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Review

Towards 'Vision-Zero' in Road Traffic Fatalities: The Need for Reasonable Degrees of Automation to Complement Human Efforts in Driving Operation

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Abstract: Human factors play a huge role in road traffic safety. Research has found that a huge proportion of traffic crashes occur due to some form of human error. Improving road user behavior has been the major strategy that has been emphasized for improving road traffic safety. Meanwhile, despite the training efforts, and testing for drivers, the global status of road traffic safety is alarming. This research highlights the seriousness of human factors on road traffic safety and provides actionable strategies to greatly reduce the negative impact of human factors on road traffic safety. Motor vehicle safety data that were made available online by the U.S. Bureau of Transportation Statistics were reviewed to evaluate the severity of traffic collisions. To evaluate the extent of human factors in motor vehicle traffic fatalities, data for Canadian motor vehicle traffic collision statistics were reviewed. The study confirms that human factors (such as driver distraction, fatigue, driving under the influence of drugs and alcohol etc.) play a huge role in road traffic fatalities. The need for a reasonable degree of automation to help reduce the impacts of human factors on road safety and recommendations aimed at providing widespread support for a reasonable degree of automation systems in driving tasks are presented. Actionable strategies that can be implemented by policymakers to reduce global road traffic fatalities are also presented.

Keywords: human factors; road traffic safety; vehicle standards; automation; collision avoidance systems; continuous improvement; vision-zero; transportation policy

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1. Introduction

Human factors play a huge role in road traffic safety. Previous works have reported that more than 90% of road traffic crashes occur because of some form of human error [1–3]. Although significant progress in traffic safety has been achieved, the results are still not satisfying [1]. Vehicle collisions have been a significant concern for researchers, governments, and automobile manufacturers over the past two decades [4]. Globally, fatalities due to road crashes are rising [5]. Despite the recent development in tackling the challenges of road safety, especially in developed countries, road traffic crashes account for 1.35 million deaths annually and cost over $65 US billion [6]. Among other things, some researchers [7] noted that the criticality of a road depends on the road condition and human factors. Actually, the major 'interacting factors' are the road, the vehicle, the environment, humans in and outside of the vehicle, traffic control devices, other road infrastructures, and various objects in and outside of the vehicle that can contribute to distraction for the driver. The ability to perceive and adequately react to an urgent issue during the driving task is dependent on a range of factors. Perception and reaction times increase with factors such as fatigue, the presence of drugs, and/or alcohol in the driver's system, age, and the complexity of the reaction [8]. Meanwhile, a driver that is distracted would have traveled some distance before realizing an issue that needs attention on the road. A driver that is fatigued may fall asleep behind the wheel. Human factors in driving can also be related to the level of experience of the driver. The age of drivers and driving history show a significant impact on some driving behavior indices and reaction time [9]. When the difficulty of driving increases, experienced drivers spend more time scanning and less time looking at their surroundings, while novice drivers do the opposite. In addition, some novice drivers cannot reasonably combine both steering and braking for emergency driving like experience drivers [10]. Research has also found that the presence of drugs and alcohol in the system of road users is detrimental to road traffic safety. It is important to prevent, avoid, and detect traffic collisions at the highest degree possible to minimize human loss [4]. By preventing and controlling the potential risks in road traffic operations, road traffic safety can be ensured [11]. To prevent accidents, intelligent vehicles that provide driver assistance and or automated driving are required to monitor, assess and predict driving behaviors [12]. Interest is rising in connected and automated vehicles (CAVs). Automated driving is gaining attention as a solution to road traffic problems [13]. The introduction of autonomous vehicles could help prevent many accidents that result from the error by the human driver [14]. Reduction of the rate of accidents that are caused by human error is one of the motives behind the development of autonomous vehicles [15]. Auxiliary driving functions and automated driving are expected to reduce burdens on drivers while improving efficiency and safety [16].

The expected benefits of automated driving include a reduction in traffic accidents and an increase in drive safety and comfort [17]. The European Commission, ref. [18] reported that CAVs are emerging as a new form of mobility and new technology that can help bring down Europe's number of road fatalities to near zero, help reduce traffic emissions and increase the accessibility of mobility services. The availability of automation technologies for automobiles and other road vehicles is increasing, and further advances are expected in the coming years [19]. More and more cars in the cities today are equipped with autonomous driving systems that are aimed at improving road safety and reducing accidents, to halve accident fatalities as quickly as possible [20]. France published a decree that adapts the provisions of the highway code and transport code to allow for automated driving systems and vehicles that are equipped with delegated driving systems on predefined routes (from September 2022). Similar legislation includes the announcement by the UK government to allow hands-free automated vehicles that offers automated lane-keeping systems on UK roads, while Germany is adopting legislation that will allow driverless delivery services and Robotaxis on public roads by 2022 [21]. Automated commercial motor vehicles have the potential to reduce crashes, significantly reduce the stress of driving, and enhance traffic flow [9]. Although a huge number of challenges must be solved by vehicle manufacturers before the widespread use of autonomous vehicles (AVs) can be achieved, AVs have significant potential to increase road safety in both freight and passenger transport [22]. Expected benefits of vehicles that operate independently of real-time human control include an increase in the capacity of the road network and freeing up of the driver-occupant's time to engage in leisure or non-driving economically-productive tasks of their choice [23].

Advanced driver assistance system ADAS (which is one of the major objectives of the intelligent transportation system, ITS) technology plays an important role in ensuring driver, vehicle, pedestrian, and passenger safety and comfort [24]. In different parts of the world, the intelligent transportation system (ITS) is gaining acceptance. In many technologically advanced countries, the connected vehicle component of ITS is considered a high research priority as it is expected that connected vehicles will be efficient, safe, and eco-friendly in their operations [25]. To improve safety and performance in driving an automobile, advanced driver support systems such as lane keeping and pre-crash systems have been actively researched [26]. In critical situations, driver assistance systems improve safety by supporting the driver. Safety features like emergency braking assist, automatic emergency braking, and predictive collision warning rely on an accurate measurement of the relative velocity and distance to the preceding vehicle. Side view assist alerts drivers of vehicles that are hidden in the blind spot in critical situations. Optimal collision warnings can help a driver avoid a rear-end collision [1]. Autonomous vehicles face a number of challenges that limits their operation and widespread acceptance. These challenges include cybersecurity, traffic management strategies, moral and ethical challenges, legal terms, and operational challenges. The operational challenges can be further broken down into challenges with environmental perception, vehicle control, path planning, and self-localization. The challenges with environmental perception can be broken down into algorithm challenges (hardware limitations, availability of datasets and training data, computational time and complexity) and operational design domain, ODD (variable weather and lightning conditions, small/distant objects, movement of objects, the reflectivity of objects, obstacles occlusion and truncation, etc. [15]. In order to achieve the vision of widespread use of highly automated driving, the safety of automated vehicles must be guaranteed through extensive testing of the safety systems of the vehicle [27]. In addition, it is necessary for the human driver to safely take over the driving operation when a breakdown occurs or when the system reaches its functional limit [28]. The interest in autonomous driving is not new. To reduce accidents, it is necessary to automate the driving operation [29]. Meanwhile, the challenges of fully autonomous vehicles coupled with the limitations of humans that result in lots of traffic crashes and fatalities on the road call for more review on what will be a reasonable degree of automation to complement the effort of the human driver for improved road safety. To achieve a consensus on what a reasonable degree of automation for vehicles on the road is at any point in time, it is important to evaluate the status of road safety, the causes of traffic fatalities, and whether there is any reasonable level of automation that could help reduce the fatalities on the road (towards the achievement of vision-zero in road traffic crashes, property damage, injury, and fatalities).

Objectives

This report reviews how some human factors contribute to safety issues on the road and provides suggestions on ways forward to greatly reduce the negative impact of human factors on traffic safety. The sub-objectives include:

- Assess/evaluate the extent of the impact of human factors in traffic fatalities (i.e., Discuss the human factors that contribute to traffic crashes and answer the question: Is there any need for some levels of automation?)
- Define what a reasonable degree of automation for automobile driving operation is (in the effort to achieve the goal of zero fatalities in road traffic safety).
- Present a framework for continuous improvement of road traffic safety towards the achievement of zero traffic fatalities and make a case for improvement of minimum vehicle standards to reduce fatalities from human factors.

2. Methodology

Motor Vehicle Safety Data that were made available online by the U.S. Bureau of Transportation Statistics [30] were reviewed to evaluate the severity of traffic collisions. At the time of this review, a considerable amount of data were available for 1960–2021. Among other things, these data contain information that could be used to evaluate:

- Number of crashes as related to the number of injured persons
- Number of fatalities in comparison to vehicle miles traveled
- Number of fatalities in comparison with the number of crashes

These was used to evaluate the severity of the traffic collisions as presented in this study. To evaluate the extent of human factors in motor vehicle traffic fatalities, Canadian motor vehicle traffic collision statistics that were made available online by Transport Canada [31] were reviewed for the years 2016 to 2020. These data provided information on the severity of human factors such as distraction, speed (driving too fast), impairment (under the influence), fatigue, and other human factors. Other factors that were reported as contributing factors to motor vehicle traffic fatalities include vehicle factors, environmental factors, and situations in which there are no contributing factors. The cause of traffic fatalities can sometimes be associated with multiple factors (as noted by Transport Canada, [31]). The data from Transport Canada indicated that some of the causes of traffic crashes could be repeated. Among other things, some ethical decisions relating to autonomous driving, various human factors, and the challenges with these human factors were further discussed in the report. The report mentioned some of the challenges of autonomous driving and described what a reasonable degree of automation is (for motor vehicle operations). Given the extent of the impact of human factors on road traffic safety, the need for a reasonable degree of automation to complement human efforts in driving operations is also described.

In reference to the stated objectives, Section 3 (results) presents the extent of the severity of traffic crashes (using data from the U.S. Bureau of Transportation Statistics) and the extent of the impact of human factors (using data from Canadian motor vehicle traffic collision statistics); Section 4 provides a discussion of some of the human factors that contribute to road traffic safety. Sections 4.1–4.3 present a discussion on driver fatigue, distracted driving, and driving under the influence of drugs and alcohol. Section 4.4 discusses the major emphasis on road safety and the proposed way forward. This section answers the question of whether there is any need for some levels of automation in driving operations. Section 4.5 defines what a reasonable degree of automation for automobile driving operation is. Section 4.6 discusses the ethics of remote driving and automatic braking systems for vehicles on the road. Section 4.7 discusses strategies for removing barriers to road traffic safety (including the subtle economic factor that needs to be addressed to achieve a win-win solution). Section 4.8 gives examples of some of the notable improvements that have been seen in road traffic safety in some jurisdictions around the world. Section 4.9 describes the pathway to having a smooth transition in transportation policy to reversing deadly trends in road traffic safety. Section 4.9.2 describes actionable strategies that policymakers in different communities across the globe can use to raise the minimum safety standards of motor vehicles that are licensed in their municipalities. Section 4.9.3 describes steps that can be taken towards the achievement of vison-zero for road traffic fatalities globally.

