ITS MARKET DATA UPDATE STUDY

Phase 1 Report
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By Joseph K. Lam

Chair International Business Development Committee ITS Canada

INTRODUCTION

Over the last decade, ITS market data were used in many ITS Canada activities. These include technical committee work as well as international business development (IBD) activities such as CanExport subsidy application and trade mission planning. The current set of ITS market data is obsolete, and an updated set is needed to execute our Strategic Plan, to assist our technical committees, to conduct our IBD program and to serve our members effectively and without embarrassment.

For this reason, ITS Canada initiated an ITS Market Update Study (IMDUS) in January 2021. The Study is divided into two phases, with Phase 1 covering the domestic market while Phase 2 is mostly related to the international one. Phase 1 was completed in early April 2021 and Phase 2, if approved, will be initiated in late April and completed by mid-October 2021, but the results will be confirmed and modified, hopefully by face to face meetings with international experts at the ITS World Congress in Hamburg in October 2021 and the TRB meeting in Washington DC in January 2022. The following is a report on Phase 1 findings.

STUDY FRAMEWORK

IMDUS was to be carried out in a short time frame by conducting web research and member survey and interviews. To organize and control the study, a framework was established, setting limits on the study scope, and providing targets for the interviews. Research and stakeholder lists were prepared and submitted for review. The lists, covering both Phase 1 and Phase 2, are considered live throughout the Study, and could be modified or expanded as required.

In Phase 1, research on emerging technologies and how it impacts or enables ITS development was conducted. Because of the Covid-19 crisis, almost all the research was carried out on the web, including review of the following:

- Recent papers and presentations by our members
- Web pages on various appropriate technology and ITS topics
- Recent reports available from various agencies (e.g. Transport Canada, NRC)
- ITS newsletters and magazines (e.g. ITS International, Intertraffic Newsletter)
- ITS consultant and vendor newsletters (e.g. Inrix, Iteris)
- Websites, newsletters and papers provided by the academic community (e.g. UTRRI, SFC)
- Reports and newsletters from ITS-related organizations (e.g. TRB, CAVCOE, ITS America Smartbrief, ITS UK, TAC)

In addition, complimentary webinars on pertinent ITS topics presented by academic and industry experts were attended, including the following:

- Florida Automated Vehicle webinar series
- UTTRI webinars
- Smart Freight Centre webinars
- MOVE Conference (a virtual conference on mobility)
- Webinars hosted by various vendors, integrators, and consultants.
- Webinars with international partners (e.g. ITS HK and ITS Indonesia)

A number of papers, presentations, reports and blogs on ITS development was collected and will be submitted after classification. This will serve as valuable references for ITS Canada officials staff and members alike. Although completed for Phase 1, web research on ITS development and the related marketplace is continuing for the benefit of Phase 2.

THE BIG PICTURE

This determines where we are and helps us to establish a context for the study. It was based on the investigator's experience and expertise in ITS and his knowledge of the industry. At the same time, a number of documents and other pieces of information were reviewed, and the notable ones are as follows:

- Membership list and distribution
- ITS Canada Strategic Plan (2020 – 2025)
- Canada ITS architecture 3.1
- ITS Canada International Business Development Strategy for Fiscal 2021/2022
- Memberships of various technical committees and documents available.
- Various scoping papers on ITS applications available from Transport Canada.
- Transport Canada's Transport 2030 Plan
- Canada's Innovation and Skills Plan

Intelligent Transportation Systems

ITS Canada defines Intelligent Transportation Systems as "The application of advanced and emerging technologies (computers, sensors, control, communications, and electronic devices) in transportation to save lives, time, money, energy and the environment."
The above definition is an elastic one and covers all modes of transportation. ITS provide an important key to achieving many of today's transportation objectives, namely mobility, safety,

efficiency, and sustainability. Leading-edge technologies are already embedded in a variety of ITS to improve transportation around the world. As new technologies emerge, integration of these emerging technologies into ITS applications is necessary to enhance the performance and cost-effectiveness of our transportation systems.

Governments around the world are investing hundreds of millions of dollars in ITS solutions to solve transportation problems. For example, cities and states in the United States will be spending 14 billion dollars this year in transportation technology. An innovative ITS industry in Canada will not only help to solve domestic transportation problems but also be able to take advantage of the huge ITS global market.

Transportation 2030 Plan

The Transportation 2030 Plan is Transport Canada's vision for a safe, secure, green, innovative, and integrated transportation system that supports trade and economic growth and a cleaner environment, with the following themes concerning mobility and technology:

- The traveller by providing greater choice, better service, lower cost, and enhanced rights
- Safer transportation for all operators and travellers across all modes
- Green and innovative transportation by reducing environmental impact and embracing new technologies

It is significant that the focus is on the traveller and his/her mobility rather than the various modes of transportation and the hardware, software and systems involved. Mobility enhancement has to be mode neutral.

Canada's Innovation and Skills Plan

Announced in 2017, the Innovation and Skills Plan is an ambitious effort to make Canada a world-leading centre for innovation, to create well-paying jobs and to help strengthen the economy. It will help establish Canada as one of the most innovative countries in the world and foster a culture of innovation from coast to coast to coast.

Labour has been highlighted as an area of great concern. Actions by government to ensure a competitive supply of labour are important. In particular, the shortage of software skills, which are crucial in many ITS deployments, has been identified as a problem.

As part of the Innovation and Skill Development Plan, an e-book on Building a Nation on Innovators is provided, which contains very useful information on the innovation process and a long list of grants and subsidies to help Canadians in innovation.

Canadian ITS Architecture

Technology and therefore innovation are critical for successful ITS development. To assist Canadians to understand ITS and their building blocks, Transport Canada developed the Canadian ITS architecture, which identifies various ITS technologies as "User Services".

The Canadian architecture has been updated a few times to align with updates in the US, as it makes sense that Canada adopts similar design approaches and standards as the States. The latest version of the Canadian architecture is Version 3.1.

ITS Canada Strategic Plan (2020 – 2025)

The recently developed Strategic Plan stipulates that ITS Canada is the hub for mobility technology and therefore a hub for our members. We support mobility technologies through:

- Championing the benefits of mobility technologies
- Fostering and promoting innovation
- Integrating the expertise, products and services of our members
- Enabling communication for learning and collaboration

ITS Canada therefore supports ITS innovation and development using the latest technologies.

