Impact of innovative technologies on highway operators: Tolling Organizations' perspective

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Abstract

Highways play a vivacious role in a country's economic growth, by facilitating movement of both goods and people from one place to another. Over a short period of time, innovation in automobile and information technology has seen an unprecedented growth and this exploratory research highlights the impact of advent of innovative technologies like Autonomous and Connected Vehicles, Internet of Things applications and Big Data analytics on highway operators, as reflected in the opinions of organizations around the world (highway operators, toll agencies, suppliers, consultants and associations). The opinions were collected on a Likert scale type online survey, which was later tested for its empirical significance with non-parametric Binomial and Wilcoxon signed rank tests, supported by descriptive analysis. The research results clearly indicate that these technologies and products are not far from realization and while on one hand they would facilitate highway operations on the other hand they may pose some serious challenges for operators.

Keywords: Internet of Things; Autonomous Vehicles; Connected Vehicles; Highway Operators; New Trends, Mobility Behavior

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1. Envisaging the future of transportation

An ever-increasing need for freight and public transport has been seen all over the world. This need calls for efficient road transport, which is highly flexible in terms of distance covered by people and nature/number of goods transported. But it also puts a lot of strain on difficult-to-expand bottle necks and existing infrastructures. Increasing urbanization is causing an upsurge in the urban population and their needs as well and this will shape the future of transport (Daimler, 2014). Of late, the advancement in technology has influenced the automobile industry to a great extent, by introducing automated driving, which is a new concept to many (Fagnant and Kockelman, 2015). Conventionally vehicles have always been driven by humans but the new technology offers automation in driving by the use of communication, controls and embedded systems (Gerla et al., 2014). Over the next few years there will be a paradigm shift in road transportation, with the release of automatic vehicles on the road connected with (Makridis et al., 2017) Internet of Things (Miorandi et al.,2012) and Big Data (Shi and Abdel-Aty, 2015). These technological advancements would make highway commute easier and more efficient, however they may also pose some difficult challenges (Shi and Abdel-Aty, 2015). While ingenious, modern communication technologies provide an intensive tracking and monitoring system for vehicles and infrastructure, in keeping with the safety and security legislative framework, they also require effective policies and infrastructure to handle the flow of automated traffic. In order to prepare them for facing the challenges of the future and to equip them for the opportunities that in holds, it is essential that our highway operators should be aware of these technological advancements.

1.1. Study focus

Scientific work and researches have highlighted mainly the technical aspects and potential societal impact of modern technological advancements, as discussed by Fagnant and Kockelman (2015), Litman (2015), Azmat et al., (2016). However, their impact on highway or toll operators has mostly been neglected and very little work has been done towards this domain by researchers and organizations like Shi and Abdel-Aty (2015), UDOT (2016), Bierstedt et al., (2014). This study is the starting point for understanding and exploring the organizations[1] point of view on how innovative technologies would affect highway operators, toll agencies and highways in the future. More precisely, this study focuses the following dimensions of innovative technologies:

- Technology maturity time line
- Potential future opportunities, benefits and challenges for highway operators and toll agencies.

The first focal point tries to identify the time it would take for technologies like connected vehicles, autonomous vehicles, and Internet of Things to be ready for implementation by highway operators. It is important as it would facilitate the policy makers of such organizations in long term organizational planning, redefining and reshaping the existing code of conduct. Whereas the second point tries to identify their potential benefits, allowing highway operators to plan for and avail all the opportunities that come with them. Moreover, this study attempts at making highway operators aware and preparing them for the challenges they might face in the future.

2. Highlights of innovation in automobile industry

Recently, exponential technological growth has been observed in the automotive industry. In this section, we will highlight the current state of the modern technologies as well as potential benefits and challenges so far discussed by different researchers.

2.1. Autonomous vehicles (AV)

An autonomous or self-driving vehicle is one that can drive itself from one point to another given point, without constant control and input from a human driver (Azmat et al., 2016). However, every commercial automobile manufacturer has his own definition of an autonomous vehicle (Bierstedt et al., 2014). Autonomous Driving is considered to be the biggest transformative development in the post-modern era, which will change the dynamics of transportation. As it is based on the use of inventive, modern technology its impacts on road transport are

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[1] Organizations which are directly or indirectly involved in highway operations like: toll agencies, highway operators, suppliers, consultants etc.

diverse (Rosenzweig and Bartl, 2015). These include enhanced vehicle and road safety, reduced impedance of traffic and a change in travel behaviour (Fagnant and Kockelman, 2015).

