Emerging Vehicle Technologies and their Impact on the Transportation Professionals

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Abstract

Whether transportation engineers love it or are skeptical about it, emerging vehicle technologies have led an evolution converting traditional gasoline driven vehicles to connected vehicles, electrical cars, and autonomous vehicles.

Connected vehicles are already here in certain forms and reportedly by some to be fully functional by 2023. Today we communicate with other drivers around us and are connected to the world via the internet. The car manufacturer Volvo has announced that all their cars will be made electric in two years. In the progress of autonomous vehicles we are at level two or three out of the five levels of development as defined by the National Highway Traffic Safety Administration, with some optimists boasting that full automation can be achieved as early as 2025.

Irrespective, the question is not if but when transportation engineers will come face-to-face with such reality. The implications are profound. It will mean that transportation engineers need to equip themselves with new skills to avoid becoming obsolete. Universities will have to conduct researches in this area and to reassess their transportation curriculum to see if they are still relevant and sufficient. Professional organizations such as the Transportation Association of Canada (TAC) and the Institute of Transportation Engineers (ITE) may have to re-adjust their programs and change its agenda to suit the needs of the industry and their members. Government bodies and highway authorities must re-position themselves if they are to continue to function effectively. These agencies will be faced with the dilemma of how to balance the retrofitting of existing infrastructure with the construction of new facilities to allow the new breed of vehicles to operate smoothly.

Historically the study of transportation is a multi-disciplinary science but this emerging trend will bring it to a new and higher level. Future transportation engineers will be expected to have at least a working knowledge in areas such as information technology, communication science, computer algorithm, human factor safety engineering, public engagement, business and legal environments, and social media management. The knowledge which we have accrued in the past at universities such as geometric design, traffic flow theory, transportation planning, travel demand modeling, etc., may no longer be sufficient. Standards organizations will have to work on setting up protocol architectures that are interchangeable, interoperable and expandable.

This paper explores the many issues facing the transportation engineers and the industry and discusses how best they should position themselves for the future. It sets the stage for further research. Commercial sectors including automobile manufacturers (hardware) and IT companies (software) are already on board. The time for transportation professionals to jump onto the bandwagon is now; and arguably not a moment too soon.

1.0 Introduction and Background

With the rapid growth of internet technology (IT); the easy and reliable access to communicative devices and techniques, and the readily availability of big and real time data; emerging technologies in surface transportation including automated vehicles have proliferated in recent years. Today electric vehicles, connected vehicles, and autonomous vehicles are hot topics much talked about by transportation professionals, and vast amounts of research funding have been injected into the industry and at universities for their development. Admittedly the new class of modern vehicles comes with substantial benefits such as increased convenience and safety, reduced congestion, lesser fuel consumption and pollution emission, enhanced efficiency in operation, and greater mobility for everyone. However they also raise a number of concerns in terms of privacy, cybersecurity, potential job losses, urban sprawl, expanded infrastructure requirements, consumer awareness, public education, and government readiness.

The change of driving habits and the future of the automated and other advanced vehicles is a disruptive technology; and whether we are ready or not, the transportation industry is approaching the end of an era for the traditional, individually-owned human-driven automobile, to make way for a revolutionary change to driverless vehicles. Advocates and optimists predict that autonomous vehicles may be here in significant scale as early as 2025. Others who are more skeptical argue that it will probably not be until the 2040s or 2050s, or even further beyond, before autonomous vehicles will become widely affordable and acceptable.

Transportation professionals, government bodies, professional institutes, interest groups and stakeholders have an important role to play in the development and deployment of these emerging technologies. They can help support the new concept's development and testing, establish performance standards that must be met to allow them to legally and safely operate on public roads, and create compatible roadway infrastructures to accommodate their operation. The planning, design and operation of infrastructures such as roadways, parking and public transit facilities will take on a new perspective and dimension. University curriculum and teaching must be changed to cover a wider spectrum of topics to educate their students and preparing them to respond to the needs for a different future.

While the industry claims that the "hardware component" (cars) and the "software component" (control systems) are largely ready today, other softer areas involving driver acceptance, consumer awareness, cost/benefit ratio, insurance, legal, and a host of other societal issues need to be addressed before a full scale implementation of the new technology can become fully implementable.

This paper explores the many issues facing the transportation industry. Engineers, government bodies and highway authorities, as well as professional associations need to position themselves properly for the future. Business and stakeholders must be prepared for the shift in paradigm. The paper sets the stage for further research and exploration. While many companies of the commercial sectors including automobile manufacturers (hardware) and IT companies (software) are already on board, others are less ready and prepared to face the challenge. The time for the "non-believers" to jump onto the bandwagon is now; and arguably not a moment too soon.