This is a strategic position as there are numerous ITS enabling technologies waiting to be utilized.

TRENDS OF ENABLING TECHNOLOGIES AND THEIR IMPACT

In the past two decades, many new technologies have emerged and impacted our daily lives more significantly and rapidly than previous times. ITS have relied on these technologies to provide cost-effective solutions to our transportation problems. The following are key emerging ones that will enable further development and enhancement of ITS in the next decade.

5G Communications Network

Canadian telecommunication carriers have been busy implementing 5G networks in the country, and this is going to revolutionize digital communications throughout Canada and enhance the efficiency and effectiveness of countless businesses, including ITS. In addition to providing Canadians with the latest technology, wireless industry investments in 5G networks are expected to contribute an estimated $40 billion to the country's economy and 250,000 permanent new jobs by 2026.

Compared to 4G, 5G provides 10 times the speed, 1000 times the capacity (allowing for multiple streaming) and 70% less latency. With ultra-low latency, the lag between sending a request and the network responding will theoretically drop to one millisecond, 400 times faster than the blink of an eye. This will allow for a massive increase in the number of connected devices (1 million per square mile vs 6500 for 4G), which is beneficial to ITS network development.

The above advantages of 5G also provide a significantly more favourable environment for edge computing, which is really an advanced form of distributed computer processing. Using AI or data analytics, 5G allows heavy data manipulation in a large network to be pushed to the edges or the points where the data is collected without sacrificing response and support from the cloud or central server. The edge could be a video camera with AI incident detection algorithms, a signal controller which adapts the signal timing to the real-time traffic flow, or a mobile phone used for route optimization in an e-commerce dispatch centre. Moreover, since a network typically has many nodes or edges doing the same thing, identical, off the shelf and modular hardware and software can be used in all the edges within the network more reliably and cost-effectively. These features are exceptionally beneficial for the control of traffic management and most ITS networks.

Internet of Things

In simple terms, the Internet of Things (IoT) consists of any device with an on/off switch connected to the Internet. This includes mobile phones, traffic sensors, video cameras and connected vehicles. The IoT can be used to organize such things as traffic sensor networks and "Smart cities" can use it to reduce waste and maximize the efficient use of energy.

With the emergence of technologies like AI and Data Analytics, the number of IoT devices recently exploded from 7 billions in 2018 to almost 27 billions in 2019, with close to 130 new IoT devices connected to the web every second. It is projected that 75 billions of IoT devices will be connected to the web by 2015.

In terms of revenue, the IoT global market was $737 billion, growing to $1.29 trillion in 2020, and experts estimate that by 2026, the IoT device market alone in the world will reach $1.1 trillion.

Connected and Autonomous Vehicles

The Connected and Autonomous Vehicle (CAV) cluster consists of various types and generations of technologies, which can be classified into 5 levels in an ascending order, ranging from a Level zero of traditional non-automated vehicles through various levels up to Level 5 of fully automated ones. Depending on the features installed, a connected vehicle may be able to communicate with:

- its occupants through their mobile and similar devices
- with other vehicles and road users
- with the transportation infrastructure including roadways and traffic signals.
- Internet based applications and other entities

An automated vehicle:

- Uses a combination of sensors, controllers, and onboard computers, along with sophisticated software
- Allows the vehicle to control at least some driving functions, instead of a human driver (for example, steering, braking and acceleration, and checking and monitoring the driving environment.)

CAV Testing and Piloting. CAV technologies are rapidly emerging, and a number of public agencies and private companies around the world are involved in testing and assessing these technologies. In Canada, Transport Canada uses a hands-on approach to safely study driver interactions with CAV technologies utilizing an in-house driving simulator with driver assistance systems. Eye tracking software is also used to study driver visual behaviour. Information from these research activities provide evidence for the development of guidelines, standards and regulations.

The Government of Canada owns a world-class Motor Vehicle Test Centre in Blainville, Quebec which is a well-equipped area for testing CAV technologies. A number of tests are being carried out here to assess the effectiveness of driver assistance technologies currently available on the market.

In addition, Transport Canada provides funding to agencies across Canada for various endeavours in CAV testing and development. For example, the City of Calgary was funded to test an automated shuttle for light rail connection. The shuttle moved 4,500 members of the public during the trial. The pilot was seen as a success, and the City found a number of positive outcomes, and lessons learned. The City of Calgary was further funded to create a connected vehicle test bed along 16th Avenue North in the city to test connected vehicle technologies, in supporting shorter travel times for emergency vehicles and reducing the risk of collisions.

As another example, the Ministry of Transportation of Ontario was funded to support planning for connected and automated vehicles in the greater Toronto and Hamilton areas, and the Waterloo corridor. Over 73 municipal transportation stakeholders provided input and key insights on challenges and needs related to connected and automated vehicles. The Ontario Smart Mobility Readiness Forum was subsequently created to support collaboration on and to continue conversations in CAV.

However, Canadians are still apprehensive about CAV as a recent Transport Canada public opinion research indicates. This anxiety about mainstream adoption of AV is understandable. Canadians need clear information on AV, how it works and what the limitations are, to allay fears and help them make the right mobility decisions in the future.

Artificial Intelligence

Artificial Intelligence (AI) is all around us in our daily lives, from movie recommendation on the web to electronic payment and censorship of undesirable messages in social media. More sophisticated versions use machine vision and pattern recognition in ITS functions and video detection of traffic incidents and congestion is a good example.

The number of businesses adopting AI grew by 270% in 4 years from 2015 to 2019 and the overall global AI market is expected to reach $267 billion in 2027.

Artificial intelligence is impacting the future of virtually every industry and every human being, and it will continue to act as a technological innovator or enabler of many systems, including ITS, for the foreseeable future. According to the World Economic Forum, AI will create 56 million new jobs by 2022.

Big data analytics

Big data can be defined as data sets whose size or type is beyond the ability of traditional relational databases to capture, manage and process the data with low latency. For example, data originating from traffic sensors and video cameras is generated in real time and in a very large scale.

Big data analytics is the use of advanced analytic techniques against very large, diverse big data sets from different sources, and in different sizes from terabytes to zettabytes. It can ultimately fuel better and faster decision-making, modelling and predicting future outcomes, and enhanced intelligence.