2.1.1. Expected benefits and challenges of AV

According to Litman (2015) and Kyriakidis et al., (2015), it is predicted that autonomous vehicles will escalate convenience and safety of travellers, reduce hindrance caused by congestion and limit fuel consumption, while Fagnant and Kockelman (2015) proposed that AV operations are inherently different from human-driven vehicles. AVs can be computed to make them follow traffic laws, have lesser reaction time and can be drafted to control the flow of traffic, improve fuel economy and reduce emissions. Autonomous vehicles can even be made to gauge the breaking and acceleration decisions of surrounding vehicles to avoid congestion and drastically reduce road accidents. Both researches conclude that a pivotal impact of autonomous vehicles would be reduced congestion of roads, increased road safety and an increased highway capacity as discussed by Bierstedt et al., (2014). The much-needed mobility that AVs can provide to the elderly and disabled people is also note-worthy (Fagnant and Kockelman, 2015).

An autonomous vehicle may easily administer common road situations; however, it is a daunting task to design a system that can perform safely in nearly every situation. Researchers also agree that autonomous vehicles can be easy targets for cyber-crime and may be difficult to regulate (Fagnant and Kockelman, 2015), (Azmat et al., 2016), (Litman, 2015).

2.2. Connected Vehicles

Connectivity supported vehicles able to correspond with their internal (inside of the car) and external (outside of the car) surroundings are referred as Connected Vehicles. These vehicles wirelessly perform certain activities i.e., supporting the communications of vehicle-to sensor on-board (V2S), vehicle-to road infrastructure (V2R), vehicle-to-vehicle (V2V), and vehicle-to-Internet (V2I) (Lu et al., 2014).

2.2.1. Notable benefits and challenges of CV

Connected vehicles are practical, up-to-date and synchronized. They would lay the ground several applications for road safety (like, lane change warning, collision detection or prevention and cooperative merging), green and smart transportation (for example; intelligent traffic signal controlling and scheduling, better fleet management etc.). CV would also offer location dependent services (like, POI and route optimization etc.) and access to internet in-vehicle (Lu et al., 2014).

Every technology comes at certain cost and it so do connected vehicles. There are numerous threats highlighted by researchers in the field and one such critical threat is Cyber-crime. One form of which is Malware; malevolent software designed to disrupt computerized actions or gain illegal and unlawful access to information. Malware can corrupt vehicles through numerous entry points such as Wi-Fi hotspots on vehicles, wireless communication with roadside networks, internet connectivity, infected consumer electronic devices (for example; memory storage devices, USB, smart phones etc.) connected wirelessly or physically to the vehicle. Known weaknesses in the design and applications of on board communication systems, software, hardware, and applications can be subjugated by malware to infect a vehicle. (Zhang et al., 2014)

3. Highlights of innovation in information technology industry with respect to transport industry

Problems currently faced by highways, freeways and urban areas can be addressed using technology-based solutions like Internet of things and Big Data. These technologies mainly involve internet and GPS (global positioning system) enabled devices, to provide valuable information from several data points, in combination with cameras, sensors, radio frequencies and other tools using similar technologies (Dong et al., 2015).

3.1. 'Internet of Things' (IOT) and its key benefits

Over two billion people around the world use the Internet for daily tasks, from sending receiving emails to controlling house appliances. As more and more people join the network of global information and communication infrastructure, another big leap forward is coming, connected to the use of the Internet as a universal podium for letting machines and smart objects interconnect, dialogue, calculate and coordinate (Miorandi et al., 2012). This idea of physical objects being connected to the Internet at an unprecedented rate

brings us one step closer to realization of the idea of the Internet of Things (IoT). The IoT will transform traditional objects into the smart objects by exploiting its underlying technologies like permeating and persistent computing, communication, sensor networks and internet protocols (Al-Fuqaha et al., 2015). The IoT has incredible potential of transforming the future, where almost every consumer device, from cars to a coffee mug, may connect through the Internet. This will lay the foundation of data points, which would lead to better society by providing enormous quantities of valuable sensory data for analytics and other uses (Tran, 2017).

