Design Technologies & Challenges in Intelligent Transportation System

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Abstract— **An excellent transport system is vital for a high quality of life, making places accessible and bringing people and goods together. Advanced Transportation System applies advanced technologies of electronics, communications, computers, control and sensing and detecting in all kinds of transportation system in order to improve safety, efficiency and service, and traffic situation through transmitting real -time information.**

Intelligent transportation systems enable users to be better informed and make safer and smarter use of transport networks. They also allow transport providers to better track and manage their critical assets. However, designing an embedded solution with intelligence adds complexity to an already challenging development environment. Better data collection methods with appropriate models need to be developed and implemented to improve the quantification of these transportation system applications.

Index Terms— **ITS, sensors, GPS, Bluetooth, ADAS, GNSS etc.**

I. Introduction *(TRANSPORTATION SYSTEM)*

Transport systems are those in which information, data processing communication, and sensor technologies are applied to vehicles (including trains, aircraft and ships), transport infrastructure and users. Transport systems are designed in an intelligent way to be efficient and effective in meeting the needs of users. This takes into account the design and organization of supply chains, and the design of transport infrastructure and networks in relation to location and demand.

An transportation system has the ability to provide information, both in real-time and over time, that makes transport easier, more efficient, safer and less environmentally damaging. This information needs to be available both to the users of all modes of transport, and to those planning, designing, constructing and operating the transport system.

One of the major challenges for environmentally-focused transportation applications is to properly quantify their potential environmental and energy impacts, due to a lack of data. Better data collection methods with appropriate models need to be developed and implemented to improve the quantification of these transportation applications.

Intelligent transportation systems (ITS) are advanced applications which, without embodying intelligence as such, aim to provide innovative services relating to different modes of transport and traffic management and enable various users to be better informed and make safer, more coordinated, and 'smarter' use of transport networks.

Although ITS may refer to all modes of transport, EU Directive 2010/40/EU of 7 July 2010 on the framework for the deployment of intelligent transport systems in the field of road transport and for interfaces with other modes of transport defines ITS as systems in which information and communication technologies are applied in the field of road transport, including infrastructure, vehicles and users, and in traffic management and mobility management, as well as for interfaces with other modes of transport.

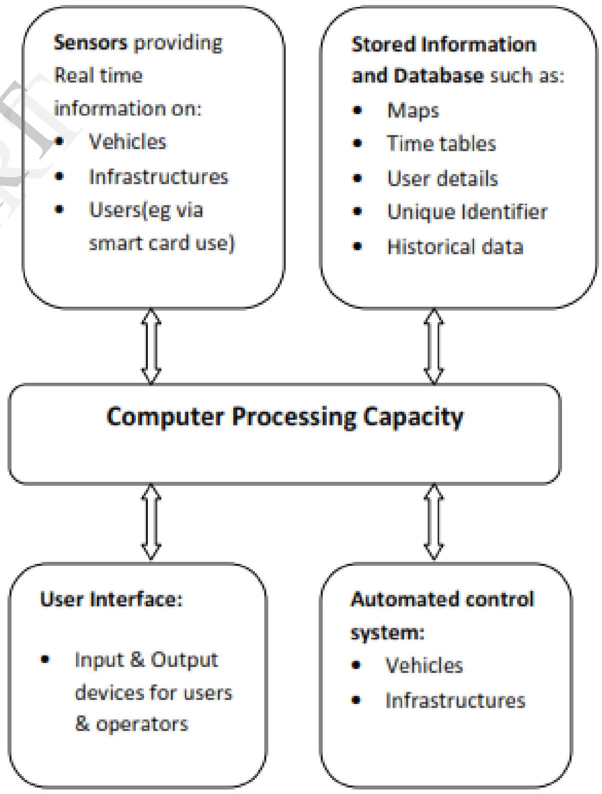

Fig. 1: Key components of intelligent transportation System

Many of the objectives on data, namely: 1) capturing environmental data from vehicles; 2) integrating these data with transportation management and performance improvements; and, 3) creating specific applications for transportation management and travelers that use environmental data.

