction to choose the time of their journeys. ATIS technologies are about collection, processing, transmitting and enabling optimal use of real time information.

Traditionally, real time data about traffic parameters (i.e. average speed, occupancy, journey time) was collected by NZTA through wide range of sensors. Typical sensors employed to collect data on the roads include inductive loop sensors, pneumatic tubes, radars, CCTV cameras and ultrasonic

detectors (Sharma, 2012; Harris, 2014). However, the proliferation of in-vehicle satellite navigation systems and location systems has made it possible to gather traffic parameters such as speed and delay with much higher accuracy.

Bluetooth technology is found in a variety of devices including cell phones, computers and various wireless communication systems. These Bluetooth devices can be used in conjunction with a roadside detector to gather various traffic parameters. AraFlow is a Wellington based ITS Company that has its Bluetooth sensors installed throughout the country. These sensors pick up Bluetooth signals from vehicles on the road and give them a unique address. If this address is picked up by another sensor, it gives the controllers an estimation of the journey times between the two sensors. This enables the creation of real time congestion maps and journey time estimation for arterial roads. Christchurch has over 100 AraFlow sensors deployed to produce journey time estimation for the Transport of Christchurch (AraFlow, 2015).

Traffic information (such as journey times, travel times and roadworks) can be viewed online or obtained by calling the authorities on a free-phone line. Road users can also receive road and traffic information directly via RSS (Really Simple Syndication) online or on their smart phones. NZTA also have agreements with the key radio station in the nation to provide real time traffic updates during morning and evening peak travel times and during major incidents. Journey times calculated from the inductive loops on the motorway can be viewed on the variable message signs or online on the Auckland state highway network.

Variable message signs or VMS are increasingly becoming popular in New Zealand. VMS is a road sign designed to convey traffic related information to commuters and travelers. These messages are dynamically altered or updated as required (McBride.C, 2011). VMS messages can present reactive incident messages (advanced warning of an upstream crash) or proactive messages such as estimated travel time on the motorway on the on-ramp. NZTA is the major provider of travel information and the sole VMS operator on Auckland Motorways. VMS were initially installed by NZTA for incident management, but later evolved to present other traffic information (McBride.C, 2011).

The tidal flow system on Auckland Harbor Bridge (AHB) was launched in 1990, to decrease the frequency of head-on collisions occurring on the bridge due to increase in traffic demand. This was the first in the world for traffic management of contrasting flow lanes to use movable lane barriers as a permanent installation. In 2009, this system was upgraded to a faster and quicker tidal flow system (Leak, 2012). Wellington on the other hand has been taking major steps in reducing the everyday struggle of commuters to find a parking spot in the busy CBD. The smart motorway in wellington manages traffic by varying speeds on sections of the motorway based on the congestion level.

Smart Parking, a bay sensor technology company is about to install 3000 parking sensors in Wellington central business districts. The users would be able to identify streets with free parking on smart phone applications (iOS, Android, Windows).

ITS for Traffic and Public Transport Management

One of the main focuses of ITS is to improve traffic management in urban and interurban transport networks (Giannopoulos.G.A, 2012). Some of the widely deployed ITS applications in this domain are:

- Adaptive traffic signal control
- Ramp Metering
- Incident detection and management
- Priority to emergency and public vehicles

- Variable speed limits
- Data collection
- Intelligent lane control
- Longer distance diversions re-routing

In some literature, ITS for Traffic Management is also referred to as Advanced Traffic Management Systems (ATMS) and is considered the backbone of ITS, due to its large scale and area wide implementations (Giannopoulos.G.A, 2012). ATMS applications deal with large amounts of traffic data and process them in real time alongside advanced traffic models to manage the dynamic traffic (Lam.J.K, 1993). Traffic signal control is an important part of ATMS. In the past, fixed light control was a popular way to manage traffic light, where the duration of green time changed based on the time of the day and the day of the week. Today, traffic signals are adaptive in nature and continually monitor traffic conditions to respond to dynamically changing traffic conditions.