In case of highways and urban areas IOT would bring with it several benefits for example; it will be possible to avoid congestion by monitoring traffic in real time and deploy services that offer traffic routing advice for better traffic management. In this angle, cars would appear as smart objects. In addition, parking issues in urban areas can also be mitigated by using smart parking devices systems, based on RFID and sensor technologies that will observe available parking spaces and provide drivers with automated parking advice in real time. Resulting in improvement of mobility in urban area. Moreover, internet connected sensors may also monitor the flow of automobiles on highways and gather useful information such as numbers of cars at any given point in time and place and their average speed. IOT enabled tools on highways could detect level of carbon dioxide, PM10, etc. and distribute such information to health agencies. Furthermore, connected sensors and other devices could be used in some highway settings for detection of traffic and speed violations and transmit the related data to law enforcement agencies for recognising the violator or to save details for following accident scene investigation (Miorandi et al., 2012).

3.2. Challenges in IOT realization

As the world becomes more interconnected through the Internet it gives birth to an interesting digital phenomenon in technology world known as Internet of Things (IoT), but this technology brings with it many legal challenges. These challenges may include but are not limited to privacy desecrations and security risks (Tran, 2017). According to (Miorandi et al., 2012) and (Bandyopadhyay and Sen, 2011) security is a critical aspect of the widespread adoption of IoT technologies and applications. Stakeholders are unlikely to adopt IoT solutions on a large scale unless guaranteed of system level confidentiality, authenticity and privacy. They further added that "data confidentiality" signifies an essential issue in IoT setups and that only ratified bodies should be able to access and alter data. The discussion also includes that privacy and trust are very important factors when addressing IOT applications and rules must be demarcated under which, data concerning individual users may be retrieved. The privacy issues are also addressed by (Tran, 2017) as he insists the legal community to prepare for this stirring yet alarming digital era and the privacy challenges that will escort its arrival.

4. Research Methodology

This is an exploratory study, where primary data has been collected from organizations across the world, actively or passively involved in highway operations, consultation, support or supplies etc. to understand and evaluate the potential impact of innovative technologies on highway operators.

4.1. Data collection tool

As discussed by Meek et al., (2007) "Likert scale" style survey tool was selected for this study, where respondents were asked for their views and opinion on innovative technologies (more precisely about Autonomous, Connected Vehicles and Internet of Things and Big Data) and their impact on highway operators. The scale measures from 1 to 5 with one being strongest response and 5 being weakest response.

The survey was executed using lime survey, an online tool to conduct survey. Data was collected between July 10th and August 15th 2017. The tool assigned a system generated ID for each respondent in order to keep the data unbiased and anonymous.

Mainly the type of data collected through this survey was ordinal data.

4.2. Respondents

The survey was distributed to nearly 200 different members of, International Bridge, Tunnel and Turnpike Association (IBTTA). At the end of survey submission deadline, we received 83 responses in total, but 51 out of them were completed rest were incomplete, therefore, they were not considered fit for analysis and discarded. 51 respondents make around 25.5% of the total population. *Table 1* below explains the break-up of respondents.

- N = 51 (Total number of respondents)

Table 1. Break up of responding organizations.

	Frequency	%
Other	05	9.80
Highway operator / Toll agency	24	47.1
Supplier	08	15.7
Consultant	12	23.5
Association	02	3.90
Total	51	100

4.3. Research technique

After initial assessment of the data it was observed that data does not meet the assumption of approximate normal distribution, therefore nonparametric statistical testing approach was adopted (Meek et al., 2007). The research questions were tested with Binomial test and Wilcoxon signed test, which is based on the assumption of independent observations, symmetry (about zero), and no ties (Walsh, 1959). Binomial tests allow us to see the possibility of occurrence of one of the two possible outcomes. In this research it was used to see respondent's point of view on significance of dependent variables, the significance of each dependent variable in all cases were tested with a cut-off point set at 3, which means all organizations are divided into two groups. First is less than and equal to 3, are those whose opinion is from very strong to moderate intense and group 2 is greater than 3, whose response is from little to no when measured on respective test scale. The test proportion is set at 50%. On the other hand, Wilcoxon sign test allows us to see if the mean rank of two related samples differ, or in other words it allows the analysis of matched-pair data, based on differences, or for a single sample (Woolson, 2008). In this research this test was used to see, which dependent variables have more or less significant impact within same group, when compared to other variables by comparing signs and mean values. In addition to above mentioned statistical tests, descriptive analysis is done to see the respondents view point on maturity time line for innovative technologies. The data was analysed using statistical software "SPSS".