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II. INTELLIGENT TRANSPORT TECHNOLOGIES

A. Wireless Communication

Various forms of wireless communications technologies have been proposed for intelligent transportation systems. Radio modem communication on UHF and VHF frequencies are widely used for short and long range communication within ITS. Short-range communications (less than 500 yards) can be accomplished using IEEE 802.11 protocols, specifically WAVE or the Dedicated Short Range Communications standard being promoted by the Intelligent Transportation Society of America and the United States Department of Transportation. Theoretically, the range of these protocols can be extended using Mobile ad hoc networks or Mesh networking.

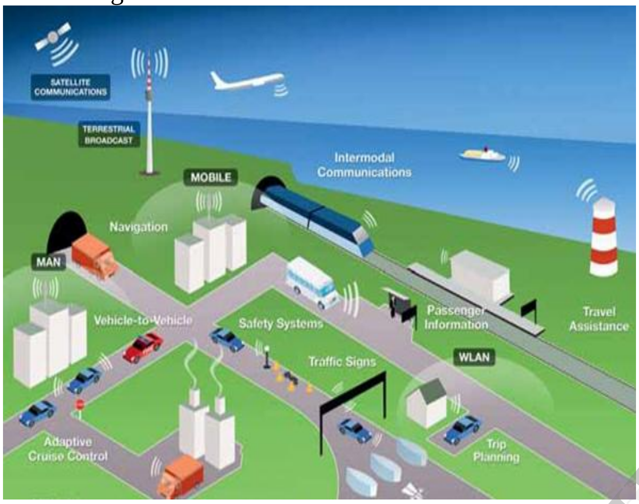

Fig. 2: Intelligent Transportation System

Longer range communications have been proposed using infrastructure networks such as WiMAX (IEEE 802.16), Global System for Mobile Communications (GSM), or 3G. Long-range communications using these methods are well established, but, unlike the short-range protocols, these methods require extensive and very expensive infrastructure deployment. There is lack of consensus as to what business model should support this infrastructure.

Auto Insurance companies have utilised ad hoc solutions to support eCall and behavioral tracking functionalities in the form of Telematics 2.0.

B. Computational Technologies

Recent advances in vehicle electronics have led to a move toward fewer, more capable computer processors on a vehicle. A typical vehicle in the early 2000s would have between 20 and 100 individual networked microcontroller/Programmable logic controller modules with non-real-time operating systems. The current trend is toward fewer, more costly microprocessor modules with hardware memory management and Real-Time Operating Systems. The new embedded system platforms allow for more sophisticated software applications to be implemented, including model-based process control, artificial intelligence, and ubiquitous computing. Perhaps the most important of these for Intelligent Transportation Systems is artificial intelligence.

C. Sensing Technologies

Technological advances in telecommunications and information technology, coupled with state-of-the-art microchip, RFID (Radio Frequency Identification), and inexpensive intelligent beacon sensing technologies, have enhanced the technical capabilities that will facilitate motorist safety benefits for intelligent transportation systems globally. Sensing systems for ITS are vehicle- and infrastructure-based networked systems, i.e., Intelligent vehicle technologies. Infrastructure sensors are indestructible (such as in-road reflectors) devices that are installed or embedded in the road or surrounding the road (e.g., on buildings, posts, and signs), as required, and may be manually disseminated during preventive road construction maintenance or by sensor injection machinery for rapid deployment. Vehicle-sensing systems include deployment of infrastructure-to-vehicle and vehicle-to-infrastructure electronic beacons for identification communications and may also employ video automatic number plate recognition or vehicle magnetic signature detection technologies at desired intervals to increase sustained monitoring of vehicles operating in critical zones.

D. Inductive loop detection

Inductive loops can be placed in a roadbed to detect vehicles as they pass through the loop's magnetic field. The simplest detectors simply count the number of vehicles during a unit of time (typically 60 seconds in the United States) that pass over the loop, while more sophisticated sensors estimate the speed, length, and weight of vehicles and the distance between them. Loops can be placed in a single lane or across multiple lanes, and they work with very slow or stopped vehicles as well as vehicles moving at high-speed.