With the global big data market having reached $49 billion in size, experts agree that the amount of generated data will be growing exponentially in the future. By 2025, it is estimated that the global datasphere will grow from 4.4 in 2013 to 175 zettabytes (10 to the power of 21). 2 exabytes (10 to the power of 18) of data are generated each day across all industries. By 2023, the big data industry will be worth an estimated $77 billion.

It is easy to see that big data analytics is taking over the world. Bringing accurate insights to every industry using big data is vital for users and operators alike. However, while there are many IT experts who are 'big data capable', there are significantly less people who are 'big data functional'. Expertise and experience in the domain area of traffic and transportation are absolutely necessary to define clearly what domain problems are to be solved and what solutions to be achieved. This way, the data can be turned into useful information beneficial to the domain user and then the information can be converted into appropriate intelligence for decision and action.

Blockchain

Another emerging technology for data processing is blockchain, which is a system of recording information in a way that makes it difficult or impossible to change, hack, or cheat the system. It is essentially a digital ledger of transactions that is duplicated and distributed across the entire network of computer systems on the blockchain. Each block in the chain contains a number of transactions, and every time a new transaction occurs on the blockchain, a record of that transaction is added to every participant's ledger. This means if one block in one chain was changed, it would be immediately apparent it had been tampered with. If hackers wanted to corrupt a blockchain system, they would have to change every block in the chain, across all of the distributed versions of the chain.

The blockchain technology is still maturing but its characteristics make it very suitable for applications involving transactions over numerous sites. Tracking of cargo through the entire supply chain is a good example.

Social Networking

The Covid-19 pandemic saw a surge of social networking as social media activities have increased dramatically across all demographics during 2020 in place of many forms of face-to-face communication. 54% of social media users, aged 16 to 64 in select countries, are reported to spend more time on social channels for shows and 42% more time for messenger services.

Certain businesses have also benefited from the heightened usage of social media. E-commerce has grown in leaps and bounds as a record number of people resort to online shopping, thus creating a new transportation challenge in our cities. All in all, social media will continue to be a highly effective medium to allow people to come together digitally.

The future of social media is tied to the proliferation of mobile phones. More and more people are using their smartphones as their main source for accessing social platforms. 4.2 billion people around the world now use social media, with 4.15 billion accessing them via mobile phones, and 490 million new users have come online in 2020.

The above statistics is significant for transportation vendors, operators, and managers. As indicated earlier, each mobile phone is a source of big data and social platforms can be used to not only transmit data back and forth the traffic management centre but also as means to engage the mobile users as traffic operators, condition informers and incident reporters.

Smart City Concepts

A smart city is a framework designed to harness the capabilities of innovative technology to connect, protect, and enhance the lives of its citizens. By harnessing information and communication technologies and the Internet of Things (IoT), a smart city collects and analyses data from multiple channels to ‘sense’ the city’s environment, providing real-time information to help governments, enterprises, and citizens make better and more informed decisions to improve the overall quality of life.

By creating a network of objects capable of smart interactions through IoT, the door is opened to a wide range of technological innovations that could help improve public transport, provide accurate traffic report, or manage real-time traffic control.

With the rapid expansion of cities around the world, the use of advanced technologies becomes critical to solve the complex problems which the city faces. Many experts agree that one of the best parameters to determine if a city is a smart city is to check its transportation and mobility parameters.

The transportation system of a city is a key service provided by the jurisdiction to its citizens. Its development and enhancement need to be consistent with the overall strategy the city uses for smart city development. At the same time, the system can take advantage of financial provision of the smart city undertaking and the improvements provided in its various components including the communications infrastructure and IT capabilities. As technologies become integrated, the transportation system should become an integral part of the overall smart city.

THE QUESTIONNAIRE AND INTERVIEW PROCESS

After several iterations of the stakeholder contact lists and some discussions, survey questionnaires were sent out around the end of February to the following major groups of stakeholders (ITS Canada members) and the responses received would be supplemented by subsequent telephone interviews of an additional number of members.

- A municipality questionnaire to 17 municipalities
- A private sector questionnaire to 77 private companies
- A questionnaire to a focus group consisting of ITS Canada BOD members, technical committee chairs, academics, and other experts.

The focus of the above process was on domestic stakeholders during Phase 1 of IMDUS while the international stakeholders would be contacted in Phase 2. At the time of the decision, it was understood that funding for Phase 2 was not yet secured.

The response to the questionnaires was quite disappointing, with a rate of about 25%. The questionnaire process was therefore quickly followed up by direct telephone calls to members. As a result, the sample size was increased to above 40%. The telephone conversations were obviously more animated and more informative than responses to the questionnaires. Information from the private sector is very consistent throughout and it can therefore be assumed that the samples collected were sufficient but can be augmented by additional interviews in Phase 2. However, ITS Canada has only a small number of municipal members and therefore some non-member municipalities need to be interviewed in Phase 2. For the focus group, there was no response from the academic members to the questionnaire. When emails were sent to them to make appointments, again there was no response with one exception. This situation has to be followed up later.

RESULTS OF QUESTIONNAIRES AND INTERVIEWS

There are many speculations as to why the return to the survey questionnaire was low. In retrospect, while the telephone interviews were less efficient, they turned out to be more effective and informative, with some in-depth discussions on mobility challenges and solutions. Responses from the private sector group were quite consistent throughout. They all understand that the emerging technologies are all around us and they are all ready to take advantage of that. However, they share the following concerns:

- Staff recruitment is a major issue and hiring people with the right mix of ITS expertise has been a challenge.
- The customer is slow to accept or adapt to new ITS technologies leading to long sales cycles
- Procurement is often a problem as the low bid is not necessarily the right bid.

However, all of them indicated that their revenue in 2020 was only marginally affected, if at all, by the pandemic and some of them even saw a revenue increase in early 2021. Some companies had to hire more staff last year. Many of the responding companies grew significantly in the last few years and some others started as small entrepreneurs with 2 or 3 people and became sizeable corporations of 40 to 50 today. Except for the multi-nationals, most of the ITS firms can be classified as SME's.

Most of the municipal members interviewed have ITS strategic plans in place and already possess ITS they can rely on. They all have plans to expand their systems in size and/or functionality. Contractor performance were also discussed but they are beyond the scope of this study. The municipality sample is rather limited, and this will be remedied in Phase 2.

