A RESEARCH GUIDE TO USING EFFICIENCY OF TECHNOLOGICAL INNOVATIONS IN AUTOMOBILES FOR ESTABLISHING UNBIASED POLICIES FOR IMPROVEMENT OF MINIMUM SAFETY STANDARDS FOR DRIVER-OPERATED MOTOR VEHICLES

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Introduction

The issue of road traffic safety is a serious challenge for humanity at large. Road traffic fatalities has become one of the leading causes of death in various communities globally. Global status on road traffic safety indicate that more than 1.2 million people die as a result of road traffic crashes every year, and up to 50 million others are injured (WHO, 2009). The 2015 global status report on road safety shows that the total number of traffic deaths has remained at 1.25 million per year (WHO 2015). Another report by the world health organization (WHO) indicated that in 2016 alone, fatalities from road injury claimed 1.4 million lives worldwide, 74% of these fatalities were boys, and men. At this time, no country of the world is yet to record a zero fatality in transportation within a year. Figure 1 and Figure 2 shows that the number of road traffic fatalities remains at an unacceptably high number even in Canada and the United States. The number of road traffic fatalities that is indicated in figure 1 refer to the number of people who died as a result of reported traffic collisions, within 30 days of its occurrence (Transport Canada). Transport Canada's statistics indicated that the number of severe injuries, and the total injury is much higher than the number of fatalities. Neither injuries, property damage nor fatalities are desirable in people's daily commute. Although a lot of effort has been made in driver education, training, and law enforcement, the world is still not free from the unacceptable high number of grave consequences in road safety. This has called for a deeper review of present road traffic safety process, and the factors that shape its policy decisions.

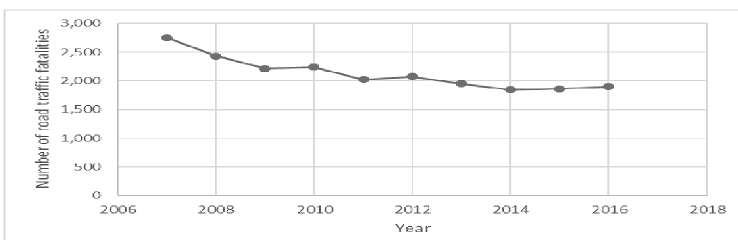

Figure 1. Road traffic fatalities in Canada (2007 - 2016)
*Adapted from Canadian Motor Vehicle Traffic Collision Statistics: 2016 – Transport Canada

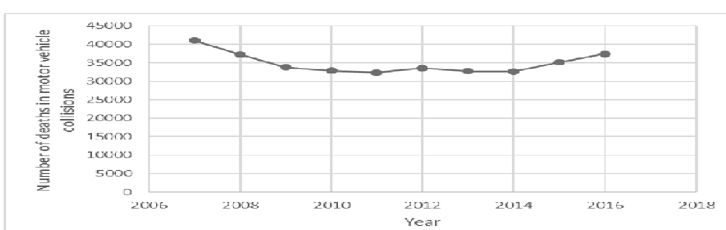

Figure 2. Fatalities in motor vehicle collisions in the U.S (2007 – 2016)
*Adapted from Insurance Institute for Highway Safety (IIHS) & Highway Loss Data Institute

Previous study has indicated that 90% accidents results from human error (Echterhoff, W., 1977). U.S Department of Transportation (USDOT), and the National Highway Traffic Safety Administration -

1 54th Annual Meetings of the Canadian Transportation Research Forum, May 26 - 29, 2019 at Vancouver, British Columbia

NHTSA (2015) also published a report of the national motor vehicle crash survey that indicated that the critical reason for pre-crash event that was assigned to the driver is 94% ± 2%. It is no doubt that humans have serious limitations that have grave consequences on road traffic safety. Various technologies now exist that can help ensure that some driver errors do not result in traffic crash and the undesirable consequences: property damage, injury, fatalities, associated emotional trauma, economic loss for various families and the community at large. Focusing most of the attention of road safety on efforts to improve human behaviors without giving a good heed to realities of human limitations, and how reliable technological innovations can be efficiently implemented as minimum standards for automobiles, to improve road safety on a global scale will not be a good idea. It cannot be disputed that road traffic crashes do not give an advance warning. Even good drivers cannot say with all certainty that they will never encounter a driver that is operating a motor vehicle under the influence of drugs and alcohol. The world will surely benefit from a bi-partisan agreement on improvement to minimum standards of safety requirements for motor vehicles. Various efforts have been made to improve road traffic safety. Previous research using driving simulator has shown that in-vehicle collision avoidance warning system is able to provide a safer driving environment. Maltz & Shinar, 2004 used a driving simulator (in which some drivers received varied alert interfaces such as, visual, auditory, and multimodal when the headway is less than 2s), and found that the "in-vehicle collision avoidance warning system" IVCAWS resulted in longer (safer) headway maintenance. Many new systems focus on provision of assistance to the driver during the driving operation.