E. Floating Car Data/Float Cellular Data

"Floating car" or "probe" data collection is a set of relatively low-cost methods for obtaining travel time and speed data for vehicles traveling along streets, highways, freeways, and other transportation routes. Broadly speaking, three methods have been used to obtain the raw data:

- GPS Based Methods. An increasing number of vehicles are equipped with in-vehicle GPS (satellite navigation) systems that have two-way communication with a traffic data provider. Position readings from these vehicles are used to compute vehicle speeds. Modern methods may not use dedicated hardware but instead Smartphone based solutions using so called Telematics 2.0.

- Vehicle Re-Identification. Vehicle re-identification methods require sets of detectors mounted along the road. In this technique, a unique serial number for a device in the vehicle is detected at one location and then detected again (re-identified) further down the road. Travel times and speed are calculated by comparing the time at which a specific device is detected by pairs of sensors. This can be done using the MAC (Machine Access Control) addresses from Bluetooth devices, or using the RFID serial numbers from Electronic Toll Collection (ETC) transponders (also called "toll tags").

Floating car data technology provides advantages over other methods of traffic measurement:

- Less expensive than sensors or cameras
- More coverage (potentially including all locations and streets)
- Faster to set up and less maintenance
- Works in all weather conditions, including heavy rain

F. Bluetooth Detection

Bluetooth is an accurate and inexpensive way to measure travel time and make origin/destination analysis. Bluetooth is a wireless standard used to communicate between electronic devices like mobile/smart phones, headsets, navigation systems, computers etc. Bluetooth road sensors are able to detect Bluetooth MAC addresses from Bluetooth devices in passing vehicles. If these sensors are interconnected they are able to calculate travel time and provide data for origin/destination matrices. Compared to other traffic measurement technologies, Bluetooth measurement has some significant advantages:

- Inexpensive per measurement point.
- Inexpensive on physical installation compared to other technologies
- No roadside maintenance needed
- Quick and easy configuration and calibration of complete solution

Bluetooth detection uses similar techniques to other traffic measurement technology, and will be as accurate as these other systems.

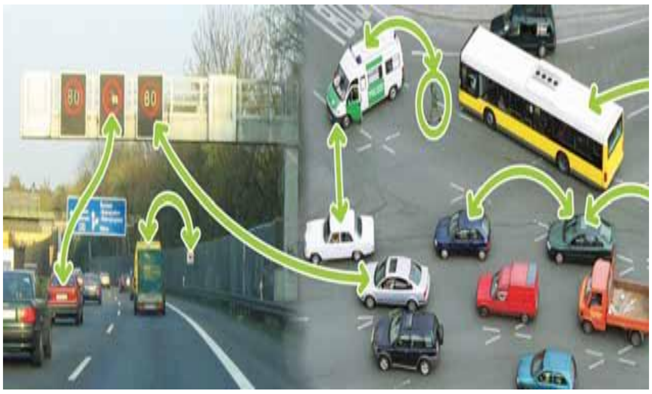

Fig. 3: ITS in action

G. Video vehicle detection

Traffic flow measurement and automatic incident detection using video camera is another form of vehicle detection. Since video detection systems such as those used in automatic number plate recognition do not involve installing any components directly into the road surface or roadbed, this type of system is known as a "non-intrusive" method of traffic detection. Video from black-and-white or color cameras is fed into processors that analyze the changing characteristics of the video image as vehicles pass. The cameras are typically mounted on poles or structures above or adjacent to the roadway. Most video detection systems require some initial configuration to "teach" the processor the baseline background image. This usually involves inputting known measurements such as the distance between lane lines or the height of the camera above the roadway. A single video detection processor can detect traffic simultaneously from one to eight cameras, depending on the brand and model. The typical output from a video detection system is lane-by-lane vehicle speeds, counts, and lane occupancy readings. Some systems provide additional outputs including gap, headway, stopped-vehicle detection, and wrong-way vehicle alarms.