4.4. Hypotheses

Two sets of literature derived hypotheses are listed under heading 6 "Hypothesis assessment summary". It allows reader to briefly understand the hypotheses, allow them to see how they have been tested? And whether it is accepted or rejected based on the test results.

5. Results and Analysis

5.1. Time line

In pursuit of understanding the realistic timeline for maturity of technologies like Big Data, Internet of Things, Autonomous Vehicles and Logistics 4.0 (Smart Logistics). The participating organizations were asked, when in their opinion, the above-mentioned technologies would be mature enough (from pilot to full operational level) to be implemented on highways in their respective countries?
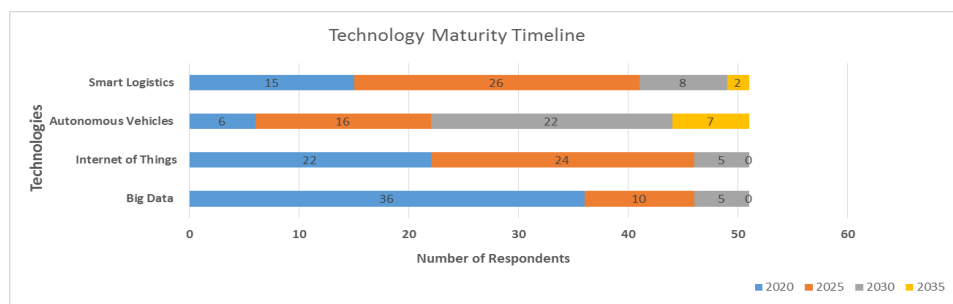

Figure 1- Maturity timeline for different innovative technologies

We can see from the picture above that out of 51 organizations who responded to this survey, majority (36) presumes Big Data would be actively placed in operations till 2020 and only 15 believed it can take another 5 to 10 years to be mature enough for highway operations. Internet of things is second rapidly increasing technological advancement where 22 organizations think it could be indulged in highway operations till 2020 whereas, 24 believe it would take another 5 years to play its role in the highway operations, only 5 organizations believe it would be actively used till 2030. For smart logistics, majority of respondents (26) deduce that it would be fully functional and on roads till 2025. 15 organizations were more optimistic about it and believed smart logistics would be in place till 2020 and 8 organizations believe it to be active and adaptable between 2025 and 2030, only 2 responding organizations had a very conservative approach and believe it might take another 5 years (2035). Opinion on Autonomous vehicles is divided into two equal halves where 22 organizations believe that AVs would flood the roads till 2025 or earlier and 22 organizations deem it would take another five years to be on roads. A small number (7) though think this technological advancement would be mature enough till 2035.

In table 2, we see that there are two main regions, which responded to this survey i.e. North America and European Union with 35 and 11 respondents respectively. It makes 90% of the total responding organizations. Whereas, only 5 organizations have responded from Asia, South America and other regions combined. Therefore, for the sake of simplicity, in further descriptive analysis we compared and discussed only two main groups of responding organizations.

Table 2 – Technology maturity time line comparison between North America and EU

Technology	Year	North America	European union
Internet of Things	2020	43%	45%
	2025	43%	55%
	2030	14%	0%
	2035	0%	0%
Smart logistics	2020	29%	36%
	2025	54%	27%
	2030	14%	27%
	2035	3%	9%
Big Data	2020	63%	91%
	2025	23%	9%
	2030	14%	0%
	2035	0%	0%
Autonomous vehicles	2020	11%	9%
	2025	34%	27%
	2030	40%	55%
	2035	14%	9%

Majority of the organizations believe that Internet of Things and Big Data would be adaptable for highway operations in their countries latest by 2025, only a small number of organizations think it might take another five years. For Smart Logistics or in other words Logistics 4.0, 83% of North American and 63% of European Union organizations have an opinion that this technology would be mature enough for adaptation latest by 2025, whereas the remaining organizations think that it might take another 5 to ten years for realization. Organizations from both regions have a similar view on Autonomous Vehicles, which is one of the most discussed topics for past few years. 44% and 36% of the North American and European organizations believe self-driving cars would be good to go latest till 2025. Whereas 40% of the North American and 55% of the European organizations think they would see AVs in operations till 2030. Only 14% and 9% of the organizations, respectively, think it might take another 5 years to be mature enough for adaptation.

5.2. Future traffic management situation on Highways, Urban and Rural areas with connected vehicles

Organizations were asked for their opinion on impact of increasing number of connected vehicles on traffic management in three different regions, namely highways, urban areas and rural areas.