Vehicle safety systems can be classified into two major categories; Some vehicle safety systems focus on injury reduction, and some are focused on prevention of traffic crashes. Mikusova 2017, classifies vehicle safety systems into active safety and passive safety. Active safety devices, features, and systems helps to prevent accident from occurring, by maintaining the vehicle under control. Active safety system was further classified into autonomous active safety systems like those that permanently support the driver (e.g. Driver Support Systems DSS, and Advance Driver Assistance Systems ADAS: Electronic Stability Program ESP, Anti-lock braking system ABS, Blind spot monitoring BLIS, Collision avoidance system CAS, Multi-collision brake, Pre-crash sensing, Seat Belt Reminder SBR, Power steering, etc.) and autonomous active safety systems that are actuated in a moment of impact (e.g. mechanical or visual driver warning systems, activation of braking systems, etc.). Cooperative active systems include those that communicate with other vehicles as well as to outside infrastructures. Passive safety features include vehicle facilities and measures that minimizes the impact during an accident. These includes: passive safety measures that are activated at the moment of impact (e.g. airbags, belt tensioners, child seats, active front bonnet, rollover protection vehicles system, etc.), and those that are activated after the impact (e.g. disconnection of the battery of the vehicle, fuel cut off, etc.). Prevention of accident is the best way to reduce road accident (Mikusova 2017).

The insurance institute for highway safety (IIHS) & Highway Data Loss Institute (HDLI) noted that crash avoidance features are making a rapid entrance into vehicle fleet. Six of the most common new technologies includes autobrake, forward collision warning, lane departure prevention, lane departure warning, blind spot detection, and adaptive headlights (IIHS & HLDI). HDLI & IIHS further provides a database of some vehicles that have the mentioned collision avoidance systems by make and model. It was noted that while some collision avoidance systems have become a standard for some vehicles, some collision avoidance systems are either optional or not available in some models. Mikusova noted that vehicle safety has become one of the cornerstones of competitiveness in contemporary market, because of customer requirements. Modern vehicles have driver support systems that are even capable to replace the driver: examples of such include automatic accident detection and notification system that can detect the position of the vehicle and call for help, automatic maneuvering system that can move a vehicle into a parking spot from a traffic lane, etc. (Mikusova 2017). The world has also witnessed the development of full autonomous vehicles.

The alarming statistics of global road traffic fatalities is a wake-up call about the need to put in more effort to implement measures that could drastically improve road traffic safety. Rather than allow basic vehicle safety measures to be only a measure of competitiveness for automakers, it is better to take proactive measures to ensure that efficiency of technological innovations and safety measures that have the potential to improve global traffic safety is adequately reviewed and technologies that truly help improve road traffic safety are accepted as minimum standard for all motor vehicles. It will not be a good idea for anyone to be contented with only passive safety systems in driver-operated vehicles, when there are advanced active safety systems that can help improve safety for all road users.

Why do we need to improve the minimum standards for automobiles that are operated by human-drivers?

It is known that majority of road traffic crashes are results of human errors. A considerable attention is now being given to full autonomous driving. However, there are factors that may prevent a global acceptance of full autonomous driving in some municipalities for a considerable length of time. Most especially, factors relating to the need for testing of full autonomous vehicles at various environmental conditions, (including harsh weather conditions in which the vehicles may operate) and not only having the safety certified by experts, but also having enough advertisement to convince people of the degree of safety of the technology. Main concern that was raised in previous research about autonomous driving includes: Software hacking / misuse, data transmitting issue, legal, and safety (Kyriakidis, Happee, & de Winter 2015). Mofolasayo (2018) evaluated potential policy issues when planning for autonomous vehicles, and (in his presentation slides at the Canadian Transportation Research Forum) proposed ways to attend to some of the concerns about autonomous driving. The fact that full autonomous driving still has issues of concern does not mean that the world should sit still and not adequately evaluate how to improve road traffic safety in driver operated vehicles. While more research is still on-going with full autonomous technologies, not doing any significant thing to improve the minimum standards in driver-operated automobile will not be a good idea.

Some innovative technologies that can help improve road traffic safety has been in the traffic stream for a while now. There is need to ensure that adequate systems exist through which these innovative automobile technologies can be fairly evaluated. Establishing a good evaluation system for efficiency of various technologies will provide a good basis for these technologies to be evaluated on a global scale without any form of bias. Open evaluation of effectiveness of technological innovations for automobiles should help to address any opposition that may arise to any of these technologies both academically and legally. It cannot be disputed that an effective system that can both warn the driver, reduce the speed, or even stop the vehicle completely to avoid collision, (if adequate evasive action is not taken) is a system that everyone that is interested in improvement of road traffic safety will love to see. Anyone who tries to obstruct a move to establish a fair system, to evaluate the efficiency of innovative technologies that are designed to improve road traffic safety in any community needs to be duly investigated for bad professional ethics, and possible ulterior motive against the progress of humanity at large.

Causes of Traffic Crashes

Traffic crash occur for various reasons. It is known that major factors that interact during traffic crash includes, the road, the driver, and the environment. Roess, Prassas, & McShane (2011) indicated other factors that interact during road traffic crash. On the part of vehicles, factor such as mechanical failure, and poor friction between the tires and the road may contribute to the cause of traffic crash. Adequate efforts should be made to ensure that all motor vehicles that are registered (allowed on the road) in every municipality are mechanically sound, with adequate tire friction. On the part of the road, every municipality need to ensure continuous improvement of road conditions. On the part of the driver, various factors that can cause traffic crashes (including fatigue, sleepiness behind the wheels, excessive speed, distraction etc.) needs to be adequately addressed. While addressing accident risk control and accident prevention, Roess, Prassas, & McShane indicated that provision of better highway designs and risk control devices that encourage good driving practices, and reduce driver error, pedestrian and driver training, and removal of drivers with bad driving records are ways to prevent accidents. Design and protection of median environments and roadside, impact attenuators, and proper guard rails were listed as ways to ensure reduction of severity or risk control.