Discussions with the focus group offer good insights into the enabling technologies and how to apply them. Opinion was offered and challenging issues were discussed. Unfortunately, it was difficult to contact the academic members, but this situation will be remedied in the subsequent phase.

All in all, the survey provided very useful information which is utilized throughout this report. Sufficient evidence was collected which enabled the development of a list of ITS requirements for Canada as well as a number of recommendations. However, these are interim in nature as further data collection in Phase 2 is expected to bring about modification and refinement.

ITS MARKET TRENDS IN CANADA

ITS Capability Clusters

Because of functional similarities among technologies and cross-cutting issues related to legal and operational aspects, boundaries among the various ITS user services as defined in the Canadian Architecture have become blurred. At the same time, recent technology advancement has resulted in a tighter integration of the various services and encouraged better collaboration of all parties concerned.

Transportation 2030 Plan calls for a focus on the traveller rather than transportation modes, and so ITS should focus on system functions and how they interact with the traveller. It is now therefore more meaningful and practical to consider ITS as mobility technology and capability clusters. The following is a potential list of clusters:

- Traffic management systems, including freeway traffic management system, traffic signal control system, ATMS, ATIS, and any combinations or parts thereof. In these systems, technologies are used to manage and control traffic in the road infrastructure. They could manifest themselves as travel time systems to inform travellers of journey time using variable message signs or through social networks, traffic adaptive control systems which manipulate signal timings based on real-time traffic information , or CCTV systems that help to detect congestion and incidents on expressways.
- Multi-modal systems including various forms of public transit, taxis, rental cars, shared rides, micro-mobility modes such as e-scooter, and in the near future, air taxis and drones, combined to serve and meet the needs and choices of travellers. This is consistent with the emphasis that Transport 2030 Plan places on the traveller. The above modes could be shared and/or autonomous.

- Smart freight and supply logistics including the use of traditional or autonomous trucks for first mile, middle mile, and last mile deliveries. Supply logistics may include automated warehousing or technologies used in optimizing delivery routes and logistics as well as the management of purchasing and sales activities. E-commerce is becoming a major consideration in this field.
- Electronic payment is a major consideration in multi-modal systems whether it is for transit rides or bike shares, using cell phones or credit cards. It is also required for parking and toll roads although the latter is not a major consideration in Canada.
- Data management and analytics refer to the management of various aspects of data processing including collecting, organizing, reporting, and archiving, and purpose-specific analytics for such things as accident black spot identification. It tends to overlap with traffic management systems above, which however tend to deal with real-time requirements.
- Smart city concepts including use of technologies in the smart city context or related to the integration of the transportation system with the overall smart city system.

It is important to first review the key enabling technologies that have impacted Canadian business and society in general, and then how their development trends enable the development of the ITS clusters above.

The emerging technologies discussed above are termed disruptive because they change our business models and impact our daily lives. However, many of the ITS designed and deployed have used concepts or technologies which are the previous generations or traditional equivalents of the emerging ones. Traffic managers do not see these new technologies as disruptive but rather enabling them to enhance their systems smoothly and incrementally.

Traffic management systems

Communication infrastructure is the backbone of any traffic management system (TMC) for a signal or expressway network. It is the costliest component and could cost up to 80% of the total system. Copper circuits were first used which were later replaced by coaxial cables and then fibre optics. The Highway 401 Compass System was the first TMC in the world to use fibre optics in its entirety. Its design was quickly copied by several systems in the States. Toronto chose to lease Bell circuits at the beginning and by the 1980's, the rental cost exceeded 1M a year. Later, the Region of York became the first municipality to lease cell data service (not Wi-Fi) from Bell. As Wi-Fi connections became available, many traffic managers opted for them for many of their sensors and other field devices. However, they still insist on using hard wires to connect to the controller cabinets for safety and security reasons. The provision of 5G with ultra-low latency and reliable edge computing may change all that.

Traffic control networks are multipoint by nature. For example, the Toronto system control over

2,000 traffic signals and collect data from thousands of sensors of various types. Some of the sensors are already connected to central via Wi-Fi. Conversion to 5G communications and of the entire sensor network to IoT would be a welcome scenario. Subject to budget availability, the conversion may be phased over a few years or down to unit by unit level.

For many years, the City of Toronto used algorithms to analyze detector data to estimate parameters such as speed, queue length and various indices for control and performance evaluation purposes. Video cameras with image processing capabilities were later introduced for traffic counting and subsequently for incident detection. Currently, video detectors with AI are offered by some ITS product suppliers.

The above history illustrates that the emerging technologies of 5G, IoT and AI are not foreign to the traffic community, but suppliers are concerned that the uptake has been slower than anticipated. This may be due to budgetary constraints and the procurement process often favours the low bid vendor who may not be the one using the desired emerging technology. In general, traffic managers are risk averse and they often insist on testing any new product locally before purchasing it.

Multi-modal systems

The public transit industry is a big one consisting of many modes and new ones are still being added to the fold. For example, with the help of technology, BRT has become popular in recent years, while the last mile challenge is being tackled by many enterprises using e-bikes and e-scooters. Demand-responsive micro-mobility solutions are also on the rise. The CAV technology will also satisfy some of the mobility demands, particularly for the first and last mile journeys. Self-driving shuttles connecting to mainstream transit are good examples. The entire transit arena should therefore be viewed as a multi-modal industry.

The transit industry uses an array of traditional and emerging technologies, some of which are like those used by TMC operators. The traditional technologies are giving way to new ones but in general, public transport managers are slower to change, particularly in the rail industry. For example, AI is still not allowed in many rail-based solutions.

However, lidar (light detection and ranging) detectors which are used mainly in the CAV area are being introduced to public transit for passenger counting. Universal payment technologies are being used for fare collection. GPS is introduced to traffic signal priority and pre-emption for buses arriving at intersections. A variety of emerging technologies has been introduced to various ITS mobility functions. AI is used in mining ridership data to study passenger trends, social media platforms for bus locations and travel time estimation, and web application for route recommendations. Many transit networks have IoT connections which can be put to good use. The use of self-driving shuttles has been tested successfully in many cities, including Calgary, Las Vegas and Taipei and autonomous modes will be more common soon.