3. Results

3.1. Status of Road Traffic Safety (Example from the U.S.)

Figure 1 is an illustration of the number of injured persons in comparison with the number of crashes in the U.S. between 1990 and 2020. When a person is injured in a traffic crash, depending on the severity of the injury, in addition to the pain of the injury, and the psychological trauma for the injured person, friends, and family, the person may not be able to go to work for a considerable amount of time until evidence of good recovery is seen. Hence, it is important that we continue to evaluate how to reduce traffic crashes on the road. It is equally important that this issue be addressed in a bipartisan manner (with an open heart to explore tried and tested technologies that have a high chance of helping to improve road traffic safety).

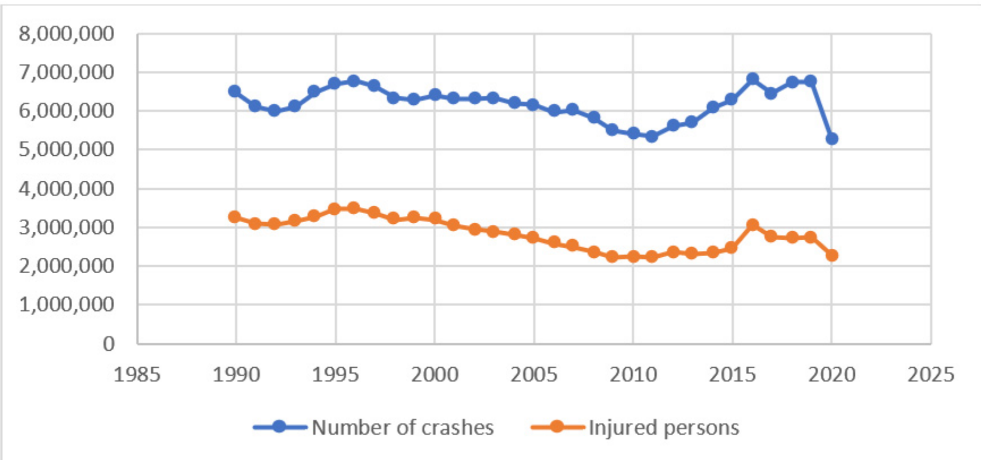

Figure 1. Comparison of number of injured persons with number of crashes from U.S motor vehicle safety data (1990–2020).

From Figure 1, it is obvious that the likelihood of injury from motor vehicle traffic crashes is high. Figure 2 shows a comparison of the vehicle miles traveled on the major vertical axis with the number of fatalities on the secondary vertical axis with the years on the horizontal axis. The result showed that there is a need for more work to bring traffic fatalities back to a downward trend toward the achievement of vision-zero for traffic safety.

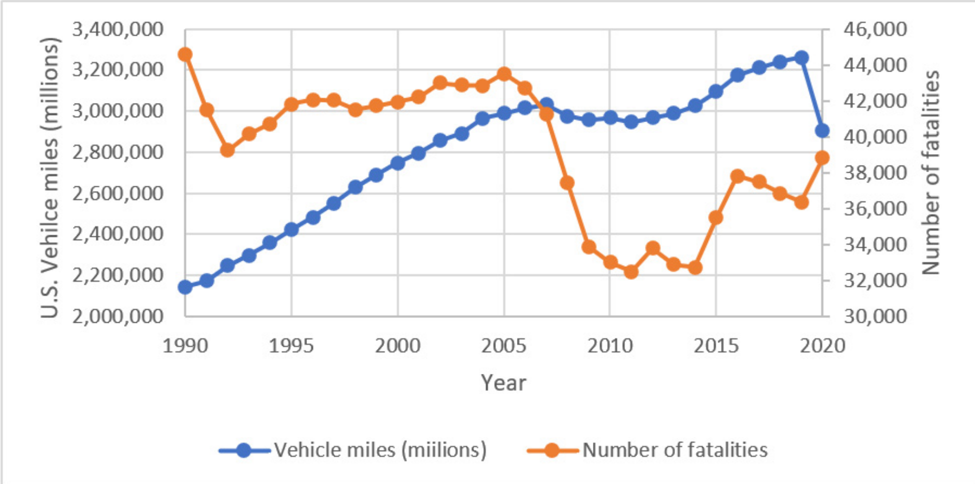

Figure 2. Comparison of U.S vehicle miles with number of fatalities from U.S motor vehicle safety data (1990–2020).

Figure 3 shows a comparison of the number of crashes on the major vertical axis with the number of fatalities on the secondary vertical axis with the years on the horizontal axis. The result also showed that there is a need for more work to bring traffic fatalities back to a downward trend. There is certainly a need for more effort in the avoidance of traffic collisions.

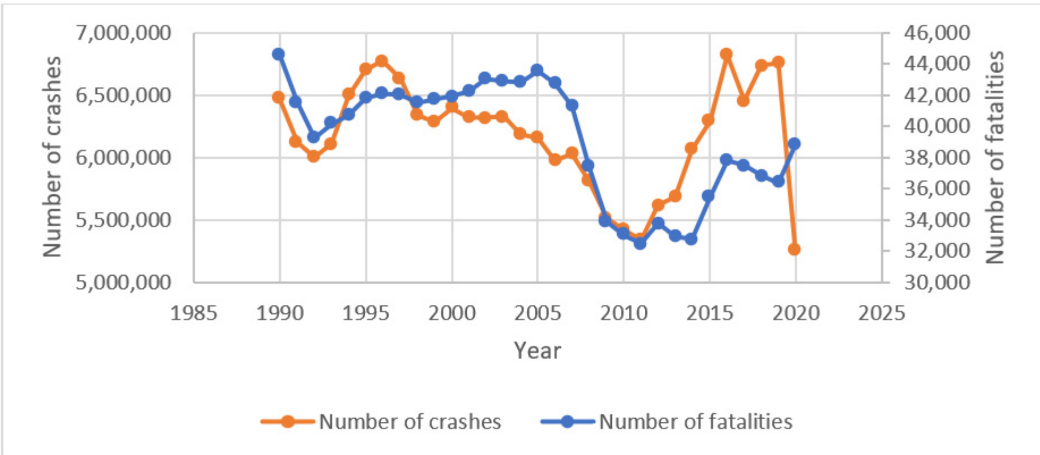

Figure 3. Comparison of number of crashes with number of fatalities.

3.2. Extent of Human Factors in Road Traffic Fatalities (Example from Canada)

Figure 4 shows various factors that contribute to fatal collisions using an example from Canadian motor vehicle collision statistics (2016–2020). Sometimes factors that contribute to traffic collisions can be more than one. Figure 4 showed that the sum of the cause of all crashes is not 100%. This was normalized to 100% in the illustrations in Figure 5.

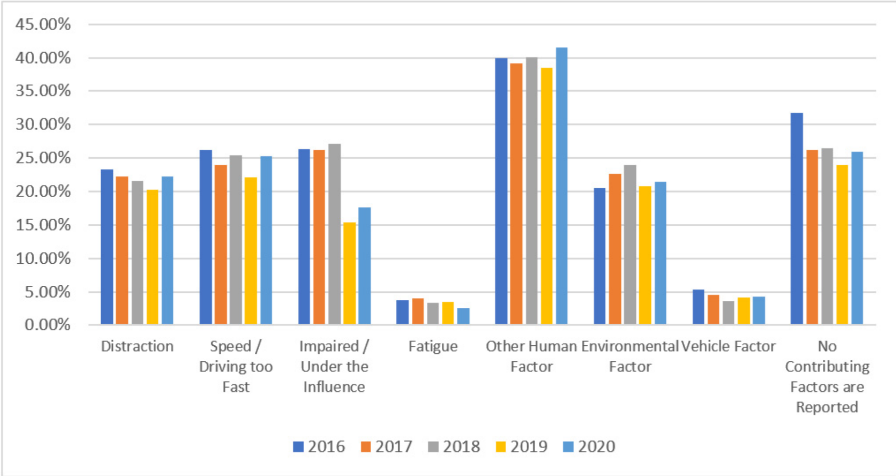

Figure 4. Factors contributing to fatal traffic collision (Canada).

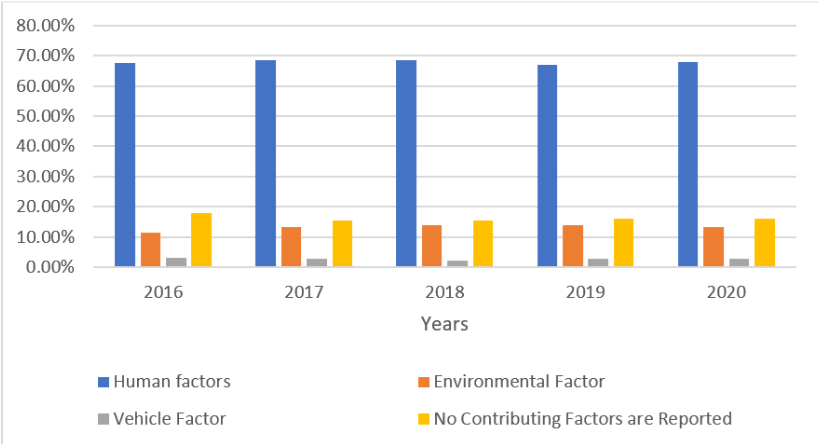

Figure 5. Comparison of proportion of fatal traffic collisions by the associated contributing factors (Canada).

Figure 5 also shows various factors that contribute to fatal collisions (with all the human factors mentioned in Figure 4 grouped together), and all factors for each year normalized to 100%.

Figure 5 shows that human factors have a significant contribution to road traffic fatalities in Canada. Hence, there is a need to explore ways to reduce the impact of human factors on road traffic fatalities in Canada. This study recommends a similar evaluation for all municipalities globally to further emphasize the extent of human factors in road traffic fatalities, and also develop strategies and systems to significantly reduce the impact of human factors in road traffic fatalities in a bi-partisan way.