Binomial and Wilcoxon signed rank test indicate that participating organizations agree on a positive impact of connected vehicles on highways and urban areas as they increase in numbers. It is expected that CVs would lead to noticeable reduction of congestion and capacity challenges and result in smooth traffic management. Whereas, in rural areas there would be little to no effect, which means there would be barely any reduction in congestion and capacity challenges compared to the present traffic condition. The possible reason could be that augmented

number of people are moving to urban areas leaving rural areas less populated. Less population means less vehicles and subsequently less impact on traffic management in future, when compared to present time.

5.3. Internet of Things enabled potential value-added services (VAS) offered by highway operators in future

Organizations were queried for their view on three potential value added services including real time information on available parking/charging slots along the highway for private and commercial vehicles, live feed on congestion on highways and real-time information on platooning possibilities that might be offered by highway operators in future, as Internet of Things become a veracity.

Based on results of both tests we can conclude that induction of Internet of Things in highway operations would increase the likelihood of value added services being offered by the highway operators along the highways. This would be very practical approach as many cars in future would be mainly electric, connected and autonomous, it would allow a better communication in real time with the cars and within the cars to manage congestion, providing information on nearest free car parking and charging slots and creating possible platooning networks mainly for trucks, of course these value-added services could be charged and generate some extra revenues for highway operators. Nevertheless, chances of realising real time possible platooning information are quite low. It can also be projected from the teste results that even after induction of IOT, there will be a significant difference between the service levels, quality or willingness to provide these value-added services by highway operators in different regions.

5.4. Autonomous vehicles driven outlook of highway capacity utilization, congestion and accidents in 2030

In this section of survey, organizations were questioned for their judgement on the impact of autonomous vehicles on highways in terms of capacity utilization, congestion and accidents on. For this section researcher created a scenario that till 2030, at least 30% of all vehicles on highways are fully autonomous and organizations were supposed to answer this question in light of given scenario.

The test results propose that fully autonomous vehicles would play an important role in mitigating capacity utilization and congestion issues of highways in future. But in early phase (2030) self-driving cars would possibly result in reduction of accidents on highways, but not in total elimination. Test further highlighted that in a given scenario AV would have insignificant impact on accidents when compared to congestion and capacity utilization

5.5. Autonomous vehicles induced challenges for highway operators

Highways operators like many others shall be prepared for several challenges that would arise as technological advancements overtake conventional systems. Out of several possible potential challenges in this section researchers have primarily focused on three challenges, which are, cyber security threat, formulating new legislations for highways and implementing these legislations. Organizations were asked for their view point on these three potential challenges again considering the same scenario as mentioned in 5.4.

Outcome of the survey highlights that it is highly rational to believe that autonomous vehicles would be prone to cyber security threats. Possibly due to the fact that they would be mainly connected vehicles and internet would provide a gateway access for its core activities. It is also presumed by respondents that it would be highly difficult for highway operators in initial phases to formulate newer regulations for such a mix of vehicles where at least 30% of all automotive are autonomous and rest are still conventional. Even harder would be to implement these regulations. Furthermore, all three challenges were found almost equally critical when tested via Wilcoxon sign rank test.

6. Hypothesis assessment summary

Table 3 - Set 1: List of hypotheses assessed using Binomial test

Hyp.	Description	P-Value	Status
H1a	Increasing number of connected vehicles would improve traffic management in rural areas in future.	0.780>0.05	Rejected

H1b	Increasing number of connected vehicles would improve traffic management in urban areas in future.	0.000<0.05	Accepted
H1c	Increasing number of connected vehicles would improve traffic management on highways in future.	0.000<0.05	Accepted
H2a	Induction of Internet of Things would enable highway operators to offer real time information on parking and charging slots, as value added service	0.000<0.05	Accepted
H2b	Induction of Internet of Things would enable highway operators to offer live feed on congestion, as value added service	0.000<0.05	Accepted
H2c	Induction of Internet of Things would enable highway operators to offer real time possible platooning information, as value added service	0.021<0.05	Accepted
H3a	Increasing number of fully autonomous vehicles would improve highway capacity utilization	0.000<0.05	Accepted
H3b	Increasing number of fully autonomous vehicles would reduce congestion on highways	0.000< 0.05	Accepted
H3c	Increasing number of fully autonomous vehicles would reduce accidents on highways	0.003<0.05	Accepted
H4a	Higher the number of autonomous vehicles, higher would be the difficulty in dealing with cyber security threat.	0.000<0.05	Accepted
H4b	Higher the number of autonomous vehicles, higher would be the difficulty in formulating new highway regulations.	0.000<0.05	Accepted
H4c	Higher the number of autonomous vehicles, higher would be the difficulty in implementing new highway regulations.	0.000<0.05	Accepted