III. ITS Design Requirements: Rugged, Small, Certified

Transportation solutions are most often housed outdoors or in moving vehicles, where exposure to a variety of climates dictates the need to operate in extended temperatures and to support the extremes of shock, vibration and humidity. In addition, space restrictions require putting expanding functionality on ever-smaller board form factors. Because of cost and the complex nature of intelligent embedded computing solutions for transportation, system qualification can take a very long time and require designers to look for products with a long lifecycle. Finally, transportation infrastructure is highly regulated around the world, so extra certification requirements are almost always part of a rugged ITS specification. There is no panacea for the challenges that are inherent in the variety of rugged, horizontal applications for ITS, but rather there are optimal solutions that can provide the highest level of success based on the specific application requirements.

TRAIN OPERATOR DISPLAY

A leading provider of technology solutions in transportation, aerospace, defense and security was creating an in-vehicle operator display system that could be installed in rail networks across the globe. The purpose of the display system was to provide an interface for conductors to monitor and manage train activity. Because the display system was being designed for subway and rail systems in multiple countries, the solution needed to account for variation: multiple sizes for display installation areas; multiple power requirements; multiple certification requirements.

This display system was also designed to meet a stringent mean time between failure (MTBF) requirements of over 100,000 hours (~2x normal MTBF requirement). To accomplish this, the design had to be rugged; The initial step was to select a rugged board that was designed for harsh environments from the ground up. With rugged—as opposed to ruggedized—solutions that support the extremes of shock, vibration, humidity and temperature, care is given to component selection, circuit design, Printed Circuit Board (PCB) layout and materials, thermal solutions, enclosure design and manufacturing process.

LOCOMOTIVE DVR & DATA GATEWAY

Intelligent transportation system requires an onboard locomotive video/audio capture system to aid in accident investigations and to provide safety training to crews. In addition to video and audio recording, requirements for the system included remote monitoring and control, real-time health monitoring and wireless video download.

To address vibration issues with data storage, the system incorporated solid-state media in a sealed, tamper-resistant housing. General options for storage include rotating hard disk drives (HDDs) for economy or solid-state drives (SSDs), which are more rugged, but also come at a higher price point. HDDs contain spinning disks and movable read/write heads, whereas SSDs use microchips that retain data in non-volatile memory chips and contain no moving parts, making them less susceptible to physical shock, altitude, and vibration issues. SSDs have faster access time and lower latency than do HDDs, and the flash memory and circuit board materials of SSDs make them lighter than higher performing HDDs. With the weight and vibration resistant requirements of mobile applications, solid-state media is a better choice for most ITS solutions.

INTELLIGENT BUS NETWORK

A leading designer of innovative technology solutions for all modes of public transportation implemented an on-board smart system enabling transit agencies to communicate with customers and dispatch, maintain its fleet and collect and analyze operating data. The numerous control inputs included vehicle run switch, front and rear door, wheelchair ramp, stop request, odometer and emergency alarm. The solution also required GPS with driving recorder and support for both wireless and cellular transmission. Finally, the company required a Class A device for testing against SAE International standards.

The complete solution to create the intelligent bus network consisted of a rugged COM Express module plus custom baseboard with an Intel Atom processor. Mini PCI Express slots support 802.11 a/b/g/n and cellular modems for connectivity and specified operating and storage temperature, shock and operating and non-operating vibration requirements were all designed into and extensively tested to create the custom solution.

MEETING THE ITS DESIGN CHALLENGE

As exemplified in the previous ITS designs, consistent requirements included the need for extreme environmental standards, space restrictions and specialized certifications to meet both technical and regulatory standards. To overcome these challenges, developers utilized already proven rugged hardware to provide a solid foundation for their designs. In addition, a familiarity with the pros and cons of small form factor options helped them to create a baseboard design that could best accommodate size and performance requirements. And to ensure certification success and system longevity, designers created solutions around standards-based hardware and products that follow the roadmap of an established architecture.