2.0 Emerging Technologies in Surface Transportation

Autonomous vehicles (AV), connected vehicles (CV), and electric vehicles (EV) are much talked about in the transportation industry these days. Collectively they are sometimes referred to as the "ACE" vehicles. Other emerging technologies in surface transportation that are in existence but probably have less widespread application include personal rapid transits (PRT), gondolas in urban area (aerial transit), hyperloops, and magnovate trains. Although strictly speaking not considered a surface transportation equipment, passenger drones taking various forms and under different blend names (e.g. Volocopter, EHang, Uber Elevate, etc.), have also been included in recent and similar discussions on the subject.

The impact of these emerging technologies in the transportation industry is not only significant, but its effects are also highly disruptive, similar to some of the latest technologies created at the turn of the century. Examples of these technologies which have proven to rock the world and change the way we live are the internet communications (Skype, WhatApp, Viper, WeChat), emails (replacing snail mail), digital cameras (replacing film cameras), smartphones (iPhones and androids), online travel websites (Expedia, Priceline), internet shopping (Amazon, Ali Baba), Entertainment (Netflix), peer to peer transportation (Uber, Lyft, Green Tomato), digital music (Spotify, Pandora, Apple Music), and market-on-close (Uacity, edX, Coursera, Khan Academy)

It may be useful to define some of the emerging transportation devices here.

Autonomous (also called self-driving, driverless, or robotic) vehicles are vehicles that rely on sensors and computer analytics to sense their environments and perform varying degrees of the driving task. As defined by the National Highway Traffic Safety Administration **[Reference 1],** there are five (or six if we include level zero) levels of driving automation, ranging from level zero (no automation, where a human driver controls all aspects of the driving task), to level one (driver assistance, where an advanced driver assistance system helps a human driver with either steering or braking but not both at the same time), to level two (partial driver automation, where both steering and braking is possible at the same time through automation), to level three (conditional driving automation, where an automated driving system performs all aspects of driving under specific circumstances), to level four (high driving automation, where the automation system can perform all driving tasks and monitor the environment in specific circumstances without the driver paying attention), to finally level five (full driving automation, where the human occupants are merely passengers and are never involved in driving).

Connected vehicles (CV) are vehicles that are connected to the internet to offer drivers convenience and information services, CV can be V2V (vehicle-to-vehicle) or V2I (vehicle-to-internet) through a wireless technology called dedicated short-range communications (DSRC) that allows rapid communications (up to 10 times per second) between elements of a connected vehicle network within a range of about 300 to 500 metres; or with a 5.9 GHz band assigned for ITS applications.

PRTs are currently deployed in London at the City's Heathrow Airport, and in Abu Dhabi. Metrocable and Medelin are successful gondola systems operating in Columbia. The city of Banff in Alberta Canada is considering the potential of a similar gondola network to boost its tourist industry. Hyperloop is the vision floated by the CEO of Tesla, Elon Musk, of a vast tunnel system with a suggested route from Los Angeles to San Francisco. Magnovate is Alberta's version of the Maglev train which is capable to reaching up to a speed of 500 km/h **[Reference 2].**

3.0 Major Players in the Industry

Much is at stake with this imminent change in technology. For those companies which are prepared, business opportunities abound. For those who are unwary and may be caught unawares, there will be job losses. Government agencies need to be positioned to adopt to the change. Universities will have to consider revising their transportation engineering curriculum to better ready their students for future challenges. Professional associations need to re-adjust their outlook to stay current with their members. The following, though by no means exhaustive, are some well-known names and organizations in both the public and private sector currently taking an active role in the research and development in this area.

Automobile Manufacturers: Tesla, Daimler (Mercedes), Toyota, Honda, VW, Kia/Daewoo, Volvo

Telecommunication: Verizon, AT&T, T-Mobile

Manufactures: Processing (Toshiba, Texas Instrument), Sensors (Hitachi, Bosch, Delphi), Connectivity (QNX, Denso), Mapping (Harman, Mapscape), Algorithms (dSpace, Vector), Security/Safety (Wind, NXP, KPIT)

Software: Google, Pandora

Universities: U of British Columbia, U of Alberta, U of Calgary, U of Toronto, U of Texas, U of Washington, Nanyang Technological University, Beihang University

Government Organizations: ITS Canada, Transport Canada, US Department of Transportation, FHWA, Federal Transit Administration

Transportation Consultants: IBI, Delcan (now part of Parsons Company),HNTB, Parsons Brinckerhoff (now part of WSP)

Industry Associations: AAA, TAC, ITE, C-TEP

4.0 Roles of Government and Other Roadway Authorities

For autonomous and connected vehicles to function properly, appropriate roadway infrastructure needs to be existent to support this new technology. Automobile makers, material and parts manufacturers, product suppliers, as well as software companies in general; and the levels of government in particular, must work closely together to help to create the smart roads of the future.