Table 4 - Set 2: List of hypotheses assessed using Paired Samples – Wilcoxon sign rank test

Hyp.	Description	Z-Value	P-Value	Status
H5a	Increasing number of connected vehicles would have a stronger effect on traffic management in urban areas compared to rural areas.	-5.364	0.000<0.05	Accepted
H5b	Increasing number of connected vehicles would have a stronger effect on traffic management in urban areas compared to highways.	-1.014	0.310>0.05	Rejected
H5c	Increasing number of connected vehicles would have a stronger effect on traffic management on highways compared to rural areas.	-5.640	0.000<0.05	Accepted
H6a	With Induction of Internet of Things highway operators would be more likely to offer real time information on parking and charging slots, as value added service compared to offer live feed on congestion.	-5.555	0.000<0.05	Accepted
H6b	With Induction of Internet of Things highway operators would be more likely to offer real time information on parking and charging slots, as value added service compared to real time possible platooning information.	-5.773	0.000<0.05	Accepted
H6c	With Induction of Internet of Things highway operators would be more likely to offer live feed on congestion, as value added service compared to real time possible platooning information.	-4.143	0.000<0.05	Accepted
H7a	Increasing number of fully autonomous vehicles would have better impact on highway capacity utilization compared to congestion.	-1.387	0.166>0.05	Rejected
H7b	Increasing number of fully autonomous vehicles would have better impact on highway capacity utilization compared to accident.	-4.656	0.000<0.05	Accepted
H7c	Increasing number of fully autonomous vehicles would have better impact on congestion on highways compared to accident.	-4.594	0.000<0.05	Accepted
H8a	Increasing number of autonomous vehicles would make it more difficult to deal with cyber security threat compared to formulating new highway regulations	-1.407	0.159>0.05	Rejected
H8b	Increasing number of autonomous vehicles would make it more difficult to deal with cyber security threat compared to implementing new highway regulations	-.978	0.328>0.05	Rejected

H8c	Increasing number of autonomous vehicles would make it more difficult to deal with formulating new highway regulations compared to implementing new highway regulations	-1.508	0.132>0.05	Rejected

7. Research Limitations

- The research highlights the view point of only such organizations which are directly or indirectly involved in highway operations, therefore, the test results are not recommended to be generalized or implemented in other industries, which might be affected with advent of these technologies, even though the possibility of differences in outcome is very little.
- The sample size for this research is reasonable but if it was bigger the test results might would have been slightly different. Particularly, in case of reduction in highway accidents and real time possible platooning information as value added service.
- The researcher has presumed different scenarios which are close to reality but may not truly represent the future scenarios (like, till 2030 – 30% of vehicles on road are AVs)
- The results mainly reflect the opinion of North American and European Union organizations and it is likely that organizations from other regions might differ from the opinion of these two regions. Therefore, it is not recommended to generalize the opinions for all regions even though the possibility of difference in opinion is very little.

8. Conclusions

In this paper, we have presented a brief overview of current state of the art of innovation in automotive and technology industry, with respect to its impact on future of transportation. we further tried to explore how these advancements are going to affect the traditional transport modes and transport infrastructure and impact of advent of these technological advancements on highway operators. The following outcomes define what to expect from these high-tech vicissitudes:

- Highway operators and tolling agencies should prepare themselves for the beginning of new era, which will bring with it several opportunities and challenges. Between 2020 and 2030 a revolution in transport technology is highly expected, which would have a direct impact on highway and toll operators.
- The technologies like connected vehicles, Big Data and Internet of things would help highway operators to manage traffic more efficiently and effectively but at the same time they would be expected to provide safe and secure networks both internet and intranet so that these technologies are used at best of their potential.
- It is not a hidden truth that AVs will help improving highway throughput with better navigation, route planning and traffic management. But with the increase of autonomous vehicles, highway operators will need to develop clear guidelines, rules and regulations – as the marriage of autonomous vehicles with conventional vehicles might result in several disputes. It would also be very challenging for Highway operators to implement new regulations made specifically for autonomous vehicles.

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