4. Discussion

The evaluation of the impact of human factors on traffic fatalities showed that human factors significantly affect the rate of traffic fatalities on the road. Figures 1–3 in Section 3 above confirm that traffic crashes (and the subsequent injuries and fatalities) have been an issue of concern for a while now. Figures 4 and 5 also show that human factors play a significant role in fatalities from traffic crashes. Hence, there is a need for further review and development of actionable strategies to address this issue for humanity at large. Specifically, Figure 4 shows that distraction, speed, impaired driving, fatigue and other human factors contribute significantly to fatal traffic collisions. Hence, a reasonable degree of automation to complement human efforts will be a good endeavor. Bipartisan legislation on a reasonable degree of automation for the improvement of road traffic safety in various municipalities around the globe will be commendable. The results presented have shown that there is no doubt that human factors have a significant impact on road traffic safety and subsequent fatalities on the road. The following discussions can be helpful during bipartisan deliberation on how to minimize the impact of human factors on road traffic safety.

4.1. Driver Fatigue

Driver fatigue has been found to be one of the major factors that negatively impact road traffic safety. Driver fatigue, sleep restriction, and falling asleep while at the wheel has been identified as some of the major factors that contribute to accidents on the road [32]. Various researchers have presented figures that indicated that driver fatigue is a significant contributor to traffic crashes. Some researchers [33] identified driver fatigue as a critical aspect of public health that is responsible for 10–40% of road crashes. The European Transport Safety Council report [34] on the role of driver fatigue in commercial road transport crashes also noted that driver fatigue has been identified as a significant factor that contributes to about 20% of road crashes, with surveys showing that over 50% of long-haul drivers have fallen asleep at some point behind the wheels. Interacting factors that contribute to fatigue have been identified as the time that is available for rest and continuous sleep, length of continuous work and daily duty, and the arrangement of duty with rest and sleep within every 24 h cycle [35]. The Royal Society for the Prevention of Accidents [36] indicated that there will be impairment of performance if sleeping is less than 4 h per night. Alertness, concentration, vigilance, and reaction time (critical elements for safe driving) are reduced by sleepiness. The causes of accidents as noted by some other researchers [37] include: sleep disorders, hours of work driving, alcohol and drug abuse, higher levels of sleepiness, higher levels of stress, fatigue, lapses of attention, OSAS associated with alcohol, higher body mass index (BMI), and sleep medication. Another study [38] also noted that sleep deficit, stress, duration of driving, and alcohol have a significant contribution to driver fatigue, at 5% and 10% significant levels.

It is generally recognized that fatigue does not only result from prolonged activities. Socioeconomic, psychological, and other environmental factors that affect the body and the mind also cause fatigue [35]. While the contributing factors to fatigue as stated [35] are valid, there may be the need for more research into how other factors that could cause undesirable stress for various people lead to various forms of fatigue, absent-mindedness, and eventually accidents on the road. Although some recommendation that should minimize the impact of driver fatigue has been made in the literature, driver fatigue remains a challenge on the roads. The strategies to prevent crashes include naps, caffeine intake, physical exercise, breaks to rest, healthy nutritional habits, restorative sleep, phototherapy, reducing working hours at the wheel, and treatment of sleep disorders [37]. To guard against driver fatigue, among other things, some researchers [38] recommend avoiding driving when ill, sleepy, or taking medication and planning a journey to incorporate regular rest breaks. At least 15 min of rest every 2 h was recommended. The study [38] further recommended that people should avoid embarking on a long drive after working for a full day. While this recommendation is good, it may be difficult to enforce. Will any law enforcement officer dissuade people from traveling home to see their family after a long work day? What if people claim they are not fatigued before a traffic crash? Driver inattention monitoring systems are crucial as fatigue and driver distraction have become one of the leading causes of serious traffic accidents [24]. The lack of reliable testing and the blurred concept of fatigue makes it very difficult to make fatigue an operationalized component of criminal or traffic law [39].

Some behavioral psychometric and physiological tests that are being used increasingly to evaluate the impact of fatigue on driver performance include polysomnography, actigraphy, oculography, and the maintenance of wakefulness test, etc. [37]. In evaluating the issue of fatigue, sleepiness behind the wheels, and the need for a reasonable degree of automation to help human drivers avoid traffic crashes, some important questions to ask include:

- Is it possible for humans to completely eradicate various stressors that may result in driver fatigue?
- Could there be some undiagnosed medical conditions or emotional issues that could result in more likelihood of sleepiness behind the wheel for various people?
- Will it not be an invasion of people's privacy if anyone tries to monitor or confirm the amount of sleep that a driver has had before getting behind the wheel?
- Is there a universal agreement on the amount of rest that everyone needs, to avoid fatigue or sleepiness behind the wheel and can this be effective for everyone?
- Is it possible to enforce a universal plan (that everyone will truly follow) for work and rest before driving a motor vehicle?

Some researchers [37] in the study about "sleep disorders as a cause of motor vehicle collisions" cited studies that indicated that sleep disorders like insomnia, narcolepsy, obstructive sleep apnea (OSA), etc. are associated with excessive sleepiness, cognitive deficits, and fatigue symptoms like reduced driving skills, and these have been linked to increased risks of highway accidents and fatalities. The study also recommended that all disorders that produce excessive sleepiness should be investigated and monitored to reduce accidents, associated injuries, and loss of lives on the highway. Even if a driver is well rested, it is also not going to be an easy task for law enforcement officers to know at what point a driver needs a break from driving in order to avoid falling asleep. If we all agree that it is not possible for humans to provide adequate answers to the above questions without intruding on the private lives of people, and if we all know that some reasonable autonomous motor vehicle technologies exist that can help the driver in reducing the likelihood of a crash, then we should all be able to come to a consensus on improving the minimum standards of all motor vehicles to have these reasonable levels of automation, to keep people safe on the roads. Given the various level of autonomy that is presently available, a discussion about what can be referred to as a reasonable degree of autonomy for driver-operated motor vehicles is included in a later section of this study.

Fatigue is not adequately recognized and reported as a cause of road accidents; the effects of fatigue begin mostly from irregular working hours, and not only from the time spent while driving [35]. Without great foresight and welcoming of technologies that can ensure that this human limitation does not result in traffic crashes, and the associated consequences, the sad statistics of traffic fatalities on the roads, globally may not see a significant decline. It is good to note that a fatigued driver that is asleep behind the wheel, may neither see the vehicle speed on the dashboard, nor any other warning systems that various vehicles may have. An important question that needs an appropriate answer from us all is, "for innocent road users, whether it be vulnerable road users, (pedestrians, bicyclists, etc.) or other motorists, should the consequence of any fatigue driver bring these innocent people to an untimely death?" Figure 4 showed that driver fatigue has some contribution to fatalities on Canadian roads. Efforts to eliminate the impact of these human factors through technological innovations that can complement human efforts in the driving of motor vehicles will be commendable. Knowing that road traffic crashes do not discriminate between the young and the old, the rich and the poor, the politician or the farmer, there is a need for a concerted effort in the implementation of legislation that can help humanity overcome the pertinent challenge of road traffic crashes. No one in human wisdom can say with all certainty that he or she will never be in contact with a driver that is going through some form of fatigue that may result in a road traffic accident.

4.2. Distracted Driving

Distracted driving is a serious issue in road traffic safety. The Center for Disease and Control Prevention, as well as NHTSA, have classified distracted driving into three main categories. These include: visual, a situation in which the eyes are taken off the road, manual, a situation in which the hands are taken off the wheels, and cognitive, a situation in which the minds are taken off driving. While cognitive distraction is a state of diminished vigilance with respect to the driving environment, visual distraction occurs when the attention of the driver is diverted from the direction of travel of the vehicle [40]. Some researchers [41] classified three types of distraction into physical tasks, auditory or visual diversions, and cognitive activities, and further noted that some forms of activities like texting can include three types of distraction (physical, visual and cognitive), given that eyes, minds, and hands can be engaged in the distracting operation. Various efforts have been made in research to evaluate how the distraction of drivers can be evaluated. Gaze angle, eye closure, and blink are usually used to evaluate the variations in the driver's cognitive states [42]. The human pupil is also considered an indicator of cognitive load. Previous studies have suggested that variation in the size of the pupil is related to cognitive information processing [42]. As opposed to the standard deviations of gaze angle and head rotation angle, some researchers [40] were able to improve the performance for detection of driver's cognitive distraction by adding the average value of heart rate RRI (interval between R-waves) from the electrocardiogram (ECG) waveforms and the average value of the diameter of the pupil from camera images. Many studies have worked on brain activity tracking (Electroencephalogram) EEG-based measures for the cognitive load [43]. Some other researchers [44] focused on monitoring drivers' cognitive impairment due to daydreaming, thinking about other things different from driving-related matters, or talking on a mobile phone. A previous work [42] noted that two subtasks were imposed on the human subjects in their study (one doing arithmetic and the other having conversation) to imitate cognitive distraction by thoughts. However, the detection and management of wandering thoughts while driving is a challenging task, as people have different challenging situations, which may not be easy to access with basic means of measurements of cognitive distraction methods that are presently used in various research methods. Cognitive distraction by thoughts is a complex thing to measure. The distraction of drivers that results from the use of in-vehicle information systems results in many car crashes and related incidents [45].

Distraction can occur when drivers have to take their eyes off the road to look at the information on the display boards in the vehicles (Head-down display, HDD). Another study [46] looked into the potential impacts of both head-up-display (HUD) and head-down-display (HDD). There is no agreement in the research effort on whether head-up displays cause less distraction to drivers than head-down displays. The use of smartphones while driving comes with great risk in the task of guiding the vehicle safely [47]. The potential risk to road safety due to the exponential growth in mobile phone use in society has become a matter of concern for policymakers. The proportion of drivers using mobile phones while driving has also increased. Although it may not be an easy task to ascertain the exact impact of the use of mobile phones on crashes, some studies have indicated that drivers who use a cell phone while driving are four times more likely to be involved in a crash [48]. Meanwhile, various municipalities have instituted distracted driving laws. For example, the Canadian Automobile Association (CAA) [49] indicated that 10 provinces in Canada have some form of distracted driving laws.