The need for uniformity in the way road traffic crashes are being recorded.

Establishment of uniformity in the way road traffic crashes are being recorded will be beneficial for comparison of efficiency of technological innovations between various municipalities. Uniform recording systems for road safety will facilitate data comparison, and help ensure a more robust data for analysis of the impact of the innovative motor vehicle safety systems across various jurisdictions. Road traffic crashes can be evaluated both by factors that contributed to the occurrence of the traffic crash, and the type of crash. Table 1. shows a list of some of the terminologies that are used in traffic safety in some municipalities.

York region includes collision by road surface condition (Snow/Ice, wet, dry, other); Collisions by initial impact type (Approaching, right angle, rear-end, sideswipe, single motor vehicle, turning movement); Collision by driver action (following too close, failed to yield right of way, improper turn, lost control, improper lane, disobeyed traffic control, driving too fast for condition, improper passing, exceeding speed limit; Collision by at-fault driver condition (medical or physical disability, fatigue, impaired driving, unknown, distracted driving, normal). *Region of Waterloo* classifies impact type as: Approaching (head on), angle, rear end, sideswipe, turning movement, single motor vehicle (Animal), single motor vehicle (fixed object), single motor vehicle (pedestrian), other; Collision type as: fatal injury, personal injury, and property damage collisions; Driver action as: driving properly, following too close, exceeding speed limit, speed too fast, speed too slow, improper turn, disobeyed traffic control, failed to yield R.O.W, improper passing, lost control, wrong way on one-way road, improper lane change, evasive action, Other (undetermined); Driver condition as: normal, had been drinking, impaired- alcohol > 80mg, impaired – alcohol, impaired – drugs, fatigue, medical disability, inattentive, other. *City of Edmonton*, in the 2017 motor vehicle collision report identifies collisions by severity distributions: Fatal collisions, major injury collisions, and minor injury collisions; Collision causes at intersections and midblock segment were listed as: following too closely, struck parked vehicle, changing lanes improperly, ran off road, left turn across path, stop sign violation, failed to observe traffic signal, improper turn, failed to yield right of way, backed unsafely, yield sign violation, left of center, improper passing, failed to yield to pedestrian, and animal action; Fixed objects that were involved in collisions were identified. Collisions were also further identified by month of the year, day of the week, hour of day, etc. For the *City of saskatoon*, the 16 Collision configurations identified by Park & Sahaji (2013) were as presented in Table 1. IIHS & HDLI classifies crash types as ‘single-vehicle’, and ‘multi-vehicle’.

It is obvious that the style of reporting road traffic collisions has some variations between different municipalities. It will be desirable to have a uniform way of reporting road traffic crashes between various communities, to be able to have a more robust data for comparison and analysis, and to provide adequate justification for legislation of innovative technologies that are effective in improving road traffic safety, as minimum standards for motor vehicles in various municipalities globally.

Setting a higher standard for ‘vision zero concept’ for traffic safety

Recognizing that no loss of life is acceptable, and that humans make mistakes, Sweden has a vision zero for traffic safety. According to Sweden’s vision zero, the road system should not only keep us moving, it must also be designed to protect everyone everywhere. The City of Edmonton has a long-term goal to reach zero traffic-related serious injuries and fatalities (Vision Zero – City of Edmonton). The City of Toronto also has a “vision zero road safety plan” (a comprehensive 5-year action plan that is focused on reducing serious injuries and traffic-related fatalities on the streets of the city). Vision zero for traffic fatalities and serious injuries is a good goal. However, it is good to note that a good step to reach zero

TABLE 1. Traffic safety terminologies in various municipalities

York Region [a]	Waterloo Region [b]	City of Edmonton [c]	Saskatchewan [d]
Rear End, Following too close	Rear end, Following too Close	Following too closely, rear end	Rear end
		Backed unsafely	
Impaired driving	Had been drinking Impaired- alcohol > 80mg Impaired - alcohol Impaired - drugs		
Improper lane	Improper lane change	Changing lanes improperly	
Improper passing	Improper passing,	Improper passing	Left turn passing, Right turn passing
Disobeyed traffic control	Disobeyed traffic control, Wrong way on one-way road	Failed to observe traffic signal, Stop sign violation, One-way violation	
Exceeding speed limit	Exceeding Speed Limit		
Single Motor	Single motor vehicle (fixed object)	Struck parked vehicle	Fixed movable object
Lost control	Lost control	Ran off road	Lost Control Right Ditch, Lost control left ditch, Lost Control Right Ditch to Left Ditch
Improper turn	Improper turn	Improper turn, Left turn across path	Left turn straight same direction, Left turn straight, Left turn Straight Opposite direction
Failed to yield right of way	Failed to yield R.O.W	Yield sign violation, failed to yield right of way-No control, failed to yield to cyclist, failed to yield to pedestrian	
Driving too fast for condition	Speed too fast		
	Speed too slow		
Sideswipe	Sideswipe		Side swipe same direction, Side Swipe Opposite Direction
Turning movement,	Turning movement		Right turn same direction
Approaching	Approaching (Head-on)		Head on
Unknown	Other (undetermined)		Unknown
Right angle	Angle		Right Angle
Medical or physical disability	Medical disability		
Fatigue	Fatigue		
Distracted driving	Inattentive		
Normal	Driving properly, Normal		
	Single motor vehicle (Animal)	Animal action	
		Left of center	
	Single motor vehicle (pedestrian)		
		Cyclist error/violation	
		Pedestrian error/ violation	