Adaptive traffic signal control (ATSC) is a concept to detect vehicular traffic using sensors and algorithms to predict the traffic conditions and adjust signal timings. SCATS (Sydney Coordinated Adaptive Traffic Control System) is the ATSC that is deployed extensively throughout New Zealand. SCATS employs inductive loop detectors to measure demand of each lane at an intersection and changes the green signal timings to minimise the delay. The Auckland branch of JTOC manages and responds to incidents and event on the transport network. They also provide information to road users of any impact to their journey and provide alternative route details. This information is delivered to the commuters using variable message signs, radio, transport agency's website and third party smart phone applications.

Ramp metering is an ITS application that controls the traffic entering a motorway. During peak hours, when the motorway traffic is slow, the uncontrolled dense traffic entering the motorway results in worsening the condition of the motorway traffic. Ramp metering is employed to prevent clogging of motorway by restricting the flow of vehicles entering into the motorway traffic and is used widely in Europe, USA and Australia. SCATS ramp metering system (SRMS) was introduced in Auckland on a trial run on 1 March 2004 at the Mahunga Drive northbound on-ramp on the south-western motorway (Brown.T, 2004). The report of the trial concluded that ramp metering is an effective tool to improve traffic condition and safety on the motorway. Since then, NZTA has installed ramp signals at 61 motorway on-ramps on the Auckland motorways and has planned to install them on another 33 on-ramps on the western ring route between Manukau and Albany as it gets built. Auckland motorways always employ variable speed limit(VSL) algorithms and technology to reduce the effect of a shock at the upstream end (Smulders.S.A, 1998).

There are many ITS technologies that aim to make public transportation efficient, effective and more readily available for public use. These applications include real time public transport information, automatic vehicle identification and real time information at bus and train stops, priority for buses and other road public transport vehicles at intersection and flexible bus lane control. Since 1998, Auckland Transport (AT) operates the Real Time Passenger Information Systems (RTPIS), which initially provided arrival times for buses at a bus stop based on GPS tracking. Today RTPIS works for all three modes of public transport and the information is available not only on the real time boards at bus stops, but also online and on your smart phones (Vencatachellum, 2003).

Public vehicles today have a driver console unit (DCU) with capabilities of communication and interfacing with other devices such as real time boards, GPS, Electronic ticketing machines and as such. The DCU units have a touch screen that shows the current stage, door status, temperature of the bus and other useful information. The bus stages are advanced automatically based on the GPS position. The vehicle tracking system is integrated with the DCU and is used to correct estimation of bus arrival time on the real time boards (Aftak, 2016).

Charging and Payment Technologies

ITS enabled transportation pricing systems include applications such as smart ticketing, electronic toll collection and e-money. HOP is Auckland's smartcard ticketing system that travellers can use to pay for public transport by topping up their cards with e-money. Similar to HOP cards, commuters in Wellington can pay for their parking fares through Snapper cards which save the hassle to gather change. Snapper cards can also be used to pay for taxi fares in 3000 taxis in Wellington, the Hutt Valley, Porirua, Kapiti Coast, Palmerston North and Wanganui (Snapper, 2015).

Electronic toll collection is the use of sensors to capture images of a vehicle's registration plate (Ganguli.A, 2013). The driver is then sent a notice to pay the respective toll. New Zealand has three toll roads which are operated by the NZTA– the northern gateway toll, Tauranga eastern link toll road and the Takitimu Drive toll road. NZ toll roads use an electronic tolling system located on the gantry on each toll road. Drivers are not required to slow down, drive in a specific lane or at a particular speed. The toll system's sensors capture the size and length of the vehicle, takes a photo of front and rear license plates along with time and date. The system then assigns the correct toll tariff and sends this information to the central computer for processing. The commuters can pay the toll tariff through different ways – online, over the phone or in person at representative shops (Toll Roads, 2016).