With the thought that fully automated vehicles becoming an everyday reality is still some research years away, and drivers in semi-automated vehicles must be prepared to intervene upon the receipt of a take-over request, some researchers [43] investigated the impacts of using extended reality (XR, an umbrella term for virtual reality, augmented reality and mixed reality) interfaces in assisting drivers during the takeover requests (during the first second of controlling the vehicles). In the effort to achieve a bi-partisan agreement on ways forward to increasing the minimum standards for motor vehicles, some of the questions that will help in addressing the issue behind distracted driving are:

- Can anyone effectively stop a human mind from wandering thoughts?
- Can anybody know the exact time that the mind will wander away from the driving task to a dangerous extent?
- Who should bear the consequence of this absent-mindedness on the road?

Given the above-mentioned human limitations, to evaluate the need for a reasonable degree of autonomy, we all need to be sincere in answering this question: 'does anyone (either rich or poor, influential or non-influential, novice or learned) deserve to be a victim of distracted driving?' The AAA Foundation for Traffic Safety [50] believes that needless death can be eliminated by improving understanding of how physical and mental distractions causes impairment for drivers, and by educating the public on avoidance of distractions. However, considering the length of time that road traffic safety has been an issue for humanity at large, can we say that enough education and awareness has not been created about avoiding distraction? Can we say that law enforcement agencies are not doing a good job to prevent distracted driving? The issue of distracted driving is serious in various places around the globe. There is an urgent need to attend to this crisis that has faced humanity at large for a long time. The injury and property damages also have their effects on the economy. It is not possible to give a price to the loss of lives, and the emotional trauma that people may go through when a traffic crash results in fatalities.

4.2.1. Evaluation of Distance Traveled While Being Distracted

The distance that a vehicle would have traveled within a specified time while being distracted is dependent on the speed at which the vehicle is moving. It is known that the distance covered by a moving object can be represented by a product of speed and time. The higher the speed, the higher the distance that is traveled within a specified time. If the driver is distracted at the same time, there is a high chance of severe collision if an object is on the way. The result presented above shows that in addition to distraction, speed also contributes to fatal collisions in Canada. The Center for Disease and Control (CDC) noted that at 55 mph, a driver that is texting or reading a text, whose eyes are off the road for about 5 s would have traveled a distance that is long enough to cover a football field [51]. Within the period of distraction, traffic crashes that may result in property damage, injury, and even fatality could have occurred. Meanwhile, it is known that the computer system cannot be distracted in the way humans are. Looking at the number of fatalities that occur around the globe from a distraction point of view, it is no doubt that automation systems that are able to help ensure that this human limitation does not result in traffic crashes will be helpful for humanity at large.

4.2.2. Expectations of a Good Auto-Pilot System While a Driver Is Distracted

In using automation to assist human driving, it is important to ensure that the driver knows the limit for the auto-pilot. For example:

- A good automation system should be one that can audibly communicate its limitations in real life.
- When entering new routes or areas that the automation is not familiar with, the driver should be alerted by the automation system.
- If road conditions are bad, or when the friction between the tires and the road is such that the estimated time to reach a stopping point may not be achievable, the automation system should be able to alert the driver.
- If using cameras for the lane departure warning system, and the lane markings are not visible to the auto-assist system (e.g., when the road is covered with snow, or when lane markers are not yet on the road), the automation system should be able to alert the driver, both audibly, on a screen in the vehicle, and possibly through vibration.
- When the driver decides to take full control of the driving and the driver gets too close to another vehicle either through distraction, sleepiness, etc., a good auto-assist system should be able to alert the driver audibly, through a screen display, a vibration (on the seat, steering or the entire vehicle), and other means that may put the driver back on an alert mode.
- If the driver is unresponsive to the impending collision, a good auto-assist system should be able to initiate braking operations to avoid or reduce the severity of the traffic crash.

Road traffic safety measures need to consider how the vehicle, human, and environmental risks intersect to influence the likelihood and severity of injury [52].

4.2.3. Perception-Reaction Time (PRT) and Total Stopping Distance

During a driving task, the foot is not applied on the brake immediately when the eye perceives an issue that warrants a reaction. The American Association of State Highway and Transportation Officials (AASHTO) [53] noted that 2.5 s is considered adequate as a brake-reaction time, as it exceeds the 90th percentile of reaction time for drivers. However, it was also noted that while some drivers have less reaction time, most complex conditions during driving tasks require a higher reaction time. Various other braking reaction times exist for different situations. In simple braking operations, the perception reaction time (PRT) is said to begin when the driver first perceives an event that warrants a braking action and terminates when the foot is applied to the brake [8]. The equation for the calculation of the expected total stopping distance was presented in previous work [8]. The human factor here is dependent on how quickly the human driver can react to a hazard on the road at a given speed under the prevailing road and weather conditions.

Another work [8] defined the reaction distance as the perception reaction time multiplied by the speed of the vehicle. For normal braking operations:

$$\text{Reaction distance } \; d_{rc} = 1.47\; x\; V_{in} x\; t \tag{1}$$

where t (secs) is the AASHTO recommended standard for braking reactions, V_{in} is the initial speed of the vehicle. From Equation (1), it is obvious that the reaction time will increase with speed. Meanwhile, the vehicle does not stop immediately after the brake is engaged. AASHTO [53] shows the approximate braking distance for vehicles traveling at the design speed of the road, with a relationship between the deceleration rate and the Speed. Some researchers [8] presented a relationship between the braking distance of vehicles, the change in speed of the vehicles, the slope of the road and the coefficient of skidding and forward rolling friction.

4.2.4. The Challenge in Bringing the Vehicle to a Stop after Perception of a Hazardous Event

Apart from the fact that distraction increases the distance traveled before a driver becomes aware of an issue that warrants braking operations, to reduce the total stopping distance after the driver becomes aware of the issue that needs attention, the major factors that determine the total stopping distance include:

- The perception reaction time,
- The speed of the vehicle, and
- The deceleration rates [53]

It may also take a distracted driver a long time to perceive a potential hazard that warrants a reaction. In addition to the speed of the vehicle, the effect of grade and acceleration due to gravity also plays a role in the braking distance [8].

4.2.5. Recommendations to Reduce the Total Stopping Distance from PRT Analysis of Braking Operations

Knowing that the concept of total stopping distance is crucial in road traffic safety (especially, given its impact when a driver is distracted) and that it is highly desirable to bring a vehicle to a stop before a collision with an object, the following recommendations are made:

- Ensure maintenance and enforcement of appropriate speed limit (giving consideration for the grade of the road, weather conditions, and friction forces between the tires and the road surface)
- Promote research in technologies that can greatly increase the deceleration rate at operating speeds of vehicles
- Incorporate autonomous systems that can automatically detect and react to an issue that needs an action during the driving task.

Recall, Equation (1) illustrated the reaction distance that the vehicle could have traveled with a perception reaction time of 2.5 s. Reduction of this reaction distance could mean that the vehicle will be able to stop before crashing into an object or even a human. Given that computer systems handle multiple processes faster than humans, it is envisaged that autonomous systems will bring the reaction time in driving closer to zero when a hazard is detected on the road. However, note that if autonomous systems that can bring the reaction time close to zero are used, before the vehicle stops, there is still a challenge with the braking time. As a result, even when all vehicles on the road have autonomous systems to detect hazardous situations, factors such as the speed of the vehicle, friction factors, the grade of the road, and the deceleration rate of the vehicle will still have an impact on the possible distance that can be traveled before the vehicle finally stops. Hence, there will be a need for continuous education of people in various municipalities as regards the realities of the braking distance of vehicles. It is not uncommon to find computer systems that begin to slow down with age and reduced memory capacity. If a vehicle that is equipped with autonomous vehicles develops issues that make it unable to function at the desired capacity, it will be a good thing to ensure that such autonomous technologies communicate such issues to the driver/vehicle owner (through various vehicle-driver communication systems such as on-screen display, audible voice prompts, etc.) to ensure that appropriate actions are taken through take-over of driving operations and servicing of the vehicles.

Improvement in engineering controls to protect vulnerable road users in various communities is also recommended. This may include the construction of more guard rails, depending on the need in various places, gates/barriers to restrict vulnerable road users from accidentally getting in the way of high-speed vehicles, etc. For example, an inexperienced cyclist that is having trouble stopping a bike at an intersection may be restricted from going into the intersection by a gate. A continuous road safety audit is also recommended, which may be able to detect things such as the need for overhead bridges for pedestrians. Continuous road safety audits should also be able to identify other measures to improve traffic safety, like the need for improvement of roadway lighting systems in dark hours, road conditions, the presence of barriers that may obstruct the view of drivers, especially at intersections, etc.

4.2.6. Effects of Outside Objects on Driver Performance

Distraction from an outside object is also a huge factor that negatively impacts road traffic safety. In a review of the impact that billboards have on drivers' visual behavior, a previous work [54] noted that external distractions seem to account for at least 6–9% of motor vehicle collisions in which distraction was a factor. The study also noted that considerable evidence exists to show that about 10–20% of all glances at billboards were $\geq$0.75 s. In a study about the effect of roadside advertisements on driver distraction, researchers [55] noted that conservative estimates put external distractors as responsible for up to 10% of all accidents, and although roadside advertisements are designed to attract attention, the industry does not acknowledge their potential threat to road safety. The study also noted that roadside advertising showed a detrimental effect on lateral control, increased eye fixations, and mental workload, and can even draw attention away from more relevant road signage in some places. An exercise of prudence was recommended when placing or authorizing roadside advertisements.

Another study [56] noted that an increasing amount of visual information like advertisements by the roadside creates visual clutter in the environment. The study further classified visual clutters into three categories: situational clutter (other road users, and vehicles that the driver interacts with), designed clutter (traffic control systems like road signs, markings, etc.), and built clutter (signage that is not installed by traffic authorities, and other roadside developments). Billboards were found to have significant effects on speed, the ability of drivers to follow directions given on road signs, and eye movements. While driver speed is reduced with billboards, their ability to follow road signs becomes slower and comes with more errors, and the amount of time spent looking at the roadside at the expense of paying proper attention to the road also increased. The distraction from visual clutter in the driving environment is certainly hazardous for road users. In the evaluation of the issue of outside objects on driver performance with the issues described here, it is important to sincerely address these questions:

- How can the issue of visual clutter in the driving environment be addressed?
- Do we have a true statistic of all traffic crashes that occurred because the driver was distracted by outside objects or people?
- Should any municipality come up with a law that completely prohibits advertisement on the roadside?
- What impact is an application of a reasonable degree of autonomous motor vehicle technology expected to make on the improvement of road traffic safety in this regard?

Another researcher [57] noted that there is considerable variation in the criteria for the management of advertising devices used by the roadside in various jurisdictions. The income derived from outdoor advertising, especially on high-volume corridors also creates a challenge.