a: York Region (2017). *"Annual collision statistic report"*
b: Region of waterloo (2016). *"Collision report"*
c: The city of Edmonton. *"Motor Vehicle collisions 2017"*
d: Park P. Y., & Sahaji R. (2013). *"Safety diagnosis: Are we doing a good job?"*. Accident Analysis and Prevention 52 (2013) 80-90.

fatalities on the road will be to have appropriate steps to avoid the traffic crashes. We cannot only concentrate on factors to improve road design, and expect to see zero traffic crashes without taking appropriate steps to attend to other factors that interact during traffic crash. Avoidance of traffic crashes will not only help to prevent fatalities from traffic crashes, it will also help to avoid property damage, minor and serious injury, and the associated emotional trauma. All municipalities globally need to aim at "vision zero" not only in traffic fatalities and serious injuries, but also "vision zero in traffic collisions". There is a need for municipalities to have adequate standards to evaluate the cause of every traffic crash. This should be supported by implementation of good systems to prevent future occurrence of such crash. Any community that experience a reoccurrence of a particular type of traffic crash without implementation of adequate systems to prevent such crash is not doing enough to ensure road traffic safety in their jurisdiction. Although this report focuses mainly on evaluation of efficiency of technological innovations that are meant to improve traffic safety in automobiles to ensure that technologies that are actually beneficial can have a good basis for which they can be fairly evaluated and legislated as minimum standards for all automobiles, some information about evaluation of road conditions and driver performance is also included. More studies on evaluation of systems to improve traffic safety through other factors that interact during traffic collisions is recommended.

Link between initial impact type, cause of traffic crashes and technological innovations that are designed to address the issue

Regardless of the variations in the style of reporting of traffic safety issues in various municipalities, various relationships can be established between driver action, and the initial impact type.

Link between initial impact type and causes of traffic crashes

Following too closely: This may result in rear-end collision. In addition to failure to maintain a safe distance (between successive vehicles) and failing to account for the road condition, in defining the terminology "following too closely", the City of Edmonton in the 2017 motor vehicle collision report indicated that driver inattention could also result in rear-end collision. In fact, other driver conditions such as impairment (drugs and alcohol) medical disability, and fatigue, as listed in Region of Waterloo's traffic collision report (2016) could contribute to not only rear end collisions, but also to other initial impact types.

Struck parked vehicle or object: A parked vehicle may be struck from various side, depending on the trajectory of the moving vehicle. A driver that did not realize that a vehicle that is ahead is in a parked position before traveling beyond the safe stopping distance of the moving vehicle may collide with the vehicle in parked position (rear-end impact). A driver that is inattentive, fatigued, lost in thought, or impaired may not pay adequate attention to a parked vehicle, or object, and may also collide with such parked vehicle or object from any side along the trajectory of the moving vehicle.

Failure to yield right of way, Improper turn, Improper lane-change, and Improper passing: A turning vehicle that failed to yield right of way to a through vehicle may be involved in an angle collision with the through vehicle. Improper lane change may result in angle collision or a sideswipe, depending on the location of the other vehicle that is affected by the improper turn. Improper lane change could also result in a rear end collision if the vehicle that made an improper lane change suddenly gets in front of the preceding vehicle and did not maintain adequate speed to avoid a rear-end collision. Improper passing may result in sideswipe with another vehicle. Impatience, distraction, fatigues, and various other driver condition earlier mentioned could make a driver fail to yield right of way.

Disobeying of traffic control: This may result in right angle crash (i.e. a vehicle on major road may crash with another vehicle from the minor road at right angles).

Losing control of the vehicle: This may result in head-on collision (also known as 'approaching'), rear end collision, or any other impact type. The vehicle in which the driver has lost the control may also go into the ditch, or be overturned. Various factors such as mechanical failure, excessive speed, driving too fast for condition in the driving environment, slippery and bad road conditions, etc. may result in a driver losing control of the vehicle. Although driver action may be deemed the cause of a collision, in some other cases, the collision may be as a result of other factors that interact during the road traffic crash.