For starters, an ITS (Intelligent Transportation System) architecture and standard must be in place to ensure that all related products planned, designed and built are compatible with each other, and which are interchangeable, interoperable, and expandable. On ITS architecture in Canada and the United States, standards were already installed since 1999 and in 1993 respectively, with the latest version of National ITS Architecture in Canada being version 2.0 in 2008, and the National ITS Architecture version 7.1 in April 2015 in the US. It will be noted that within this realm, the US ITS Strategic Plan 2015 – 2019 listed as its top two priorities connected vehicles and automation.

With overall government participation, review of the literature shows that there is in general a lack of urgency paid to the attention of the matter. In the United States, only a mere six (6) percent of the largest cities has initiated some kind of timeline to address the topic, and which has included in their future transportation plans some form of technical and legal languages related to, or addressing the possible impact of, driverless technology on mobility and other issues.

In many ways, some has compared the changes needed by government to support autonomous vehicles as similar to, and no less dramatic than; in magnitude, scale, and concept; to the changes that took place when horses and buggies were replaced by automobiles in New York City in the early 20th century.

Government bodies must therefore adopt, without delay, i.e. if they have not already done so, a holistic approach that includes an allocation of sufficient funding to help to augment those changes needed to prep themselves to the new technology.

For the Federal government in Canada, there are reports that they have already started investing in the research and development in this area through existing programs. More specific efforts however are needed and the following measures have been recommended for immediate action to promote connected and autonomous vehicles **[Reference 3]**:

- Create a policy unit to coordinate federal efforts and implement a national strategy
- Engage with provincial and territorial governments to develop a model provincial policy
- Strengthen its autonomous vehicle work with the US
- Develop vehicle safety guidelines for design parameters
- Develop cybersecurity guidance and establish a real-time crisis connect network
- Table legislation to enforce industry compliance with personal information protection

Canadian provinces and territories have been working on AV and CV issues for a while now, but to date, Ontario is the only province that has introduced AV regulations. The government of Alberta is one of the many partners including the City of Edmonton, involved through the University of Alberta in a pilot research program for the testing of AVs within the province's highways.

To be successful in integrating their effort with the private sector, local governments operating municipal roadways, must address the following critical issues **[Reference 4]:**

- Determine what types of future roads are most suitable for autonomous, connected or electric vehicles which are different from today's conventional streets
- Explore limitations and constraints such as fog, snow or other extreme inclement weather conditions
- Determine the extent of existing roadways that will require retrofitting (e.g. re-striping, re-signage, or placement of sensors and video cameras)
- Investigate into installing RFID (radio frequency identification) tags with sensors in road structures to measure real-time data about significant traffic parameters throughout the designed lifespan that could communicate with autonomous vehicles directly
- Determine the challenges and issues that roadway authorities may have to face in a mixed stream road of autonomous vehicles and vehicles under driver operation
- Examine safety for all types of vehicles, drivers/passengers, and other road users such as pedestrians and cyclists

- Consult legal advisors and insurance providers, and enact by-laws to allow the smooth operation of a partial autonomous vehicle and conventional vehicle environment

In addition, for local government and highway authorities, efforts to be considered include the updating of infrastructure to ensure safety and reliability in the future, the installation of surveillance equipment as part of the communicative system, the design and the re-design of streets to allow autonomous and connected vehicles to work, with enhanced road signs and pavement markings, temporary traffic control devices, vehicle identification systems, toll and parking fee collection, and back-up solutions in case one component of the system such as GPS (global positioning system), fails. Redundancies need to be built in to ensure safety as the number one priority in the new technology.

If these emerging technologies are to take off sooner than later, the need for change is imminent and pressing, and is now. Despite that the private sector with its vast vested commercial interest, progress in the area cannot be brought about by them alone. Goldman Sachs has projected the market for advanced driver assistance systems and autonomous vehicles would grow from about $3 billion in 2015, to $96 billion in 2025, and $290 billion in 2035 **[Reference 5**]. To match this huge projected growth government must assume a corresponding and appropriate financial role to ensure that safety and reliability standards are reached in their highway infrastructure; and that widespread acceptability by the public will be achieved.