4.3. Driving under the Influence of Drugs and Alcohol

Driving under the influence of drugs and or alcohol is another dangerous human factor in road traffic safety. In a study aimed at assessing the risk of having a traffic accident after using single drugs, alcohol, or a combination, and determining concentrations in which the risks significantly increased, some researchers [58] (in addition to other findings) noted that alcohol, in general, caused an increased risk of a crash. Cannabis (in general) also resulted in an increased risk of accidents. At a concentration of 2 ng/mL of THC, accident risk was found to be four times the risk of the lowest concentration of THC. A report [59] identified THC as "tetrahydrocannabinol", a chemical that is responsible for most of the psychological effects of Marijuana. The National Institute of Drug Abuse [60] referred to THC as a mind-altering chemical delta-9-tetrahydrocannabinol that is contained in Marijuana (Cannabis Sativa). THC is said to have the capability to change thinking, induce hallucinations, and cause delusions [59]. Cannabis has been identified as the second most impairing drug that is used in the world, after alcohol. The risk of being involved in a crash is said to be doubled when the blood alcohol level is between 0.05 and 0.08%, and at a blood alcohol level of 0.24%, the risk of a crash increases to more than 150-fold [61]. Road transportation safety will surely be in greater trouble if more people drive on the road with a significant amount of THC or alcohol, which can affect their normal thinking process, perception, and reaction time. While cannabis and alcohol cause acute impairment of many driving-related skills in a dose-related way, the effect of cannabis varies more between people than they do with alcohol, because of differences in smoking techniques, tolerance, and absorptions of THC [62].

Law enforcement for transportation operations is such that should guarantee safety for every road user. When evaluating the need for automation systems in driving operations with the issue of driving under the influence of drugs and alcohol, some important questions to consider include:

- Is it possible for law enforcement officers, 100% of the time to apprehend the offenders before they cause havoc on the road?
- Does any road user deserve to be the victim of any driver whose reasoning may have been affected by THC or by alcohol effect?
- What effect is an application of a reasonable degree of autonomous motor vehicle technology expected to bring on the effort to minimize the potential impact of impaired drivers (that may have not been caught by law enforcement officers) on the entire community?

Drunk road users in cars and pickups have the greatest odds of being a victim of a fatal crash [63]. The above results indicate that driving 'under the influence' is one of the factors that has contributed to fatal collisions in Canada. Drunk drivers are not only a threat to their own safety, they are threats to the safety of other road users. With this knowledge, it is important that enforcement actions be increased to reduce the chance of drunk driving. Random police inspection can be increased, especially during the time that is common that there will be drunk drivers outside. Those who sell alcohol may be obliged to take the car keys away from their customer and call a taxi if the customer is drunk, or even call the police if one of their drunk customers gets behind the wheel. Fines may be issued to liquor sellers if it is known that a drunk person was allowed to drive away from their center without attempting to restrain the drunk person. Police checkpoints for drunk driving may be situated close to liquor stations. These random checks may be increased to discourage drunk drivers. Adequate fines for drunk driving, including revocation of driving license after an agreed limit for a repetition of the drunk driving offence may be considered in places that do not enforce such fines. In addition to all of these, reasonable collision avoidance systems, such as lane departure warning systems, frontal collision warning systems (audible and vibrational effect to alert the driver), auto-brake systems, backup camera warning systems, etc. will be good complements in the effort to minimize the impact of drunk drivers in the community.

4.4. Major Emphasis on Road Safety Approach and the Proposed Way Forward

Improving road user behavior has been the major strategy that has been emphasized for road traffic safety [64]. While efforts to improve road user behavior may include things like driver training, and re-training, public education, enforcement of traffic laws, etc., with the number of traffic fatalities that still occur on the roads in various jurisdictions, does this mean that people do not have adequate driving training before they obtain a driving license? Are the driving licensing officers not doing adequate jobs? We certainly cannot put the blame on the driver licensing officials. As illustrated in this study, there is no doubt that humans have some serious limitations that contribute to traffic crashes. If it is known that relying on the hope of improving road user behavior alone has not improved road traffic safety to the desirable extent worldwide, certainly, it is time to expand the major strategy beyond the realm of hoping to improve road user behavior. Reviewing and upgrading to the minimum vehicle standards are recommended. It will be desirable to see the implementation of minimum vehicle standards that has various levels of automation to help ensure that human errors do not result in negative consequences for various road users. At a minimum, vehicle standards should be increased to ensure that all vehicles on the road have auto-brake systems to prevent both frontal and backward collisions [65]. Such auto-brake systems should be capable of detecting objects in the trajectory of the moving vehicles and efficiently reduce speed to prevent a collision. Such collision avoidance systems will go a long way to reduce road traffic crashes and their associated consequences globally. If properly enforced, such a collision avoidance system should also help deter/prevent the use of automobiles as weapons of mass destruction for unsuspecting vulnerable road users. If well implemented, connected vehicle technology in combination with auto-braking systems for trucks, busses, and other vehicles for mass transit (as a supplement to human driving efforts) is also expected to help reduce the possibility of collisions at intersections.

While addressing a question about if autonomous vehicles will completely replace human drivers, as raised in the Federal Automated Vehicle Policy [66], a researcher [65] suggested that pilot projects be conducted in various communities to validate the efficiency of autonomous systems. If there are no accidents at all while autonomous vehicles are on the road, this may form the basis for the adoption of fully autonomous vehicles on a large scale. It is no doubt that all traffic crashes require a thorough investigation to determine the cause, and create lessons learned for future improvement. Continuous, and rigorous investigations of any traffic crash involving vehicles with autonomous systems are recommended to ensure that the cause of any system failure is identified, and information about the necessary improvement of the technology is openly shared with all automobile manufacturers. It will be a good idea to ensure that all automobiles have not only a system that can report the present fault in the vehicles, but also a system that can track the repairs, and maintenance that has been conducted on the vehicles. Such a system will be helpful during the investigation of any traffic crash that involves vehicles with autonomous systems. If there is foul play, in which someone has tampered with a safety feature before a crash, the recommended improvement in vehicle design should be able to show that record.

At this time, it is known that not everyone appears to be comfortable with full autonomy for roadway vehicles. A study [67] that evaluates if consumers are willing to pay to let cars drive for them noted that a semiparametric random parameter logit estimate indicates that there is an approximately even split between, no demand, modest, and high demand for automation. In a study about public opinion on automated driving, some researchers [68] also found that public opinion about autonomous driving is diverse. 69% of people believe that automated driving will reach 50% market share by 2050. While some people welcome the idea of fully automated driving, another large portion of people is of the opinion that autonomous driving will not provide an enjoyable experience and are not willing to pay for it. The study also noted that the main concerns that were raised about autonomous driving include software hacking/misuse, data transmitting issues, legal, and safety. In a presentation slide on the evaluation of potential policy issues when planning for autonomous vehicles, a scholar [69] proposed ways by which these concerns may be addressed. These include ensuring that a system exists that will both promptly inform users, and refuse to work in autonomous mode when a data breach has been identified, ensuring the means to switch to manual driving exists when a data breach has been identified, and not implementing full autonomous systems on a large-scale basis if it has not been tested and safety verified in all weather conditions in various municipalities, etc. Despite the fact that automation is increasing (due to sophisticated assistance systems), the human driver will continue to play a role as supervisor of vehicle automation for a long time [70].

From the analysis of human factors evaluated so far (from Section 3 and the discussions above), there is no doubt that humans need a reasonable degree of automation in driving operations to avoid serious challenges that are posed by human factors. There appears to be a great need for more public education about human limitations in driving operations, its impact on humanity at large, (as reflected in the global statistics for road traffic fatalities), and the need for a reasonable degree of automation in the driving of automobiles. There is a need to determine what a reasonable degree of autonomous motor vehicle technology is so that everyone is on the same page with improvement efforts for road traffic safety operations.

4.5. What Is a Reasonable Degree of Automation for Roadway Motor Vehicles?

The above question is one that is expected to evolve from one generation to another. It may also be affected by the advancements in technological innovations in the transportation industry. Firstly, it is good to know that it will not be a wise idea to have a technology that can save lives, and not put it to good use. In this age, humanity at large has grown to see innovative technologies that can help humans better monitor the driving environment (or at least complement human efforts), and also take necessary actions to bring the vehicle to a stop to avoid a traffic crash. If these technologies can help save lives, and drastically reduce traffic fatalities on the roads globally, why should anyone be against it? One of the issues that have been raised in previous research is about the 'enjoyable experience' in driving operations [68]. If what is presently considered an enjoyable experience in driving operations contributes greatly to 1.25 million fatalities on the road (globally) every year, then humanity at large needs to answer the important question, "is this so-called 'enjoyable experience' a reasonable one, considering the number of traffic fatalities"? It is very obvious that humans have great limitations that previous road traffic safety efforts have not been able to overcome. It is high time that humanity at large arose in one accord to say 'no' to transportation systems that do not guarantee the safety of all road users. A good sense of judgment needs to be applied in this situation. We already have technologies that can help in monitoring the driving environment, and initiate crash prevention action in good time. Let us use it. We already have technologies that can detect objects in the trajectory of moving vehicles, stop in good time, or make an adequate manoeuvre to avoid collisions. Let us use it. A previous study [71] gave a report on the estimate of expected lives to be saved by vehicle standards that were recently implemented in India. Among six vehicle safety standards that were mentioned in the report, seat belt reminder was reported as the one to be most effective in reducing traffic fatalities on a conservative estimate. With an optimistic estimate, over-speed alerts, seatbelt reminders, and offset frontal crashes are expected to be the most effective in reducing traffic fatalities. Some researchers [72] cited some references that indicated that a few US states, the UK, Japan, and Sweden have laws and regulations that allow for the remote operation of highly automated cars with or without an onboard driver.

Even though there is a lot of optimism about the expected safety benefits of autonomous driving, it does not come without its challenges. In order to derive requirements for safe and effective remote assistance and remote driving of autonomous vehicles and also create suitable human-centered solutions for human-machine interfaces, the researchers [72] compiled a set of 74 core scenarios that are likely to occur in public transport while using automated vehicles. Some of the lists of scenarios in remote operation include the cases in which there are:

- Vandalism (in which there is damage to the autonomous vehicle inside or outside. In this case, AV cannot continue the ride).
- Passenger abuse of the intercom (that can result in distraction of the controller center employee).
- Partial defect in the autonomous vehicle, but it is still operatable (in this case, the autonomous vehicle stops).
- Difficult weather conditions (in which there is overload or soiling of the sensors on the vehicle. In this case, the autonomous vehicle cannot continue its journey), etc.