Some technological innovations that are designed to assist human drivers avoid traffic crash and the potential effects on improvement of road traffic safety

Following too closely: Forward collision warning and autobrake systems, are good technologies to help address this issue (if adequately designed, tested and implemented). While forward collision warning will warn the driver of impending collision, autobrake system will automatically apply the brake to avoid a collision. The city of Edmonton (2017) collision report, showed that 37.3% (8914) crashes out of 23,906 collisions was as a result of following too closely. In Region of Waterloo's 2016 collision report, rear end collision is also reported as the most common collision type and following too closely was reported as the most common improper driving action (2012 – 2016). 37.7% (2181) out of 5791 collisions that were reported in the 2016 collision report for Region of Waterloo were rear end collisions. Traveller safety report for York region also indicated that rear end collision was the most common collision type (2014 -

2016). The 2017 annual collision statistics report for York region indicated that rear end collision was 25% of the total collisions in York region (for a 3-year average, between 2014 and 2016). Following too closely was the most reported improper driving action in the region. For transit collisions by impact type, sideswipe was the predominant impact type for collisions involving transit in York Region. Park & Sahaji also indicated that (based on descriptive data analysis) rear-end collision has the largest observed collision proportions at the most dangerous intersection in Saskatoon between 2005 – 2009. The statistics on record for rear end collision indicates that efficient innovative motor vehicle technologies that is designed to eliminate rear end collisions will have a significant impact in improving road traffic safety. Hence, there is need to have a good evaluation of which 'automobile technological innovation' best addresses the issue of rear end collisions. After completion of unbiased, and adequate review of existing systems, as far as rear end collision is concerned, the technology that best address this issue may be made a minimum standard for all motor vehicles on the road.

Struck parked vehicle: Similar to "following too closely", Forward collision warning and autobrake systems are good technologies that can help address this issue (if the parked vehicle is directly in front of the moving vehicle). In the city of Edmonton (2017) 14.6% of the collisions were classified as "struck parked vehicles".

Failure to yield right of way, improper turn, improper lane-change, and improper passing: These are factors that are related to the driver's ability to adequately monitor the driving environment and also be able to make good judgement. Technological innovations that can assist the driver to monitor the driving environment, and warn the driver, or take adequate action to avoid a collision will be the desirable technologies here. Efficiency of these technologies need to be individually evaluated, and the technology that best provide safety in the driving environment need to be selected as minimum standard for all roadway motor vehicles. In York region, between 2014 – 2016, 36% of the traffic crashes is attributed to these 4-collision categories by driver action [i.e. Failure to yield right of way (16%), Improper turn (12%), Improper lane-change (6%), and Improper passing (2%)]. Performance of technologies that utilize Light Detection and Ranging Data (LiDAR), various sensors and cameras to monitor the driving environment may be evaluated for this collision (impact) types.

Disobeying of traffic control: Various systems including: installation of red-light camera and increased enforcement may be used to discourage disobedience of traffic control. Technological innovations such as vehicle to infrastructure communication systems (V2I) to warn drivers if they will not be able to make it to the intersection before the light change will be desirable. However, if these systems were not successful in eliminating traffic collisions that results from disobedience of traffic control, efficiency of technologies that take full control of the driving operation needs to be adequately evaluated in comparison with the efficiency of human-operated motor vehicles. If desirable, when a vehicle approaches an intersection, a system that automatically slows the vehicle down, and stop in good time (when the V2I system indicate that a vehicle will not be able to safely cross the intersection before a change of the signal light) but allow the driver to resume some other control of the driving operations after eventually crossing the intersection may be explored. Recall, the goal here is to ensure safety for all, and everyone in their right frame of mind, need to give full support to systems that provide fair evaluation of technologies that are designed to help humanity at large overcome the serious challenge of road traffic safety. Between 2014 – 2016, 6% of traffic collision in York Region is as a result of disobedience of traffic control signal.

Losing control of the vehicle: To reduce the chance of drivers' losing control of vehicles, efforts should be made to ensure that motor vehicles have adequate tires for various seasons of the year (e.g. winter tires for winter season). As regards speed, efficiency of speed control systems like cruise control, and any other speed alert system (if available) needs to be continuously evaluated. If available speed control systems, presence of speed cameras and law enforcement officers, did not bring the desired speed related traffic collision to zero, efficiency of autonomous technologies that takes the control of the speed of the vehicles away from human drivers needs to be duly compared with the safety efficiency of human-operated motor vehicles. All other factors that interact during traffic collisions that may contribute to a driver losing control of the vehicle needs to be adequately evaluated and technologies that can ensure that errors from human drivers do not result in undesirable consequences needs to be given due consideration. The 2017 annual collision statistic report for York region indicates that 10% of traffic collision happened because driver lost control of the vehicle (between 2014 – 2016).

Although Roess, Prassas, & McShane has identified pedestrian and driver training as one of the ways to prevent accidents, it should be noted medical emergencies sometimes happen. The error could also be from a pedestrian; hence, if the world is truly trying to achieve a vision zero where no loss of life is acceptable on the roads, there is need to ensure that no stone is left unturned in the effort to improve safety on the roads.

How far has the world gone at this time in recording safety capacities of automobiles?
The world already has documentation of traffic crashes that resulted in road traffic fatalities, including the make, model, and year of manufacture of the vehicles that are involved in the crashes. The insurance institute for highway safety (IIHS) and highway data loss institute (HDLI) publishes information on driver death rate by make and model of vehicles, including year of manufacture, vehicle size (mini, small, midsize, etc.), type of car (2-door cars, 4-door cars, sports cars, SUVs, etc.), crash death rates (such as: single-vehicle and multi-vehicle crash death rate, rollover death rate, overall death rate with confidence limits), etc. Information about the death rate by make and model of vehicles is useful, for end users to know which vehicles provide better protection for the occupants. However, to ensure a deeper analysis of the efficiency of innovative technologies in motor vehicles, in addition to information on the year, make and model of vehicles that are involved in road traffic crashes, there is need to have a deeper evaluation of the type and cause of all traffic crashes with the safety features that the vehicles have. This information will help to know what innovative automobile technology can help raise humanity above individual causes of traffic crash.