IV. APPLICATIONS OF INTELLIGENT TRANSPORTATION SYSTEM

VEHICLE CONTROL SYSTEMS

Vehicle control systems use real-time and other information to allow vehicles to respond to incidents and network conditions more autonomously, or to support the user in responding. ITS technology based vehicle control systems range from driver assistance systems and advanced driver assistance systems (ADAS) through to semi-autonomous and autonomous vehicles. These systems can include various degrees of cooperative ITS technologies (C-ITS).Such systems can potentially bring significant safety benefits, and can also address congestion problems and reduce emissions through smoother driving.

REAL-TIME AND NEAR TIME INFORMATION FOR TRAVELLERS

Real-time information systems use information gathered on network demand and disruptions, sometimes combined with GNSS, to help vehicle operators, public transport passengers and other users adapt and make informed travel choices. It can also be used to enable behavior change, for example by providing information to drivers, to allow them to adopt efficient driving styles.

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Fig. 4: Variable speed limit sign

TRAFFIC AND NETWORK MANAGEMENT SYSTEMS

Traffic management systems optimize the movement of vehicles, by using real-time information to intervene and adjust controls such as traffic signals to improve traffic flow. Airways' Collaborative Arrivals Manager provides an example of such systems in use in the aviation sector. These systems can improve efficiency, safety and environmental outcomes, and reduce the need to build additional infrastructure.

SUPPLY CHAIN AND FLEET MANAGEMENT SYSTEMS

For fleet managers, ITS technologies have provided improved vehicle effectiveness and efficiency through the monitoring of vehicle location performance and handling. ITS technologies can improve routing, fuel use, be used to co-ordinate freight arrival times and schedule vehicle and infrastructure maintenance. The ability to track cargo from the farm gate to the consumer has allowed for streamlining of the supply chain and improvement of supply chain logistics.

INFRASTRUCTURE PLANNING AND DEVELOPMENT TOOLS

ITS technologies are also available that support the design, construction and maintenance of transport infrastructure. The costs of infrastructure such as new roads can be large, and even small percentage gains in the way that such infrastructure is planned, designed and procured can have major financial benefits.
Technologies that support infrastructure planning and procurement include the following:
• Geospatial information systems that map areas and assist in identifying the most effective places in which to build new infrastructure.
• Tools for project management, modeling, planning, designing, constructing and operating the transport system.

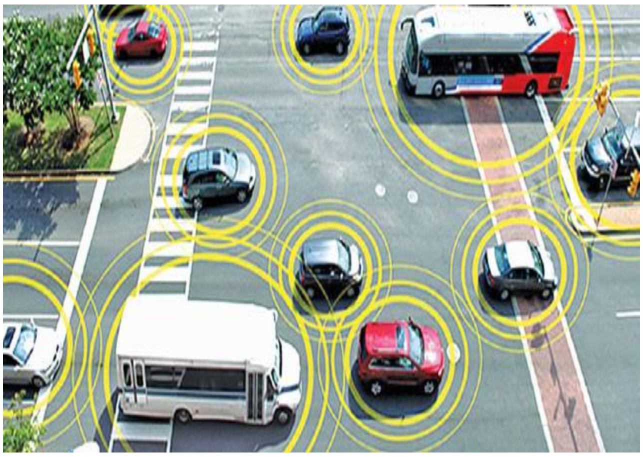

Fig. 5: Construction of new Highway Infrastructure

ASSET MANAGEMENT TOOLS

ITS technologies are also available that support infrastructure managers in managing and maintaining their assets. These technologies include the following:
• Technologies that provide feedback on infrastructure (e.g. traffic counting devices, weigh-in-motion sites and monitors), allowing maintenance needs to be better informed and managed.
• Business analytics and asset management software used to provide real-time, accurate analysis and reporting of network assets to help operators manage their assets in a more efficient manner. Well-targeted and optimally-timed asset management, based on good asset condition information, can bring significant financial savings.

COMPLIANCE AND ENFORCEMENT

Transport rules and regulations are designed to ensure that the greatest economic, safety and environmental benefits are delivered to society. ITS systems can be used to create a seamless information exchange for operators and enforcement agencies, and reduce the costs of complying with rules and regulations for all involved. It can also assist in making enforcement more targeted and cost effective, reducing the burden on those who comply with transport rules.