Rather than trying to navigate through unfamiliar territory, it is reasonable that some autonomous vehicles require that human drivers take over the driving operations when the autonomous systems encounter situations that are beyond their capability. A study [13] noted that a take-over request is issued to transfer the driving operations to the driver (from the system) when the system is unable to continue the driving operations. In this case, a smooth take-over of the driving operation is essential to reduce the chance of traffic crashes. If the driver is asleep, or distracted and unable to respond on time to the take-over request, there is a likelihood of a traffic crash. For situations in which the driver failed to respond to a take-over request in an autonomous driving operation, it is important that such autonomous technology be equipped with systems that will gradually bring the vehicle to a stop while activating the hazard light. Eventually, it will be nice to have autonomous vehicles subscribe to a dedicated emergency line from where assistance can be provided in situations where failure to respond to the takeover request is due to an emergency medical condition or distress for the driver. In such an emergency situation, connectivity of vehicles can provide automatic notification of emergency situations and how it may affect the navigation of other vehicles, including the need for the exploration of an alternate route to reduce the chance of congestion and traffic hold-up on any section of road that has such an emergency issue. Another study [9] mentioned that the behavior of commercial drivers changes significantly after the transition to manual. Thirty min of automated operations are said to intensify the effect of take over request (TOR) on driving behaviors while repeated take over request improves the reaction times to TORs, and reduces maximum and minimum speed after the TORs. There is a need for more research on the degree of safety that is offered by such autonomous vehicles as relating to the take-over responsibility of human drivers.

Six of the most common new technologies as mentioned by the IIHS and the HLDI [73] and referenced by another work [74] include auto-brake, forward collision warning, blind spot detection, adaptive headlights, lane departure warning, and lane departure prevention. Given various technological innovations in motor vehicle designs in the present day, a reasonable degree of automation for automobile driving operations will be the use of automatic technologies that has been adequately tested (in an open and unbiased way) in all weather conditions (including hazardous weather conditions, such as severe winter (extreme cold and snow), rain, fog, etc., and the safety capabilities have been verified to ensure the safety of people in their daily commute. A scholar [74] prepared a research guide for using the efficiency of technological innovations in automobiles to establish unbiased policies for the improvement of minimum safety standards for driver-operated motor vehicles. This report recommends that researchers in various jurisdictions give a fair opportunity to test reasonable autonomous technologies in motor vehicles to determine which technology is ripe to be mandated as minimum standards to improve road traffic safety in various jurisdictions globally. The Insurance Institute for Highway Safety (IIHS) and the Highway Loss Data Institute (HLDI) noted that crash avoidance features are rapidly entering the vehicle fleet. While some technologies are optional in some vehicles, there are some technologies that are standard for some vehicles. After open and unbiased testing of these technologies on a large scale, it is recommended that efficient technologies be mandated and enforced as a standard for all motor vehicles.

It is known that the world has also witnessed the advent of fully autonomous motor vehicles. A researcher [65] presented a study that evaluates some potential policy issues when planning for autonomous vehicles. Implementation of fully autonomous vehicles on a large scale in any community will depend on the efficiency of such vehicles. It is no doubt that weather conditions and roadway conditions are not the same in various communities globally. The evaluation processes for fully autonomous motor vehicles will have to be conducted in all weather and roadway conditions in every community to verify their safe use under the prevailing road and weather conditions of the community. It is known that the operations of computers are limited to the algorithms for which they have been pre-programmed. Given various factors that interact during the driving operation, various scenarios could exist on the road. Fully autonomous vehicles will need to be able to perform efficiently in all these conditions to be certified as safe for use (on a large scale in any community) under those situations.

Knowing that system failure sometimes occurs, it is better to still have human drivers that can take over the driving operations in any situation where there is a safety-related issue with automatic features (Except in a controlled environment where the system failure of a vehicle in a full auto-pilot system cannot have an adverse effect on other road users). Responsible drivers in vehicles should still be able to manually apply the brake when there is a need for it. The responsible driver in the vehicle should also have the ability to control the steering as need be. The availability of manual driving operations in vehicles should not be made to have the capacity to override the automatic braking systems that are designed to prevent frontal and backward collisions in the trajectory of the moving vehicle. However, this will be a reasonable option if there is a high level of security in the community and people do not need to collide with an object in an effort to escape a hazardous situation. Automobile designs in which an immobilizer system works directly with the auto-brake system are recommended. If the auto-brake system is faulty or has been tampered with, the vehicle should not work. With a technology like this, the world should expect to see a great reduction in collisions on the road. Let us remember that it is possible to design automobiles in a way that people cannot use a vehicle as a weapon. If some vehicles are on the road without reliable collision avoidance systems, in any situation where there is no adequate room for maneuver, and there is an impending collision from a vehicle that does not have collision avoidance systems, even vehicles that have collision avoidance systems may not be able to escape a collision with the vehicles that do not have collision avoidance systems. This shows the need to aim at a system where all vehicles on the road will have reliable collision avoidance systems. A motion like this should be a good compliment to any community with a good security system. 'Every road user deserves a safe commute, without fear that someone may use an automobile as a weapon to kill them' [69]. The suggestion that indicated that 'it is better to still have human drivers behind the wheels in vehicles that have automated features in case of system failure' does not mean that fully autonomous vehicles should not be used. Various purposes exist for which fully autonomous motor vehicles are desired, but they have to be operated only under the conditions that their safe use has been tested and certified. A scholar [74] noted that the efficiency of technological innovations that can help drivers monitor the driving environment, warn the driver, or take good actions to avoid a collision should be individually evaluated, while technologies that best guarantee safety need to be selected as the minimum standard for all roadway motor vehicles. The efficiency of fully autonomous motor vehicles may be compared to the efficiency of driver-operated motor vehicles that have a high level of autonomous motor vehicle technologies as a standard practice.

The fact that a human driver is operating a vehicle with efficient autonomous technologies (such as the common new technologies that were mentioned, auto-brake (to prevent collision), lane departure warning, etc.), does not relieve the human driver of the responsibility to control the vehicle. If an autonomous vehicle technology fails to perform as expected, the human driver has the responsibility to ensure the safe operation of the motor vehicle, e.g., by applying the brake when it is necessary. A proactive approach to test the efficiency of these technologies to improve the minimum standard of driver-operated motor vehicles has been proposed by a scholar [74]. The above-mentioned research guide [74] to evaluate the efficiency of autonomous motor vehicle technology is a good resource for this.

4.6. Addressing the Ethics of Remote Driving and Automatic Braking Systems for Vehicles on the Road

As regards to autonomous driving, researchers [14] noted that there will certainly be problems (that are beyond the programming of autonomous vehicles) that will necessitate human involvement to assess the situation, make necessary corrections or direct the automation process. The summary of the responsibilities of the human driver and system at each level of automation is given by SAE international [75]. Level 0 is no automation, level 1 has driver assistance features, level 2 has partial automation, level 3 has conditional automation, level 4 has high automation, and level 5 is full automation [14,75]. In some cases, autonomous vehicles can be remotely operated. Meanwhile, situational awareness is different when drivers are in the vehicle that they are driving and when they are not there [14]. The detection of objects by autonomous vehicles is an important operation that comes before other tasks such as object tracking, trajectory estimation, and collision avoidance. Other tasks include path planning, ego-vehicle self-localization, environmental perception, and vehicle control. Due to continuous changes in behavior and location, dynamic variables on the road (vehicles, cyclists, and pedestrians) pose a greater challenge [15]. Hence, it is important that fully autonomous vehicles only operate on roads that they are very familiar with, and have been tested and certified as having the ability to safely operate on those roads in all weather and road conditions. It is also important to ensure that human drivers on such roads are aware that some of the vehicles that they encounter on the roads are driverless vehicles.

Remote driving comes with the ethical challenge of whether a remote driver should have the capability to override the auto-brake function of an autonomous vehicle. A previous study [76] noted that manual driving must override automated driving when a driver needs to avoid emergencies. The ethical question is the limit to what manual driving should be able to do (Should the ability to collide with an object be removed from manual driving, if it is not a law enforcement vehicle?). To ensure that autonomous vehicles are not being used for terrorist missions, hitting different targets in town without any driver behind the wheels, it is ideal to ensure that all autonomous vehicles have auto-brake functions that remote drivers cannot override (to ensure that the vehicle comes to a full stop upon detection of an obstacle, object, or person). To minimize the potential for head-on collisions, rear-end collisions, etc., the world still struggles with a decision on whether to make the auto-braking function mandatory for all vehicles on the road.

Benefits of automatic braking system include:

- Reduction in the possibility of a driver using the vehicle as a weapon.
- Reduction in the number and severity of various forms of collisions (such as head-on collisions, head-to-side collisions, etc.).

- Reduction in the possibility of collisions when the driver falls asleep behind the wheel, becomes distracted, or when some other human factors set in.

Implementation of an automatic braking system as a mandatory requirement for all vehicles should not excuse the driver from activating or pressing the brake when needed, or if the auto-brake system fails. The disadvantage of an automatic braking system to avoid collision when there is an object or obstacle on the way includes:

- Loss of ability to collide with any obstacle on the way in a situation where the driver needs to use the vehicle to escape from an impending danger (such as armed robbery, terrorist, etc.).

In the decision to choose between legislating an auto-brake system as a minimum requirement for all vehicles on the road, it is important to compare the pros and the cons mentioned above. The expected number of reductions in fatalities that could be avoided when all vehicles on the road have reliable automatic braking systems can be compared to the expected number of fatalities through deficient public safety situations such as the need to collide with obstacles when being chased by some terrorist or armed robbers. In places where public safety is very high, it is reasonable to have an automatic braking system as a minimum standard for all vehicles on the road. While the effort to reduce traffic crashes is noble, it is important to ensure that any autonomous functions in vehicles are such that are tested and found to be truly helpful in all circumstances. The limitations need to be clearly specified to allow for human interventions where needed. It is not a smart move to allow for blind approval of fully automated vehicles without full assurance of their effectiveness in all weather conditions. In the effort to combat the alarming rate of global traffic collisions, widespread testing of autonomous vehicles on the road is reasonable to ascertain their effectiveness before any legislation on the subject (as long as there is no reasonable ground to doubt the safe use of the technology in the circumstance where it is to be used).