Traditionally, the transportation industry is managed in a stove-pipe fashion, with different modes operated by different departments or agencies with different expertise and therefore biases. Various modal units see each other as a competitor. For example, many transit agencies who operate buses and subways treat bike-share enterprises as competition, and in many jurisdictions, bicycles are regarded as recreational vehicles and their management is relegated to the Parks Department who focuses on the use of bicycles in parks. Public transit will always be fighting for ridership and the modal split will never be improved significantly if the first and last mile transfer problems are not solved. There have not been enough collaborations among the different parties. With our current urbanization trend and its ill effects, this condition must change and is changing.

Mobility as a Service (MaaS). Electric and hybrid vehicles, e-bikes, e-scooters, and shared mobility services have changed the traditional transportation landscape. The system is changing into a more demand-driven way of travelling from A to B. In this process, the focus has shifted from solely supplying transport itself, to additionally providing this service to the traveller in the most effective and efficient way. This led to the development of the MaaS concept in Europe a few years ago. As a Canadian example, the City of Calgary has just completed a study of shared micro-mobility using e-scooters and will be implementing e-scooter sharing service as a step towards MaaS.

Mobility as a Service or MaaS entails one mobility service platform to provide various modes of transport services to the user on demand. It offers added value facilitating an integration of mobility service providers into one application offering real-time and on demand mobility options to the user, including payment services and ticket sales. MaaS therefore covers all mobility segments, from transit and infrastructure to traffic management and parking, all coming together by putting the user first. The mobile phone is used by the traveller for mobility choice and payment with the help of the various emerging technologies, which collect the appropriate data from the various modes connected to develop recommendation and make reservation for the customer. Based on a personal experience in the City of Helsinki, a typical trip may start with a taxi ride (which arrives within 5 minutes) from the hotel to the subway and then to a bus terminal where a bus ride is taken to a bus stop 2 blocks away from the meeting place.

The key premise around MaaS is evolving from a product-focused or mode-focused mentality where customers are sold personal vehicles, or transportation on a particular mode on an exclusive basis such as railroad passes, to an open holistic environment where travellers have seamless and flexible access to all modes based on route, preference, price, special needs or services (e.g., carrying packages or traveling with children). This is consistent with the vision of Transportation 2030 Plan which focuses on the mobility requirement of the traveller. However, reorganization of the administrative framework may be necessary. For example, the City of Helsinki reorganized its transportation department from mode-based to mobility-based with the traveller in mind before the introduction of MaaS.

Electronic payment systems

An automated fare collection (AFC) system is vital for transit operation. The smart card-based Octopus System was implemented in Hong Kong in 1997 and Oyster was installed in London, UK in 2003. It was not until 2009 that Presto was introduced in Ontario and Compass was not fully operational in British Columbia until 2015.

The smart card technology is facing some new challenges. In the last century, a major gap existed between the transportation and banking sectors for various reasons and the latter declined to support transit operators in any AFC payment schemes. For a variety of other reasons, the banking sector has now decided to join the competition. Multiple (or Universal) payment machines with advanced software have been developed and the passenger can use his/her credit card for fare payment very easily. Naturally, social media also became involved and the mobile phone is rapidly becoming the choice as a tool for fare payment. In many major cities in China, for example, most passengers prefer using credit cards or mobile phones. Considering that the implementation of a smart card system requires major capital up front and/or the system operator charges a processing fee higher than the everyday household credit card, the attractiveness of the smart card is quickly diminishing, not to mention that the passenger has to invest money to buy a stored value card ahead of the trip.

Electronic payment is also important for toll road operators. The Highway 407 ETR in Greater Toronto was the world's first all electronic toll highway when it came into operation in the 90's. A significant investment was made to deploy a credible and accurate payment system using two way transponders, active infra-red lasor detectors and a massive central computer, supplemented by video cameras with licence plate recognition software for vehicles without transponders. The transponder has the potential to be used for parking payment, data collection, travel time measurement and many other purposes. For example, transponder readers are used in Taiwan to measure vehicular speeds on non-toll roads.

For parking, payment by credit cards or using mobiles is already commonplace but this is giving way to direct licence plate reading by AI software residing in the video camera at the entrance. On detection, an appropriate payment is charged via your mobile. This technology is now extremely popular in China but is not likely to be popular in this country due to privacy concern.

Smart freight and supply logistics

The logistics, freight, and trucking industries have been experiencing major transformations in the past decade thanks to technological advances and market dynamics. New technologies and opportunities have been introduced to these industries, altering operations at every stage of goods movement. The following are some major transformations that are reshaping the present and future of logistics, freight, and trucking.

CAV is reshaping the future of cargo transportation in major ways. Autonomous trucks are likely to gain widespread adoption quicker than the other types of vehicles. This is mainly attributed to the fact that driving on highways is much more straightforward than in cities. Also, the benefits and cost advantage of deploying autonomous trucking is much greater than those of personal vehicles. For instance, autonomous trucking has been recognized as an opportunity to solve the shortage in truck drivers faced nowadays in the industry and a means for boosting the operational capacity. However, the route to having fully autonomous trucks on roads is quite long, with truck platooning maturing by 2025 and full automation beyond 2027.

Experts agree that the freight and logistics sector will be the first to adopt CAV technology, along with an array of emerging technologies such as AI and blockchain. With a shortage of manpower and the pressure of competition, any innovation that makes business sense will be quickly assimilated and implemented, whether it is for the first-mile journey from production facilities to warehouses, the middle-mile delivery from the warehouse to the distribution centre or the last-mile dispatching of goods to the customers. The entire supply chain is greatly impacted by the emerging technologies.

Apart from technological advances, e-commerce also plays a major part in the digital transformation of the freight industry. The popularity of online shopping has ben increasing in recent years but rose sharply during the pandemic. Revenues of the array of companies involved in e-commerce are spectacular and provide significant funding for innovation. For example, companies like Walmart are investing heavily into CAV and the related emerging technologies.

When the pandemic is over, the situation is not expected to change significantly as consumers are becoming comfortable with the new normal. E-commerce sales reached $43 billion in 2018 and are expected to increase to $55.4 billion in 2023. However, as e-commerce grows, consumers' preferences and expectations for deliveries also rise, calling for a smarter customer service.

The middle mile of the goods movement involves mostly long-haul trips, many of which are straight forward point to point movements in an expressway network. CAV is very suitable for this type of journeys and truck platooning using IoT and AI technologies will be attractive to the industry.