Phone2Park is an ITS technology currently being used in all Wellington City Council parking zones. Phone2Park allows commuters to set up an online account and use it to pay for their parking spot, all by sending an SMS to the authorities. The commuter can opt to extend their parking or request a refund for unused parking time. The three things required to use this technology are a mobile phone, a bank account and internet access (Phone2park, 2016).

ITS for Safety and Security

Safety and security is a key element of any transport policy worldwide. Ideally, a safety ITS application would advise drivers of safety issues and give them enough time to react. Some ITS applications such as active lane driving or adaptive cruise control take steering wheel and braking into their own control to avoid accidents. Determining the correct ITS application to reduce accidents and their severity requires a framework to link the effects of ITS applications to the causes of accidents (Giannopoulos.G.A, 2012). These frameworks have three main pillars – the driver, the vehicle and the traffic infrastructure.

The ITS safety applications combine all three pillars to make driving a safe and pleasurable experience (Giannopoulos.G.A, 2012). Some of the applications in this domain are passive in nature, where the system is incapable of avoiding an accident but protects the driver in case of one (such as seat belts and air bags), while other technologies are active in nature where they proactively help the driver to achieve a desired level of safety and help avoid accidents (such as forward collision warning, automatic braking system, adaptive cruise control, lane control). Typical examples of such technologies include:

- Advance vehicle control systems
- Advanced cruise control
- Hazard warning
- Night vision enhancement
- Vehicle lateral and rear area monitoring
- Collision warning and avoidance
- Object detection
- Lane change support

Advanced Vehicle Control Systems (AVCS) denote vehicle-to-infrastructure and vehicle-to-vehicle integration that involves establishing a communication infrastructure that supports communication between them for a variety of vehicle safety applications. For example, two vehicles approaching an

intersection can avoid collision if the vehicles are continuously communicating with each other or with a roadside device that could recognise a collision between the two vehicles based on their speed and position (Tomizuka, 1994). This technology could issue a warning to the driver of an impending collision or even communicate directly with the vehicles to decelerate them.

ITS for Freight Transport and Logistics

Annually, 50 million tonnes of road freight originates in Auckland, 80% of which remains in Auckland while 19% moves to the south of Auckland and the remaining goes north of Auckland. It is critical to the region's economy that the transport network is able to support this high freight demand and allows businesses to reliably predict travel times (NZTA, 2016). ITS plays a critical role in the effective management of freight transport by gathering, storing, analyzing and providing access data to help users make better decisions (Giannopoulos.G.A, 2012). Typical information necessary for improving freight transportation includes traffic and infrastructure data, vehicle and freight location data, freight condition and positioning data, vehicle identity information, cargo information and warehouse operations and inventory data. This data are used in the following applications:

- Weight-in-motion systems
- Delivery space booking systems
- Vehicle location and condition monitoring systems
- Route planning systems
- Driving behavior monitoring and control systems
- Crash preventing systems
- Freight location monitoring systems
- Freight status monitoring systems

NZTA and Auckland Transport have joined hands on the 'East West Connection' project, which aims to improve freight efficiency, commuters travel, public transport and walking and cycling options over the next 30 years. The program covers six Auckland suburbs including Onehunga, Penrose, Mt Wellington, Mangere, Otahuhu and East Tamaki. The project aims to provide more efficient, predictable and safe freight journeys to minimise the costs created by delayed freight delivery.

Ports also play an important role in NZ's freight economy, with approximately one million containers being moved by Port of Auckland every year. The interconnectivity of these ports with the rest of the transport network is vital.

Travellers and commuters using NZ roads are liable for its upkeep and maintenance. Others, such as drivers of heavy vehicles have to pay road user charges (RUC). EROAD is an automated solution for RUC purchase and management (Easier RUC Management, 2016). Weight-in-motion (WIM) systems are used by NZTA to measure the weight of the heavy vehicles on the state highways. WIM systems are present at six locations on the state highway network. The information derived from these systems schedule highway maintenance along with other management issues (NZTA, 2014).