Although improvement in motor vehicle standards is expected to result in an improvement in road traffic safety through a reduction in the negative impacts of human factors (fatigue, distraction, impaired driving, etc.), it is important to continue research on how to minimize traffic fatalities for motorcyclists and other vulnerable road users. Figure 6 shows that although the percentage of serious injuries and fatalities is highest with drivers, there is a considerable percentage of fatalities from motorcyclists and other vulnerable road users. The data for motorcyclists in Figure 6 also includes moped users. With the knowledge of perception and reaction times and the distance that a vehicle will travel before stopping at varied speeds (the fact that it takes a while for a vehicle to come to a complete stop after the brake is activated), it is important to ensure continuous education for motorcyclists and other vulnerable road users to not assume that fully autonomous vehicles will stop immediately when an obstacle comes their way.

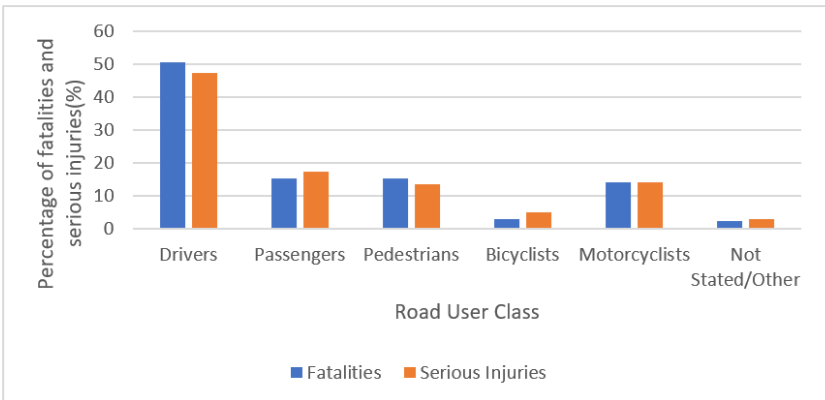

Figure 6. Percentage of serious injuries and fatalities by road user class for year 2020 from Transport Canada database [31].

4.7. Removing Barriers to Improving Road Traffic Safety

If the world truly wants to see a change in the trend for traffic crashes, there is certainly a need to put all politics, and hope of financial gain from any system aside, and ensure that safety is truly the first priority in transportation systems.

In the effort to remove barriers to improving road traffic safety, major questions to evaluate include:

- If the world continues with the existing policies in the transportation sector, are we going to see a drastic change in fatalities on the road worldwide? If the answer is no, the next question is:
- Do humans have a natural ability to make everyone's mind focused on the driving task through increased enforcement, and not be involved in any form of distraction whether visual, manual, or cognitive? If the answer is no, the next question is:
- Do humans already truly have technologies that are able to help ensure that human limitations as described do not result in negative consequences as has been in the past? If the answer is yes, the next question will be:
- What can be done to bring these technologies into full implementation to help reverse the trend in road traffic crashes, and the associated consequences?

It is no doubt that since no one can confidently say that humanity has a system that can make people concentrate on the driving task at all times, there is certainly a need for some autonomous system that can ensure that human errors do not result in dangerous consequences. Note that even if systems are implemented that warn drivers about impending danger, there is still a need for the driver to be in a reasonable state of mind to be able to properly respond to such an alert. Will such an alert be efficient for fatigued drivers or for someone who is driving under the influence of drugs or alcohol? Will such alerts stop a terrorist? If everyone has agreed that humans need autonomous systems like automatic braking systems, and other automatic crash prevention systems, the next question to address will be "what are the limiting factors that may create resistance to implementing technologies that are aimed at improving safety for everyone on the roads globally, and how can this be resolved"? Some of the crash avoidance features listed by the Insurance Institute for Highway Safety (IIHS) and the Highway Loss Data Institute (HLDI) mentioned earlier include auto-brake, adaptive headlights, and blind spot detection, lane departure prevention, forward collision warning, etc.

It is not a happy thing to see a traffic crash in which some fellow human beings have lost their lives. If we ask people that have witnessed (or heard about) an accident scene (with sad consequences) if they would love to support a technology that could help prevent the loss of life on the road. The reasonable answer will be yes. But if we ask these people what their support for the technology will be, if the technology has the potential to dangerously affect the economic well-being of their community, probably, at this point, the question may be going to a seemingly tough area for some people. Normally people will not want anything to affect the source of their income. It is known that the movement of vehicles from one place to the other does not come without other factors that have implications for the economy in various places around the world. To adequately address the issue of road traffic safety, there is also a need to address the economic implications for people in various regions. While there is concern about road traffic safety, there are also other concerns like the release of toxic gases into the atmosphere from various exhaust pipes. Although it will be good to find a way to address all the concerns in a way that brings positive results for all, knowing that it may be somewhat challenging to implement changes that will make everyone happy at this time, it will be a good idea to address the issues one after the other.

According to the World Health Organization (WHO) on the top ten causes of death [77], road traffic injuries were rated among the top 10 causes of death, killing 1.3 million people (76% of this are boys and men), just before tuberculosis (1.4 million), diarrhea (1.4 million), diabetes (1.6 million), lung cancer, including bronchus and trachea cancers (1.7 million), lower respiratory infections (3.2 million), heart diseases and stroke (15 million deaths) in

2015. Although there are other causes of death globally that exceed that of road traffic injuries, road traffic fatality is one that can be drastically reduced and eliminated by having effective changes to transportation policy. Because some autonomous technology systems in transportation that can help ensure that some human error during the driving task does not result in negative consequences are associated with other advanced technology that does not require the use of fossil fuel, to eliminate potential barriers to achieving improved road traffic safety, there is need to implement systems that will first assure those who make a living from sales of fossil fuel that the goal is not aimed at adversely affecting the economy of such nations. In a writing about why electric vehicles and autonomous vehicles are linked, a previous work [78] noted that the autonomous vehicles' future is dependent on the cost-effectiveness of electric vehicles. But the statistics that were given do not show that all autonomous vehicles are electric vehicles.

It is known that fossil fuel resources in an area can be depleted after continuous mining over a long period of time. The Petroleum Technology Research Centre (PTRC) [79] described a project (that occurred between 2000 and 2012) that studied carbon dioxide injection and storage into two depleted oil fields in South-Eastern Saskatchewan. The injected CO_2 is used for enhanced oil recovery. PTRC also noted that operators of oilfields in West Texas have been injecting carbon dioxide into oil fields for a long time now. Knowing that the world's deposits of fossil fuel are not an infinite reserve, while the resource is being wisely extracted for daily use, there is a need to also ensure continuous support for the development of technologies that can use renewable energies. For example, it will not be good to wait until the reserves for fossil fuel in a community remains as little as a year's worth before the world begins to explore the production of vehicles that can use alternative energy on a large scale. This knowledge should be enough to bring those who mine natural resources for the benefit of humanity at large, and those who develop technologies that will be of good use to humanity when the fossil deposit begins to show a significant depletion rate together as partners in achieving a breakthrough for mankind both in the energy and safety aspect of the transportation industry. While it will not be advisable to adopt a strategy that may send an economic shock to any nation, it will also not be good for anyone to try to go against plans for long-term sustenance because of the perceived effect on the present financial situation.

Allowing for a gradual adjustment to economic situations while improving road traffic safety will be good. Instead of having a viewpoint that somewhat associates automobiles that have a good level of autonomy with automobiles that do not require the use of fossil fuel, a good collaboration between those who have high expertise in producing automobiles with advanced technologies to help ensure that human limitations do not result in negative consequences will be good. In the face of depleting 'non-renewable energy', in various municipalities, and the concern about possible economic shock from a drastic change to technologies that use non-renewable energy, it may be good to explore a quota system in which there will be a certain percentage of vehicles that are made that can use non-renewable energy for a pre-determined length of time, while each manufacturer also has a quota for vehicles that use renewable energy. The quotas may be periodically adjusted depending on the need and global concerns. However, the vehicles (either the ones that use fossil fuel or the ones that rely completely on renewable energies should all have a reasonable level of autonomous system) to ensure adequate crash avoidance. The quota system described is aimed at giving various economies the opportunity to adjust and have a smooth transition with global technological developments, and long-term realities of non-renewable resources.

Overcoming Potential Fears of Loss of Revenue from Fuel Tax

Proper design and adequate road maintenance are important to ensure the safety of people on the roads. For example, falling into an unexpected pothole can be hazardous for drivers, especially those who are not familiar with the roads. This can even be dangerous for someone that is in a vehicle that is using an automatic driving system. A good portion of the revenue for the maintenance of the roads comes from the fuel tax system. A situation in which a considerable portion of highly automated vehicles with advanced safety features are electric vehicles can generate a concern about sustainable funding for road maintenance. With a mind to create unanimous support for automakers who have specialties in highly automated vehicle technologies (that can help improve safety on the roads), and renewable energy technologies (that may help reduce fears from potential realities of non-renewable resources), and automakers who make vehicles that use fossil fuel, it will be a good idea to consider adoption of other systems that makes all road users pay a fair share of the cost of using the roads. The use of a road user charge system as described in a previous work [80], which involves assessing owners of personal vehicles on a per-mile basis for distance driven, may be adopted. The mileage-based road user charges system has also been used in various places, including road user charges on both trucks and automobiles in New Zealand, and road user charges on trucks in Switzerland, Austria, and Germany. Small-scale experiments of this system both on state and local levels have also been conducted in the United States [80]. A previous work [69] also recommended that efforts should be made to implement systems that can automatically capture, and report vehicle miles traveled by all vehicles (in a road usage finance system), in all jurisdictions, for a periodical billing system. This will ensure that electric-powered autonomous vehicles and other vehicles that do not pay fuel tax can pay their fair share of road maintenance fees.

News from the National Conference of State Legislators [81] through USDOT FHWA's program on Surface Transportation System Funding Alternatives (STSFA) also indicated that there is interest in alternative revenue mechanisms for the Highway Trust Fund. This interest in alternative funding for surface transportation is surely a good step to ensure that governments can take a neutral stand on this. Governments in various jurisdictions should try to move to a neutral position as regards to the source of revenue for the government (as regards to revenue for infrastructure construction and road maintenance). While providing due encouragement for those who mine natural resources for daily use, those who focus on preparing humanity for future realities of the use of non-renewable energy in the transportation sector should also receive due encouragement. Recall that this is aimed at creating a mutual understanding and support by all parties, to the extent that everyone will be supportive of adopting technologies that are expected to improve transportation safety for all. A vehicle-mile-travel fee (VMT) system for road usage can help bring various governments to a neutral position on the effort to conserve natural resources for present and future generations, ensure better energy security in different places while increasing efforts in the exploration of more renewable forms of energy for various tasks including transportation.