The last-mile or curbside delivery of cargo to the consumer's front door is probably the most transformed part of the supply chain and the keys to success here are connectivity and data-driven decision making. Technologies like AI and IOT will play a significant role and the amount of tracking and the security involved will also accelerate the use of the blockchain technology. A large variety of CAV's are being developed, tested, or deployed for curbside delivery to satisfy customers' needs. These include both ground and aerial vehicles such as drones, droids, mobile lockers, and two-legged robots.

Warehousing is a vital link in the supply chain and a variety of technologies are used in automated warehouses. Various emerging technologies will be adopted here quickly. Tracking and the visibility of goods will be improved by deploying IoT and sensor technologies. The use of AI and advanced data analytics is essential for forecasting warehousing and predicting maintenance requirements. Augmented and virtual recognition using AI can improve the warehouse management process by aiding staff in goods scanning, object recognition and indoor navigation in real time. A large number of heavy duty self-driving machines will be used for cargo movement, loading and unloading. The availability of the new technologies will also allow consideration for building warehouses for special purposes (e.g. for frozen food)

Data management and analytics

ITS have traditionally relied on a variety of sensors to collect traffic data, various data sciences to analyze the data and optimization algorithms to improve capacity and minimize congestion. In the past, this activity was hampered by the limited amount of traffic data collected over a slow communications network, lack of effective algorithms and appropriate software, and/or the absence of speedy computers. As a result, the ITS users moved through a phase circa the turn of the century when they were dependent on hardware equipment to provide the solution. The emergence of 5G, AI and data analytics will be a welcome scenario, but technology expertise is not enough. Traffic domain expertise and experience have to be recruited and added to the team to help define traffic problems correctly and craft solutions effectively.

Opportunities for traffic improvement are also offered by the social media and the data technologies available on these platforms. Each mobile phone carried by a traveller is a moving node in a gigantic IoT network and it can be used to provide up to the second information on the surrounding traffic condition. Several ITS vendors supply blue tooth sensors which, when installed on a pole near the highway, can monitor the movement of vehicles with mobiles in them. Travel time and speed information can be calculated and broadcast back to the motorists through the social media. The Region of York implemented such a network prior to 2019 and intends to expand it this year.
GPS data can also be used for a similar purpose. A Toronto company made use of bus GPS data freely available on the TTC website, estimated travel time on Eglinton Avenue and display it on message signs within the Eglinton subway construction area.

There can also be interactions, human or otherwise, with the social network for a better result. During the last Pam Am Game in Toronto, a mobile software start-up, retained by MTO, provided a social media platform to detect accident and identify congested location, and advise the mobile user game venue and recommend multi-modal routing. The drivers who chose to participate can provide feedback by voice or button clicks to confirm congested locations, thus enriching the database. It was found that during the Game, more people downloaded this application than Google. Another company built an application in partnership with Waze, a social platform for traffic information, based on information sharing and confirmation between Waze and the municipality in question. The Region of Durham is one of the municipalities with such arrangement.

Google also provides very useful traffic data. A Toronto company recently completed a project in New Taipei where Google data was accessed every 5 minutes and an algorithm was used to detect congestion on an expressway location. The client was satisfied with the result and intends to expand the application to other locations.

Another important and interesting aspect of data management in ITS is the construction of data warehouse to enable jurisdictions to share data. It is a part of the Canadian ITS architecture and the idea was put forward in early 2000 when the private sector was very active in procuring public data for business purposes. Not too many data warehouses were built at the time, probably due to technology limitations. Instead, agencies shared their data through data links between them. For example, an ITS data link with a common protocol has been established between MTO and the City of Toronto. However, there are at least two countries who have built national data warehouses, namely UK and the Netherlands. For a small fee, any public agency can join the group and access all the data they need to augment their own. Private companies have to pay a higher fee, but they actually prefer buying data from one national entity rather than negotiating with a multitude of municipalities. The emergence of AI and data analytics will rekindle this interest and new types of data warehouses based on the new technologies can be expected in the near future.

Instead of deploying its own sensor IoT network, an agency can outsource data collection and analysis to one of the several ITS firms who collect and store massive amounts of data via GPS and other technologies. This model is quite a commonplace in the US but not expected to be popular in Canada.

Once the deployment of CAV becomes widespread, the amount of traffic data available will explode. It is interesting to note that CAV can be considered as new modes which will support the mobility requirement of the traveller and the requirement of goods movement. However, as a technology, CAV are moving nodes within the entire transportation IoT, contributing real-time data for traffic management purposes, up to 4 terabytes an hour. In return, each connected vehicle will receive recommendations from the TMC on the best route through the city. A few year ago, the City of Las Vegas experimented successfully with connectivity between connected vehicles and its TMC, which can then download signal data to the vehicles for improved safety and progression. Similar systems are now in place in over 40 cities in the US but not yet deployed in Canada. This is certainly a viable concept and should be explored in Canadian municipalities with pilots and demonstrations.

Transportation Integrated with Smart City

Smart city development provides a great opportunity for enabling ITS. As the city is becoming more digital, the transportation people are naturally elevated and become more credible in front of the city decision makers. The mobility group should be proactive and be part of the team, with a higher degree of collaboration to achieve the smart city goals. Experience has shown that the IT

Department will become more involved with ITS and this aspect can be managed for mutual benefit.

A smart city will build new infrastructures and improve the communications network, and the transportation people can share this benefit. The streetlight infrastructure is a good example. Smart streetlights can improve energy efficiency and lighting quality while collecting traffic data. Backed by a versatile 5G network, cities can deploy machine learning algorithms to quickly process this data from IoT sensors and analyze it for traffic performance measurement, speed enforcement and incident detection.

In smart cities, crowdsourced data efforts are starting to materialize in ways that drive forward smart city policy. In these types of systems, the resident is technically the sensor. His or her car, phone, and any other connected device may be serving as a data node contributing to the city's decision-making. While not necessarily a direct replacement for municipal infrastructure, this type of data crowdsourcing can serve as a powerful complement to smart city efforts. Speed and location data from these sources are anonymized, aggregated, and used for mobility assessment. Each traveller is both a node in the sensor network and a user of it. If harnessed effectively, crowdsourcing data can enhance ITS and drive the smart city forward. At the same time, the citizens providing the data become a part of the process and feel more engaged.