V. KEY BARRIER TO COST EFFECTIVE IMPLEMENTATION

GNSS COVERAGE AND ACCURACY

Unlike many nations New Zealand faces challenges relating to satellite based positioning data. Our hilly topography and lack of augmentation make it difficult to get good satellite coverage in all areas, and there is a strategic risk because we rely on global satellite systems that can be switched off or degraded by the jurisdiction which operates them.
In future the lack of accurate augmented GNSS coverage may limit the benefits offered by some ITS technologies. At some point the government or the sector may need to invest in additional ground-based augmentation systems to ensure that GNSS technology works effectively in New Zealand.

INTEROPERABILITY AND DATA SHARING

Without a common architecture there is a risk that a task may be performed by multiple agencies, or not at all. For example central and local government agencies may gather or hold the same information without either party realizing this. An agreed architecture would also enhance the ability for the private sector to provide services because data available from existing systems could be shared at a lower cost than if new systems were built to collect the data. An agreed ITS technology architecture would contribute to the creation of an effective and efficient transport system by encouraging interoperability between systems and devices.

RADIO SPECTRUM ALLOCATION AND LACK OF INTERNATIONAL STANDARDS

Communication between C-ITS vehicles and infrastructure will depend on access to interference free radio spectrum. Currently the US, the European Union and Japan are standards setters in this area. Unfortunately, each of these jurisdictions is proposing to use a different part of the radio spectrum. Ideally, all vehicles in a fleet should operate to the same standard, so New Zealand will need to select one of these frequency ranges. Table One shows the proposed spectrum allocation for C-ITS vehicles in the US, the EU, and Japan.
The risks of having vehicles on the network using different frequencies are not fully understood; for example interference may cause a vehicle to brake unexpectedly in response to a phantom signal.

FRAGMENTED AND COMPLEX OWNERSHIP STRUCTURES

Ownership of transport infrastructure is spread across a wide range of government, local government, and private agencies and individuals. No one agency in New Zealand has direct control of the entire New Zealand roading network, the seaports and airports are competitors, and there is no agreed ITS technology goal for the network. This complexity of ownership applies equally to information and data. Ownership of the intellectual property rights of publicly funded data will need to be clearly understood and agreed by all who use the data. This complex pattern of ownership may hold back efficient uptake and use of ITS technologies, unless there is strong coordination and use of common standards. The government has a role in helping to facilitate this sector coordination.

SECURITY OF SYSTEMS AND INFORMATION

The use of wireless communication by ITS technology including payment, enforcement, and licensing systems and C-ITS-equipped vehicles and infrastructure introduces the possibility of malicious tampering with the systems, including hacking, jamming, pirating of the signals and theft of personal data. A hacked vehicle control system could cause a serious crash while the hacking of infrastructure would allow false warnings about congestion or directions to be given to road users. Hacking of payment systems would compromise public confidence and therefore the efficient operation of the system.

The security of electronic information and communication systems is a well-known issue, but may have particular implications for ITS applications that will need to be understood and managed. For ITS to be implemented and utilized, public confidence in the whole system must be maintained, including all aspects of regulation and operation.

ACCURACY AND RELIABILITY OF INFORMATION

For all ITS applications, accuracy of information is important. For some, particularly those that involve vehicle control, they are critical. In payment and charging applications, accuracy and reliability of information are essential in maintaining public confidence. Some sources of information, for example GNSS positioning data, may not be accurate enough for some potential ITS applications. For others, reliability and accuracy may require significant investment in infrastructure capacity (for example communications capacity if widespread C-ITS uptake beyond the aviation sector is to occur) which may represent a barrier to implementation.

PUBLIC PERCEPTION OF INFORMATION PRIVACY RISKS

ITS technologies can generate information about vehicles and, by default, vehicle operators. The widespread adoption of technologies that allow the tracking of vehicles has caused public concern both in New Zealand and internationally, which may affect the rate of uptake by customers.

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