Analysis of performance of collision avoidance system of vehicles in the traffic stream
When presenting findings about driver death for all 2014 and equivalent models during 2012-15, information from IIHS & HLDI indicated that 11 models had driver death rates of zero. The following make and models recorded no driver deaths: Audi A6 4WD (Large, luxury car), Audi Q7 4WD (Large luxury SUV), BMW 535i/is 2WD (Large luxury car), BMW 535xi 4WD (large luxury car), Jeep Cherokee 4WD (midsize SUV), Lexus CT 200h (Midsize luxury car), Lexus RX 350 2WD (Midsize luxury SUV), Mazda CX-9 2WD (Midsize SUV), Mercedes-Benz M-Class 4WD (Midsize luxury SUV), Toyota Tacoma Double Cab long bed 4WD (Small, Pickup) and Volkswagen Tiguan 2WD (Small SUV).

Table 2. below presents information on the collision avoidance features that are available for selected make and models of vehicles.

Forward collision warning & Autobrake
From table 2, except for 2014 Mazda CX-9 4dr and 2014 Volkswagen Tiguan 2dr that do not have forward collision warning, all the other models (8 out of 10) have forward collision warning. All the models that have the forward collision warning have it as an optional feature, except for 2014 Mercedes-Benz M-Class 4 dr. 4WD that has the forward collision warning as a standard feature. All the models that are listed in table 2 (7 out of 10) have autobrake as an optional feature; except 2014 Audi Q7 4dr 4WD, 2014 Mazda CX-9 4dr, and 2014 Volkswagen Tiguan 2dr. A deep review of efficiency of technological innovations here will compare the number of at-fault collisions for vehicles that does not have either forward collision warning system and autobrake with vehicles that have forward collision warning and auto brake systems. Review of collision records from a comprehensive database will allow for a fair evaluation of the performance of these technological innovations.

Lane departure warning & Prevention
5 out of the 10 models in table 2 have lane departure warning as an optional feature. While 3 out of 10 models have lane departure prevention as an optional feature. Efficient lane departure warning system should be able to warn a driver that is distracted, fatigued or sleepy that the driver is going out of lane and may help to reduce certain sideswipe and angle collisions.

Blind spot detection & adaptive headlights
8 out of the 10 models have blind spot detection as an optional feature; while 7 out of 10 has adaptive headlights. 2 models have adaptive headlights as a standard feature while 5 models have adaptive headlights as an optional feature. Effectiveness of adaptive headlights may be inferred from review of records of collision that occurred in the environmental condition in which the technology is expected to address. Efficiency of the blind spot detection technology may be inferred from a review of collisions that occurred because the driver did not take note of another vehicle in the blind spot of the driver. It is good to note that there may be some overlapping in the effect of technological innovations that could help ensure that driver error does not result in grave consequences, but it is still possible to use traffic crash records to evaluate the performance of these technological innovations, when used either as individual safety improvement systems, or when used in combination with other innovative safety improvement technologies.

TABLE 2. Collision prevention systems in selected make and models of vehicles

Motor Vehicles by year, make & model	Lane Departure		Forward collision		Blind Spot Detection	Adaptive headlights
	Warning	Prevention	Warning	Autobrake		
2014 Audi A6 4dr 4WD	Yes (optional)	Yes (optional)	Yes (optional)	Yes (optional)	Yes (optional)	Yes (optional)
2014 Audi Q7 4dr 4WD	Not Available	Not Available	Yes (optional)	Not Available	Yes (optional)	Yes (optional)
2014 BMW 535i 4dr	Yes (optional)	Not Available	Yes (optional)	Yes (optional)	Yes (optional)	Yes (Standard)
2014 BMW 535xi 4dr 4WD	Yes (optional)	Not Available	Yes (optional)	Yes (optional)	Yes (optional)	Yes (Standard)
2014 Jeep Cherokee 4dr 4WD	Yes (optional)	Yes (optional)	Yes (optional)	Yes (optional)	Yes (optional)	Not Available
2014 Lexus CT 200h hybrid 4dr	Not Available	Not Available	Yes (optional)	Yes (optional)	Not Available	Not Available
2014 Lexus RX 350 4dr	Not Available	Not Available	Yes (optional)	Yes (optional)	Yes (optional)	Yes (optional)
2014 Mazda CX-9 4dr	Not Available	Not Available	Not Available	Not Available	Yes (optional)	Not Available
2014 Mercedes-Benz M-Class 4dr 4WD	Yes (optional)	Yes (optional)	Yes (Standard)	Yes (optional)	Yes (optional)	Yes (optional)
2014 Volkswagen Tiguan 2dr	Not Available	Not Available	Not Available	Not Available	Not Available	Yes (optional)

*Adapted from IIHS & HDLI database on crash avoidance features by make and model

Note that the intension of this report is not to endorse any automaker. Rather, it is to create a fair system for which safety performance of specific innovative automobile technologies may be adequately reviewed for all motor vehicles on the road in every municipality globally.