ITS Navigation Services

Navigation services, include technologies related to the vehicle position identification and providing navigation instructions. An important feature of ITS navigation systems is *coupling navigation services with real time traffic data, in order to provide route guidance based on real time traffic condition* (Giannopoulos.G.A 2012). Navigation systems' accuracy depends on the communication technology and the accuracy and availability of real time traffic data and in the absence of the two, historical data.

Mapping and location data required to determine a vehicle's position are available with acceptable

accuracy. The problem arises when the navigation system tries to represent the geometry of the road while identifying the lane a vehicle is in. Hence, in New Zealand *stand-alone GNSS (Global Navigation Satellite System) are not suitable for emerging safety critical ITS applications*. However, the reliability and accuracy of GNSS positioning can be improved through real-time positioning services. *These services provide augmentation from space or terrestrially transmitted corrections*. The Performance Based Navigation (PMN) system provides real time positioning services to aircrafts landing at Queenstown airports (NZTA, 2014).

The New Zealand government is also taking initiatives by amending civil aviation rules to aid the technological changes required to implement the national air navigation plan, which aims to introduce unmanned remotely piloted aircraft systems for non-military purposes. These systems are primarily designed for farming and forestry industry in NZ.

ITS for Intelligent Mobility and Co-Mobility Services

Intelligent mobility refers to the provision of well analysed information based on real time data for an effective and sustainable planning, and execution of trip making and the management of the demand for such trips (Giannopoulos.G.A, 2012). ITS applications and technologies mentioned in this paper can be thought of also promoting intelligent mobility as they invariably promote free flow of traffic in the network of all modes, greener transport, accurate real time information provision, better managed public transport and network and safe and secure transport infrastructure. The Joint Traffic Operation Centres (JTOC) managed by NZTA are currently focusing on building a proactive management system that collects more data to give a better understanding of how the whole network performs. JTOC is seeking to integrate data obtained across all modes of transport (including arterial roads, motorway, bus, train, and freight), to give customers more options to make smarter choices both before they leave home and during their journeys (NZTA, 2016).

Future of ITS in NZ

Transportation plays an important role in peoples lives and forms the backbone of a nation's economy. The future ITS technologies will trend towards obtaining accurate and timely real time data to integrate different modes of transport, vehicle telematics and autonomous vehicles. Multi modal transport services will increasingly become popular as cities become congested and public transport sector grows. The present interest in vehicle telematics will continue in the future with an increase in demand for safer and intelligent vehicles, driver assistant technologies and even autonomous vehicles.

New Zealand must prepare itself to absorb the benefit made in this sector and must allow research and development of such technologies at home. The role of ITS in achieving New Zealand's government transport goal of an effective, safe, secure, accessible and resilient transport infrastructure is significant. The government has also underlined the importance of ITS and has released a plan for its research and development for 2014-2018. The ITS plan outlines the steps towards introducing and facilitating ITS development, deployment and usage for an efficient, effective, safe and resilient transport network.

In 2014, the Ministry of Transport established an ITS leadership forum where government, ITS stakeholders and the multi-modal end user's representatives participate to develop a strategic vision for the use of ITS technologies in New Zealand. The ITS leadership forum also looks at the traffic information collected by government agencies like NZTA and means to share this information with the public and commercial sector, in a secure way. They also monitor the worldwide development made in the ITS domain to keep New Zealand update with the technologies. The New Zealand government has also taken upon itself to remove barriers for the continued deployment of ITS applications and wants to promote NZ as a test bed for current and future ITS technologies. This will introduce new technologies in the country and will also allow transport professionals to see the benefits of them. Overall, the future of Intelligent Transportation Systems looks bright in New

Zealand with a government that is taking the right steps in promotion of ITS and the ever-growing demand for better transport services around the nation.

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