With big data and IoT technologies, the local TMC can be programmed to monitor a variety of conditions that may affect traffic, such as flooding, earthquake and power outage, and control their impact for the benefit of public safety and mobility. As an example, a Toronto company devised a link from the TMC in the City of Keelung, Taiwan to monitor the river level and by analyzing ambient rain data from the meteorological office via the web, the system decides when to warn traffic on the adjacent arterial of flooding.

However, the ultimate step of traffic management within a smart city is to integrate the TMC with smart city operation to form a "strategic command centre". All the technologies discussed so far are pooled together at the TMC to provide the following levels of control:

- Level zero – day to day automated operation (traditional TMC operation)
- Level 1 – automated operation of TMC and other systems based on data from other sources (e.g. for flooding and power outages)
- Level 2 – incident situation with intervention by managers (e.g. major accident)
- Level 3 – major disaster, such as an earthquake or hurricane, when the Mayor is invited to provide strategic direction, including road closure and opening as well as directing first line responders

INTERIM SUMMARY OF CANADIAN ITS REQUIREMENTS

To predict future scenarios, one must look at a Venn Diagram with three crystal balls, namely need, technology and will (or desire). Where the three circles intersect provides information on what can be expected in the future. There is obviously a need for mobility improvement in various transportation fronts and many new technologies are available and have been proven to work. Whether the change will happen will depend on our will or desire, or a number of institutional factors including business motive, social acceptance, legislative measure, political acceptance, and an array of cultural and societal issues. To enlarge the intersecting area of the three crystal balls or in the Venn Diagram requires the following:

- Clear government vision with socially acceptable policy and legal frameworks
- Funding to demonstrate emerging technologies and accelerate development
- User education and skill development
- Export and external partnership for diversity and revenue growth
- Domain expertise in transportation to define problems and expected solutions clearly
- Collaboration among all parties involved with an emphasis on the traveller

Based on society's needs and with the right technologies, the institutional framework can be massaged (e.g. by legislation or marketing) to enhance the environment for transportation improvement.

Many so-called disruptive technologies are emerging rapidly, and they can be expected to provide an impetus to transportation improvement by enabling ITS development and enhancing their performance. Based on the ITS Canada survey, municipalities continue to rely on ITS and have the necessary funding to expand and improve their current systems. With their ITS revenue not adversely affected through the pandemic, the private sector remains confident in their ITS business and feel that the emerging technologies will provide more opportunities. Furthermore, as explained earlier, the Canadian ITS industry is comfortable with concepts provided by the new technologies and so is culturally and institutionally ready for the shift.

The use and integration of the emerging technologies, together with the large amount of data available, the number of opportunities for ITS improvements will be countless but not all of them are suitable or acceptable in Canada. The following are some examples of what can be expected in the various ITS capability clusters, and some less likely possibilities are also discussed.

Traffic Management Systems. This is an area where ITS will be continuously developed and improved. However, most provinces and major cities in Canada already have their TMC in place and therefore, they will be seeking improvements along several directions provided by the enabling technologies. The following are some examples:

- Use of hardware with AI and edge computing capability embedded (e.g. video with AI functions)
- Reliance on other data sources (e.g. through crowdsourcing and streetlights) but outsourcing data collection and analysis to data companies will not be likely
- Increase in detailed local performance measurements in real time
- Rise in a variety of hardware and software for safety for normal, senior, and disadvantaged pedestrians and for micro-mobility mode users
- Combination and mix/match of signal and expressway systems (e.g. VMS on arterials).
- Increased use of traffic algorithms for various functions (e.g. incident detection, congestion prediction)
- Increase and expansion of traffic monitoring and information systems, using enhanced detectors, social networks, and CAV
- Use of IoT concept for controller subnetworks in a hybrid arrangement (as a wholesale change is not necessary)
- Use of CAV for data for a variety of traffic management functions
- Data sharing between controllers and CAV (e.g. signal timing data) and synchronization.
- Adaptive control of signals using CAV data

Multi-modal Systems. In this cluster, a major collaboration effort among all modes are expected to address the mobility concern of the traveller, giving rise to the following opportunities:

- Wide-spread efforts in testing and piloting micro-mobility connections to mainstream transit, including e-scooters, e-bikes, and demand responsive shuttles (including automated ones) with advanced AI techniques for safety, optimization, and interaction with customers
- Increase use of MaaS or pseudo MaaS concepts, starting with smaller and rural jurisdictions with simpler problems
- Better optimized and more responsive signal priority schemes, equipped with more advanced technologies, for transit and micro-mobility modes
- Embedded integrated payment systems in mobiles for mobility customers for MaaS-related trips

Electronic Payment Systems. No new smartcard AFC systems will be deployed in Canada. The legacy ones will slowly give way to credit cards, debit cards and a proliferation of mobile payment apps. This situation will happen to both transit and parking payments. Although a multitude of emerging payment schemes are becoming mature and available, new tolling infrastructure and road pricing schemes will not be expected in Canada.

Smart Freight and Supply Logistics. The freight industry is transforming rapidly, and the key is CAV technology. In particular, e-commerce will spark a lot of ITS and CAV development for last mile delivery. Significant investment will be made by not only trucking and courier companies but also chain retail stores such as Walmart, to meet the needs of customers and mitigate manpower problem. The following is only a few examples:

- For the middle mile, CAV platooning will be widely used in long haul trucking operation by 2025
- Full AV trucking for long hauls will be widespread by 2017
- For the last mile, a large variety of autonomous delivery vehicles and machines, both ground and air, are being developed and will be tested. This situation will be consolidated within the next few years.
- The blockchain technology will be used for tracking customer order and goods delivery, and a variety of chained processes in the industry.
- More AI-based algorithms will be used for route optimization and selection, scheduling vehicles and manpower, and managing inventory and warehousing.
- Increase in automated warehousing, employing many of the enabling technologies for storing and locating goods, predicting capacity requirement, and automated machines for moving goods
- Introduction of specialty warehousing (e.g. for frozen food) using a variety of sensors and AI techniques
- Development of smart trade corridors (e.g. Montreal to Windsor) to minimize delay and congestion to commercial vehicles along the corridors and crossing the border to the US, with integrated ITS using a variety of enabling technologies.
- Development of a variety of techniques, particularly at intersections (e.g. truck priority), to improve the safety of trucking and its sustainability by reducing the amount of braking, noise and emission

Data Management and Analytics. ITS development will benefit the most from the increase in the availability of traffic data and the speed of collecting them. Emerging data technologies and the related analytic software are required to use the data effectively. Traffic domain expertise is also essential to interpret the data correctly and utilize it properly for transportation applications.