What type of data should we be collecting for efficient analysis of road safety – Are we reporting appropriate data to the public at this time?

At this time, the world is reporting data that is close to good for efficient traffic data analysis, but we can do better than this. If various municipalities really want to get to a state of zero fatalities, 'all hands must be on deck' to evaluate how the limitations of human drivers can be adequately addressed by technological innovations. Noting that among other things components that interact during road traffic crash involves the road, the driver, and the vehicle. Efforts to see an overall improvement in road traffic safety will definitely include collection of adequate data to ensure improvement of all the individual components of the traffic system. A traffic - crash record will be thorough if it covers all the factors that interact during the traffic crash. There will be need for a consistent evaluation of road design properties in various areas, in addition to other road design properties, factors such as available sight distance, and possible impact of transient obstruction (e.g. other vehicles on the road) and fixed obstructions are important things to consider when performing a road safety audit.

Without appropriate data, it may be difficult to know if some traffic crash at any location within any municipality is majorly due to the poor condition (or design) of the road, or if it is a result of mechanical failure of the vehicle, or a driver error. As regards data relating to the driver, it may be difficult to obtain personal information from various drivers, if those drivers have not had an encounter with law enforcement officers. Hence, every municipality need to continually improve on their efficiency on: traffic law enforcement, the use of speed cameras, and various external components to warn drivers of excessive speed and dangerous driving behaviors, and the efficiency of the municipality in taking driving privilege away from drivers who frequently exhibit dangerous driving behaviors. Some municipalities currently report data that includes statistics on impact type, 'outcome of the collision', driver action, condition of the driver, time of traffic crash, and condition of road. For example, as earlier mentioned, Region of Waterloo report impact type as, approaching (head on), angle, rear end, sideswipe, etc.; Collision type as, fatal injury, personal injury, and property damage collisions; Driver action as: driving properly, following too close, exceeding speed limit, speed too fast, speed too slow, improper turn, disobeyed traffic control, improper passing, etc.; Driver condition as: normal, had been drinking, impaired – alcohol, impaired – drugs, fatigue, medical disability, inattentive, etc. All these records are good. In addition to the vehicle make, model, year of manufacture and other records that are presently being collected, to allow for adequate analysis of the efficiency of technological innovations in motor vehicles, information such as list of innovative automobile technologies in the vehicle (if the vehicle have any innovative technology beyond the present minimum standard) will need to be collected, analysed and periodically reported. Table 3 illustrates an example of the information that will be needed for a more detailed analysis. If evaluation of performance of vehicle technologies found that certain technologies better improve road traffic safety, this report should also be made available to both the public and policy makers for appropriate actions. For older vehicles that do not have the collision avoidance systems that improve road traffic safety, every municipality globally need to take due actions with these vehicles. Mofolasayo (2018) recommended that 'more research be made on how to update existing vehicles in the traffic stream to having collision avoidance technologies, and reasonable incentives be given to people to upgrade their vehicles'. Mofolasayo also recommended that a timeline should be set in which all vehicles on the road must be equipped with adequate collision prevention technologies.

TABLE 3. Evaluation of performance of vehicle technologies

Vehicle Condition (Technology performance report)												
S/No	**Impact (collision) Type**	**Outcome of Collision**	**Technological innovation designed to address the type of impact (collision)**	**Vehicle make and model of at-fault vehicle**	**Year of manufacture of at-fault vehicle**	**Does at-fault vehicle have required technological innovation to address the collision type?**	**Vehicle make and model of other vehicle that is involved in the collision**	**Is there any technological innovation that is designed to avoid this collision?**	**Does the other vehicle that is involved in the collision have the technological innovation to avoid the collision?**	**Is there a failure of technological systems that is designed to address the collision?**	**Record lesson learnt, notes for further investigation to improve vehicle performance.**	**Record action items, and specific date to have the issues completely addressed**
1	Rear end, or sideswipe, or …. etc.	Property damage, or injury or fatal,				Yes or No		Yes or No	Yes or No			
2												
3												
⋮												

Some technological innovations that are designed to help avoid certain traffic collisions has been earlier discussed. These may be reported in column 4 of table 3, (where applicable). Please, note that it will be a good practice to maintain a system that will ensure adequate review of all other innovative technologies that can help improve road traffic safety (for technologies that are currently known and those that may come to light in future). A continuous evaluation of technological innovations for road traffic safety is recommended until the world is able to achieve a state of vision zero (not only to fatalities from traffic crashes) but also a state by which all traffic collisions can be avoided.

Maintaining adequate data – Recording the right data for improvement of traffic safety
In addition to ensuring uniformity in the way traffic records are being recorded and reported in various jurisdictions, it will be a good idea to ensure that traffic safety records are properly documented for future analysis of overall improvement in road safety. Adequate records of road traffic safety data of every community will be a good resource for trend analysis, and also to check whether road condition, external objects, transient obstructions, or the present design properties of the road contribute to any traffic crash. Making data about impact of technological innovations of motor-vehicles on road traffic safety available to both researchers and the public will help to facilitate openness and ensure that researchers can continually evaluate factors that contribute to traffic crash from all view points. This process will help the public to be able to make informed decision about which technologies better guarantee road traffic safety. It is high time to ensure that innovative automobile technologies that are designed to improve road traffic safety received open and fair evaluations. As regards to obtaining appropriate data for driver performance, table 4 indicates some of the information that will be useful in monitoring the performance of a driver. It will be good to have a consensus on what point the driving privilege can be taken away.