5.0 Education

Education is not limited to the mere education of the general public, informing and prepping them of the imminent arrival of this new technology and of the ensuing phenomenon. Education also means teaching both our young transportation students, as well as practicing professionals in the industry, and those who are taking courses in universities at the undergraduate and graduate level, by equipping them with the skillsets necessary to properly handle problems facing them in their future career.

Public acceptance of autonomous vehicles is currently still very low. Society in general is conservative when it comes to the acceptance of any new technology. Commercial viability and affordability is another key factor. Recent surveys estimated that only one out of every four drivers/passengers interviewed will readily embrace the concept and to ride worry-free in a driverless car. The resistance to newly introduced technology can be demonstrated by the historic public acceptance of innovations. The automatic transmission cars were first developed in the 1930, but it was not until 1980s when they became reliable and affordable (a period of about 50 years). Likewise airbags were first introduced in 1973 but were only mandated by US regulations in 1998 (a period of about 25 years). Vehicle navigation systems became available as an expensive accessory in the mid-1980s but are only a commonplace feature today (a period of 30+ years). Hybrid vehicles became commercially available in 1997 but only represented about 3.3% of total vehicle sales today (a period of 25+ years) [Reference 4].

On university education the traditional courses in traffic and transportation engineering that we are so familiar with in the past are no longer deemed sufficient. Traditional transportation engineering courses such as transportation management, structural engineering, urban and transportation planning, system engineering, highway engineering design, geometrics, current transportation issues, transportation engineering, logistics and international transportation, marketing and transportation, mechanical engineering for transportation, and supply chain management; while all relevant and are still mostly necessary, need to be supplemented with additional new courses to recognize the present emerging and disruptive technology.

Statistics, and the correct and proper way of handling big data, remain as a very relevant and important topic for transportation professionals. Statistics dealing with real time information have changed the analyst's mindset from a static point of view to the more current stochastic analysis using neural networks and mathematical models. Sensors, detectors, cameras, videos, satellites, and cell phones are able to transmit data to traffic control centers via the internet which will help the assimilation and the analysis of traffic data; and subsequently sending decisions back to driverless vehicles that are not manned, through built-in communication devices. The traditional travel demand forecasting method adopting the use of the well-known 4-step process (trip generation, distribution, assignment, and modal split) used for the last one hundred years may no longer be able to forecast accurately the future growth of vehicular traffic and the subsequent planning of infrastructures. Computer science and numerical analysis will become an integral part of the curriculum in the learning process. Increasingly too, transportation engineering has become a highly interdisciplinary subject that embraces many areas including the social sciences, psychology, human factor engineering, electrical engineering, law and regulations, computer sciences and programming, communication technology, public outreach, financial management and capital raising, robotics and control theory, remote sensing, and many others,

Experimental courses in autonomous vehicles have already been taking place at some universities in America. The Harvey Mudd College in California has started a hands-on interdisciplinary freshmen course in autonomous vehicles which was reported to be highly successful **[Reference 7]**. Out east, the University of Michigan in Ann Arbor has developed a ground-breaking course on connected and automated vehicles (CAV) which deals with the latest concept of CAV, safety standards, and key challenges facing the industry.

The seven top universities in the world pushing the boundaries of autonomous vehicles and their driving include Carnegie Mellon's robotic laboratory in Pittsburg, Pennsylvania; Stanford University's on-going research at Palo Alto, California; Oxford University in England in its robotic driving plan; the expertise of Tsinghua University in Beijing, China, joint venturing with the Japanese car manufacturer Nissan in the combination of automated driving and electric powertrains; the University of Michigan in Ann Arbor, Michigan; Seoul National University in Incheon, South Korea with an autonomous car dubbed "SNUver" equipped with 64 LIDAR (Light Detection and Ranging) sensors; and Massachusetts Institute of Technology in Boston, Massachusetts in the use of block-chain technology for self-driving cars – an approach to enable secure data exchange in vehicles **[Reference 8]**.

Numerous seminars and workshops are also being offered by professional associations such as C-TEP (Centre for Transportation Engineering and Planning in Alberta), ITE (Institute of Transportation Engineers), TAC (Transportation Association of Canada), and others; but these courses are less structured in format, and are considered as professional development training only. Some kind of agreement and consensus needs to be reached amongst the higher learning institutions as to what constitutes as an acceptable curriculum which will cover the fundamentals of the various components of the topics that collectively will define the science of this emerging technology.