- Increased use of social network data for various transportation purposes, from analyzing transit ridership pattern to incident detection
- Use of web data (from other city departments or agencies) for traffic prediction, control, and management (e.g. weather data)
- Rise of social platform-based traffic information systems by engaging travellers to provide feedback and validate traffic network condition
- Use of CAV data for various transportation purposes, including intersection performance measurement, pavement condition assessment and provision of origin and destination data for modelling.
- Trials of applying micro-simulation model for real-time traffic signal optimization with the availability of data and speedy computer
- Synchronization of data between CAV and the TMC for various functions (e.g. incident warning and parking availability)

Smart City Concepts. As the city is being transformed digitally, more focus will be placed on technology. The credibility of transportation personnel involved in ITS will be increased and they should take advantage of this. There will be a higher degree of cooperation between the transportation and IT departments to mutual benefits. With increased collaboration across all city departments and proactivity on the part of the transportation personnel, many opportunities for ITS enhancements will become available.

- Increased sharing of infrastructures for traffic purposes (e.g. use of streetlights for data collection and sharing of 5G network)
- Use of parking meters for a variety of transportation applications, such as parking reservation, curbside management for delivery trucks and traffic monitoring
- Increased data sharing across city departments and crowdsourcing data from citizens
- Increased use of social media platforms for traffic information and management purposes
- Management and control of events like parades and incidents like flooding
- Increased use of TMC for a variety of city functions (e.g. trucking management and emergency operation)
- Use of mobile as emergency TMC in case of major incidents (e.g. fire chief operating the mobile TMC during a major fire)
- Formation of strategic command centre by integrating traffic operation with smart city requirements

The above requirements are only a small list developed based on the following:

- Anticipated impact of the various emerging technologies discussed above
- Readiness of the enabling technologies
- Needs identified in the transportation industry
- Comments from ITS Canada members interviewed
- Consideration of societal, political, and cultural factors in Canada
- Judgement of the investigator based on his knowledge of the ITS industry

However, the list is interim in nature. Some of the requirements will be confirmed and refined as more information is collected through research and interviews in Phase 2 of this Study, as additional discussions will be conducted with both domestic and international experts.

Concerns and Challenges

It is obvious from the list of ITS requirements that the numerous technologies and ITS functions are inter-twined and mutually inter-dependent. There are significant cross-cutting linkages among them, and endless possibilities can be created. There is absolutely no question that the enabling technologies will significantly impact ITS with improved mobility for the next decade and beyond. However, the following challenges have been identified:

- lack of integration between modes and between systems
- speed of implementation
- risk taking appetite of users
- lack of emphasis on technology in infrastructure undertaking
- lack of expertise in the emerging technologies and transportation domain
- lack of training and skill development
- Staff recruitment and development

Elimination or mitigation of some of these will further enhance the positive impact of the enabling technologies.

ITS AS AN EXPORT

The Canadian ITS private sector consists of the following types of companies:

- Multinationals whose Canadian operations do not have the mandate to export
- Multinationals who allow their Canadian operations to conduct some or all of their international business
- Canadian companies who export to the US only
- Companies who export to selected countries based on their connection, cultural background, and perceived opportunities
- SMEs (Small and Medium Enterprises) who want to export but need guidance and/or funding
- Companies who only work in Canada or in some provinces

For many ITS companies, Canada is too small an ITS market, with its small population spread over a large area. Engaging in international trade is essential for them. Also, Canadian organizations would do well in partnering with agencies and companies abroad, which would provide the necessary external stimulus to diversify and innovate. With the first traffic computer in the world implemented in Toronto as early as 1963, Canada has a strong heritage in ITS which will serve as a good foundation for exporting our ITS technology.

Meanwhile, ITS development has increased elsewhere and many cost-effective ITS hardware and software products have become available from other countries. These may be beneficial to the Canadian ITS industry, even for domestic projects. A two-way international trade is therefore a feasible proposition.

Exporting ITS is important for the Canadian ITS industry to grow and diversify. However, the country lacks major integrators or contractors with sufficient financial strength to lead the many interested but smaller companies to pursue many of the worthwhile projects overseas. One of the strategies would be to access the international ITS network and find foreign partners to work in the country offering the project opportunity. In this regard, ITS Canada's strong link with her sister organizations worldwide can be an asset.

The recent signing of CETA between Canada and Europe provides Canadian companies a duty-free status for product sales and eliminated restrictions on manpower deployment, and the European ITS market is a busy one. Meanwhile, major ITS expenditures have been announced in Asian economies such as Taiwan and Hong Kong. These factors will render exporting more attractive for Canadian companies.

In Phase 2 of this Study, the focus will be placed on the international market. With additional interviews of both domestic and foreign experts, more market information will become available for a better definition of global ITS market requirement and a more complete export strategy.

INTERIM RECOMMENDATIONS (PHASE 1)

In the future, our transportation systems have to be smart and integrated while focusing on the traveller's mobility. This is a very appropriate concept as ITS Canada moves forward as the hub of mobility technologies. The following is a list of recommendations for ITS Canada to consider in being a hub of support for our members:

- Continue to champion mobility technology and serve as a mobility hub for our members and interested parties
- Promote the use of mobility technologies by conducting user education webinars featuring success stories of ITS enhancement using enabling technologies
- Review the ITS requirements with appropriate agencies for feasibility of implementation
- The technical committees discuss the concept of mobility clusters and identify strategic projects form the list of requirements. These projects can be used to promote Canadian ITS expertise.
- Discuss with Transport Canada and other government agencies on the funding for some of the strategic projects
- Continue to facilitate webinars and virtual meetings with our sister organizations around the world to seek potential partners
- Set up panels (or task forces) to discuss some of the expressed concerns, notably recruitment, procurement, and skill development. The panels should have about 5 experts each and should assemble virtually in short order. It may be possible to include this in Phase 2 of IMDUS

The above recommendations are interim and will be refined as more information becomes available by the end of Phase 2 of this Study. As a minimum, recommendations on supporting our members for export activities will be added.

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