TABLE 4. Evaluation of driver performance

Driver condition								
S/No	Is driver impaired by drugs or alcohol?	How many demerits is in the drivers abstract within the past 1 - 3 years?	Is there an ulterior motive for the crash?	Is the driver fatigued, distracted, or have other serious condition?	Is there a need to suspend driving privilege for the driver?	Record lesson learnt from investigation of cause of traffic crash	Notes for further investigation to improve driver behavior.	Record action items, and specific date to have the issues completely addressed
1	Yes or no?		Yes or no?	Record the driver condition	Yes or no?			
2								
3								
⋮								

Table 5 shows some of the factors that will be useful in evaluating the possible impact of road conditions on traffic crashes. Review of road design should include field check of available sight distances for drivers. Locations having sight distances that are less than the safe stopping distances should receive appropriate corrective actions. If review of the surface frictional properties of location in which a traffic crash occur is not adequate, due corrections need to be made to the surface friction of the pavement. Periodic review of surface friction of roadways should be a safety habit of every municipality. During inclement weather, efforts should be made to ensure that the roads are cleared of snow in due time and appropriate measures to guard against slippery road surfaces should be put in place. It is important to: take each traffic collision seriously, establish an unbiased list of lessons learnt from each traffic crash, establish a list of action items, establish specific dates for which the action items need to be completely addressed, and make a periodic revisit to the list to ensure that a recurrence of such traffic crash is avoided.

TABLE 5. Evaluation of road condition

Roadway condition										
S/No	Surface condition	Is available sight distance appropriate?	Could presence of transient obstruction reduce the sight distance of the driver?	Are fixed objects within acceptable clearance from the road?	Is pavement condition good?	Is surface frictional property adequate?	Does road meet acceptable standard for design and maintenance?	Is the design of median and road side adequate?	Record lesson learnt, notes for further investigation to improve roadway condition	Record action items, and specific date to have the issues completely addressed
1	Dry, or wet, or ice, or snow etc.	Yes or no?	Yes or no?	Yes or no?	Yes or no?	Yes or no?	Yes or no?	Yes or no?		
2										
3										
⋮										

Using unbiased analysis of reliable road traffic data as basis for legislation of technological improvement of minimum standards for motor vehicles

Open and unbiased analysis of road safety results from a comprehensive database on performance of innovative technologies will be a good tool for policy makers in various municipalities, to make informed decision on the technologies that will be good to legislate as minimum standards for motor-vehicles. It is not advisable to base major decisions for safety improvements on incidences which may be seen as statistical outliers. Rather, each incident needs to be carefully investigated and the lessons learnt from all incidence should help shape improvement of innovative technologies and policy decisions. The guide presented in this report will be helpful in establishing a fair basis of evaluation of technological innovations in motor vehicles that is aimed at improving road traffic safety. Minimum standards for motor-vehicles need to be continuously improved until the world achieve a state in which smart motor vehicles can help ensure that human errors in driving operations do not result in undesirable consequences in people's daily commute.

Conclusions and recommendations

The world has experienced technological innovations (in automobiles) that have the capacity to help transform road transportation safety. There is no doubt that humans make mistakes, even in driving operations. Noting that in addition to the driver and the road, the vehicle is one of the major components that interact during a traffic crash, efforts to ensure an overall improvement in road safety need to include a consistent and thorough review of how to improve on all the components that interact during traffic crash (without leaving any one out). With the aim to establishing strategies to eliminate motor vehicle crashes and the associated consequences (property damage, injury, fatality and emotional trauma for various families around the globe), this study presents strategies to ensure that appropriate data are being collected and analysed, to ensure that efficient technological innovations to improve transportation safety are duly identified, fairly evaluated and can be made as minimum standard for motor vehicles. It should be noted that although this report presents a guide to using efficiency of technological innovations in automobile as a basis to establishing unbiased policies for improvement of minimum safety standards for driver-operated motor vehicles, this report does not oppose research in full autonomous driving. In civilized societies unnecessary contentions need not exist on a topic like this when a due process could be established to evaluate the efficiency of all the technologies (in all weather conditions) and use lessons learnt to both guide further developments and policy decisions. Safety efficiency of full autonomous vehicles may be compared with the efficiency of motor-vehicles that are operated by human drivers, and that of motor vehicles that have advanced automatic driver assistant systems. The need for uniformity in the data collection system for road traffic safety has been identified. Minimum standards of roadway vehicle need to be continuously monitored and improved. Results from open and unbiased evaluation of the efficiency of innovative automobile technologies, and other road traffic safety data should be a good tool to consistently increase the minimum safety standards for motor vehicles, improve road conditions, and monitor driver performance, until the world reach a stage in which no life is lost in people's daily commute. It is hoped that this report will be helpful to researchers in various parts of the globe, to have an open and unbiased way through which the safety performance of technological innovations in motor vehicles can be constantly monitored, and the dividends of the technological innovations can be better applied to improve road traffic safety for all.

References available by request to mofoladek@live.com