6.0 Professional Associations

The technology transforming conventional automobiles to autonomous vehicles is disruptive; and professional associations need to adapt to these changes to stay relevant. Organizations such as TAC and ITE are already formulating strategies that will allow them to handle some of the uncertainties facing the industry in the years ahead. It will however be recognized that the transition to, and the adoption of, autonomous vehicles will not happen overnight. Public acceptance and vehicle fleet turn-over will take some time. Connected vehicle technology is already being deployed on a small scale at the moment, and the related apps and systems that are built from these platforms are already evolving; but again the final stage will take several years to finish. While there is no need to panic now, we need to plan and design our future with flexibility and to constantly monitor the environment for any risk which may come from the evolving technology, and be proactively rather than reactive in this area. These organizations have to take a leadership role in all major discussions affecting these disruptive technologic changes. Because of their membership numbers, with their members' qualifications and expertise, they are perfectly placed to help bring forward the technological advances. The ultimate decision makers still lies with government but the organizations have the power to inform and to shape the decisions that will be made.

7.0 Deployment of Automated and Connected Vehicles and their Implementation Timeline

There is currently no timeframe and there are no deadlines set for the initial launching and final universal acceptance of the new technology. With regards to the actual implementation timeframe, no-one has a crystal ball to see into the future, other than to just make an intelligent guess as to when this will be coming around.

In general while the "hard" part of the new technology is, or will be, ready soon, it may take society a longer time to accept autonomous vehicles as an integral part of people's everyday life.

Without committing to either an optimistic or a pessimistic view, this paper has examined some of the critical factors affecting the industry and society's readiness as follows:

What is now or will soon be ready:

- 2016 (now) – many new vehicles have some level 1 automation feature (cruise control, obstruction warning, parallel parking)
- Tesla now offers level 2 features (automated lane guidance, accident avoidance, driver fatigue detection)
- Electric vehicles and the method of battery charging
- Google level 3 test vehicles (under restricted conditions e.g. fair weather, mapped routes)
- Autonomous vehicles becoming legal by 2025
- AV may be first deployed in taxis and in truck fleets
- Low speed level 5 autonomous vehicles may be available in five years (?)
- Communication devices are ready

What may not be ready for a while:

- No level 4 automation vehicles are predicted within a few years
- No current technology can operate safely in inclement weather such as heavy rain or snow
- AV that will transport people between cities is likely going to happen in 20 to 30 years' time; and within a city 10 to 15 years' time
- Higher cost of purchase, maintenance, and subscription fees for navigation and mapping services (unaffordable for the average middle class family) will persist at least into the 2030's
- Privacy (e.g. informed consent, enforcement) and safety issues not resolved
- Available with large price premium (2020s) to everybody wants it (2060)
- Consumer acceptance (or resistance)
- Well defined policy and law enactment by government are non-existent
- Need to plan for mixed traffic (not ready until 2040-60s)
- Narrower lanes and interactive traffic controls (2050-70s)
- Employment, loss and make up of jobs
- Education, university curriculum, evolving but slowly
- Insurance industry, underwriting, pricing, sales distribution, and claims management, accident liability
- Legal matters, division of responsibility, multiple jurisdictional liability, law of tort

8.0 Conclusions and Recommendations

Emerging technologies in surface transportation involving the changeover to the large scale use of autonomous, connected and electric vehicles appear to be the way of the future. Autonomous vehicles, while having a lot of apparent advantages, including safety, environmental, human and social, and economic benefits, also have the potential for tremendous disruptive societal impact, and substantial economic and administrative barriers remain before society can see their widespread adoption. Given the uncertainties, the many unresolved issues, and the risks involved, skeptics argue that autonomous vehicles may take up to 2050 and beyond before they are fully implementable. While we need not be in a panicky situation now , transportation engineers and planners, government bodies and highway authorities, universities, professional associations, and commercial enterprises, must not stay complacent, or just sit back and wait for happenings, or wait until drastic actions are needed, at which time reacting to realties may come a little too late. On the positive side we must all work closely together to ensure that this exciting new technology will be able to take off from the ground with a seamless transition. Safety is always a number one concern, and should not be compromised for reasons of convenience, efficiency, mobility, novelty, energy cost savings, and a myriad of other economic benefits. As transportation professionals, we are uniquely placed to help to bring about this transformative technology enabling a new set of travel options, new business and career opportunities, and new degrees of personal and delivery mobility freedom. We must equip ourselves with skillsets required of this new technology, and be ready and able to take on its many challenges in a meaningful manner. Much has been done by many to advance the science of the future in this area. A lot more, in terms of research and development, needs to be done before society and the world is able to embrace and enjoy the fruitful outcome of the upcoming exciting travel era.

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