4.8. Improvement in Road Traffic Safety: Few Examples

Measures to improve road traffic safety have been implemented in various places. While some acknowledgeable improvements have been made, road traffic crashes and fatalities are still a big challenge in many places. Places with low road traffic accidents as currently presented on world health rankings include Micronesia, Sweden, Kiribati, United Kingdom, Netherlands, Switzerland, Denmark, Norway, Spain, Japan, Singapore, Israel, Iceland, etc. [82]. As early as 1997, the Swedish parliament has the plan to eradicate road fatalities and injuries (vision-zero). In 1997, the Swedish parliament adopted the vision-zero policy as a new direction for road traffic safety [83]. The aim of the vision-zero policy is to reach a stage where no one will be seriously injured or killed due to traffic accidents. The design of the road transportation system should be based on these requirements. If we will achieve vision-zero of traffic safety through system design (including vehicle design), it means that in terms of vehicle design, all vehicles must be designed in such a way that the maximum speed that is achievable by the vehicle does not exceed such that will result in serious injury or fatality when there is a traffic crash. This may include ensuring adequate cushioning and using stronger materials that are not expected to exceed a certain level of deformation even if a collision occurs at the maximum speed of the vehicle. The establishment of automatic seat belts that ensures that the vehicle does not move without seat belts for all passengers will help promote the use of seat belts in motor vehicles.

Sweden's roads have achieved a record of the world's safety roads, with three out of every 100,000 people dying on the roads each year [84]. A report about traffic and road conditions in Micronesia indicates that speed limits are very low: in most places, speed limits are 20 miles per hour, and 15 miles per hour when children are present in school zones [85]. Among other things, a report [86] on how South Korea has drastically reduced road deaths indicated that comprehensive policies played a major role in the reduction in children's deaths from road and traffic injuries. Transport safety acts, guidelines, and regulations were thoroughly revised and complemented as need be. Run-red and speeding cameras were installed on roadsides, and there was an improvement in transportation infrastructures such as new pavements, guardrails, and speed controls for various hazardous locations. As tactics to discourage high-risk behaviors and drunk driving, driver's license issuing programs were reviewed. The penalty for violating traffic laws in school zones was more severe than in other areas. Campaigns were held to promote road safety. Road safety also attracted considerable political support. Within a 22-year period, from 1992 (1566 death of kids) to 2014 (53 deaths of kids), South Korea witnessed almost 97% reduction in traffic fatalities for children under 14 years. While the general population witnessed a 59.1% reduction in death from road crashes (a reduction from 11,460 to 4762 deaths from road traffic crashes over the 22-year period).

While there is news about notable achievements in the reduction in traffic crashes with policy improvements in some municipalities, there is still a need to put in more effort to achieve more improvement in road traffic safety in all jurisdictions globally.

- A concerted effort is needed (cooperation between all nations on transportation (road traffic) safety).
- Open sharing of knowledge on what has resulted in positive achievements (improvement) in road safety in various municipalities is needed.
- There is a need to create a sense of global accountability for road traffic safety for people in all jurisdictions.
- There is a need to set a timeline for various nations to come up with adequate legislation, and enforcement of legislation aimed to improve road traffic safety.

The fact that traffic fatality is still a big problem in many parts of the world further corroborates the need to improve reasonable automation systems and ensure adequate legislation that promotes the use of systems that are designed to ensure that human limitations in the driving of vehicles do not lead to negative consequences.

4.9. Pathway to Having a Smooth Transition in Transportation Policy to Reversing Deadly Trends in Road Traffic Safety

For individual jurisdictions who wish to see improvement in traffic safety, the following processes may be followed:

4.9.1. Engaging with the Community

- Create more awareness about the severity of road traffic safety, and the need to take urgent actions.
- Allow the general populace to contribute to the proposal for the improvement of road traffic safety.
- Have a team of experts review the suggestions from the community and rate the suggestions.
- Select the best proposal to improve road traffic safety in your community (lessons learned from other places with great improvement in road traffic safety may be taken into consideration).
- Use established statistics from research, good reasoning, engineering judgment, and adequate logic to defend the selected proposals.

- Ensure that those who are in charge of the decisions are people that are not biased, either in favor of a certain technology over another because of economic or political interests (i.e., allow the safety of people to rise above political or economic interests).

In analyzing safety improvement suggestions from the community, criteria significance (weights) may be assigned to various suggestions based on evidence-based research on the effectiveness of the proposals. While it is a good thing to carry the community along in decisions of safety improvements, this study recommends the use of evidence-based research. Sample trials of various safety improvement suggestions may be evaluated to determine their effectiveness. If the suggestions from people in your community are not expected to improve road traffic safety based on research records, good reasoning, and expert judgment, ensure adequate education and counseling of people in the community on new technologies that are well-tested, and proven to guarantee safety, and use adequate research records as a defense for policy improvements, as described below.

4.9.2. Using Research Records as a Defense for Policy Improvements

One of the traditional approaches to traffic safety is on the change in individual road user behavior [87]. It is known that humans have limitations in driving. Efforts to change human behaviors in driving have not achieved the desired goal to eliminate road traffic fatalities for many years. Meanwhile, technologies already exist to help ensure that human errors while driving do not result in negative consequences. To see the effective implementation of a policy that can bring about good change, the following recommendations may be used in various municipalities:

- Call a meeting with the executives of all car manufacturers in the community.
- Showcase the newest standards of collision avoidance features that can drastically reduce traffic collisions.
- In the presence of all, ask to know if there is any car manufacturing company that is unable to produce vehicles that meet the standards for collision avoidance systems, regardless of the form of energy that is used to power such a vehicle.
- Ensure a good collaboration among the automakers to assist anyone who does not have the technology or facility to meet up with the desired standard.
- Ensure adequate compensation for those who came up with a technology that is beneficial to all and ensure that the technology is available for use by everyone to improve road traffic safety for all.
- Ensure unbiased, and continuous testing of all the desirable technologies under every condition that a driver may see on the roads.
- Make legislation that raises the minimum vehicle standards for all vehicles on the road in that jurisdiction.
- Make legislation that disallows vehicles that do not meet the desired standards from being imported into the country.
- Establish a deadline by which all vehicles on the road in that country or jurisdiction must have the minimum standard that is specified.
- Ensure that adequate centers exist that will check to confirm that all vehicles in each municipality meet the minimum vehicle standards for automatic collision avoidance systems.
- Ensure that the vehicle manufacturers can provide an upgrading service to existing vehicles to have the desirable collision avoidance systems.
- Recommend that all vehicle owners take their vehicles to the car dealership for upgrades to the desirable collision avoidance systems.
- Ensure legislation that mandates everyone in the municipality to either upgrade their vehicles to meet the minimum standard for collision avoidance systems or disallow such vehicles from the community. (A fine may be instituted for violation of the legislation).
- Refuse to renew vehicle license for any vehicle that does not meet the minimum vehicle standard for collision avoidance systems on the road.

- Ensure adequate enforcement, which may include a periodic search of any property that has a vehicle that does not meet up with the minimum standards for collision avoidance systems and disallow such vehicles.

The above strategy may be implemented by various task forces that are appointed by governments of nations that are interested in moving towards vision-zero for traffic collisions, injuries, property damage, and fatalities. It can also be used as a guide by subcommittees of legislative bodies that are appointed by various governments to oversee continuous improvements to vehicle standards. Note that except the fully autonomous vehicles are equipped with systems that are able to recognize environmental conditions in which their operations have not been adequately tested, and the safety of road users is guaranteed, (and also refuse to work in a fully autonomous version in such cases) good professional ethics may not allow the approval of fully autonomous vehicles for use in various communities on a large scale.

While there is news about notable achievements in the reduction in traffic crashes with policy improvements in some municipalities, there is still a need to put in more effort to achieve more improvement in road traffic safety in all jurisdictions globally.

- A concerted effort is needed (cooperation between all nations on improvement to transportation safety).
- Open sharing of knowledge on what has resulted in positive achievements (improvement) in road safety in various municipalities on a constant basis is recommended.
- There is a need to legislate an increase to the minimum safety standard for all motor vehicles on the road.
- There is a need to ensure that all manufacturers of motor vehicles are aware of the increased minimum safety standards for motor vehicles. Enforcement of these increased standards is recommended.
- There is a need to create a sense of global accountability for road traffic safety for people in all jurisdictions. This should be strictly motivated by the intention to improve road traffic safety in all communities globally.
- There is a need to set a timeline for various nations to come up with adequate legislation, and enforcement of legislation aimed to improve road traffic safety.

Some researchers [1] noted that further big successes in improving road traffic safety are only possible through a broad penetration of active safety and driver assistance systems that has great potential to reduce injury risks or fatalities on the roads. Broader penetration of active safety and driver assistance systems can be facilitated by periodic reviews of efficient innovative technologies to improve road traffic safety and subsequent legislation to increase the minimum standards for motor vehicles to reduce the impact of human errors on the road. Given various human limitations (which the present driver training and law enforcement have not been able to eradicate for many years) that affect the driving operation, and the fact that the achievement of zero traffic death is still a challenge in a lot of countries, it is high time for the world to explore the breakthrough idea to turn around from what presently appears to be an unending journey with road traffic fatalities in many places. The need to welcome a reasonable degree of autonomous motor vehicle technologies to ensure that human limitations in the driving of motor vehicles do not lead to negative consequences has been discussed in this report. This report recommends adequate testing of the technologies on a large scale in every community, in an open and unbiased way. This report also recommends that technologies that are found to be efficient in improving traffic safety be made as minimum standards for all motor vehicles on the road. A periodic and consistent review of the status of transportation safety standards and subsequent improvements to the standards is recommended in every community globally. A model for continuous improvement of road traffic safety as in Figure 7 will be beneficial in sharing knowledge about what has helped to improve road traffic safety in some jurisdictions and how others can benefit from it. The idea of vision-zero for road traffic fatalities is one that ought to be consistently pursued by all countries. With a prediction that indicates that the anticipated goals by the European Union as in vision-zero cannot be achieved within a 10-year period from 2015 to 2025, a previous work [88] reported that to achieve vision-zero, there is a need to explore more opportunities. Some other researchers [1] also noted that new technical concepts are needed for vision-zero.

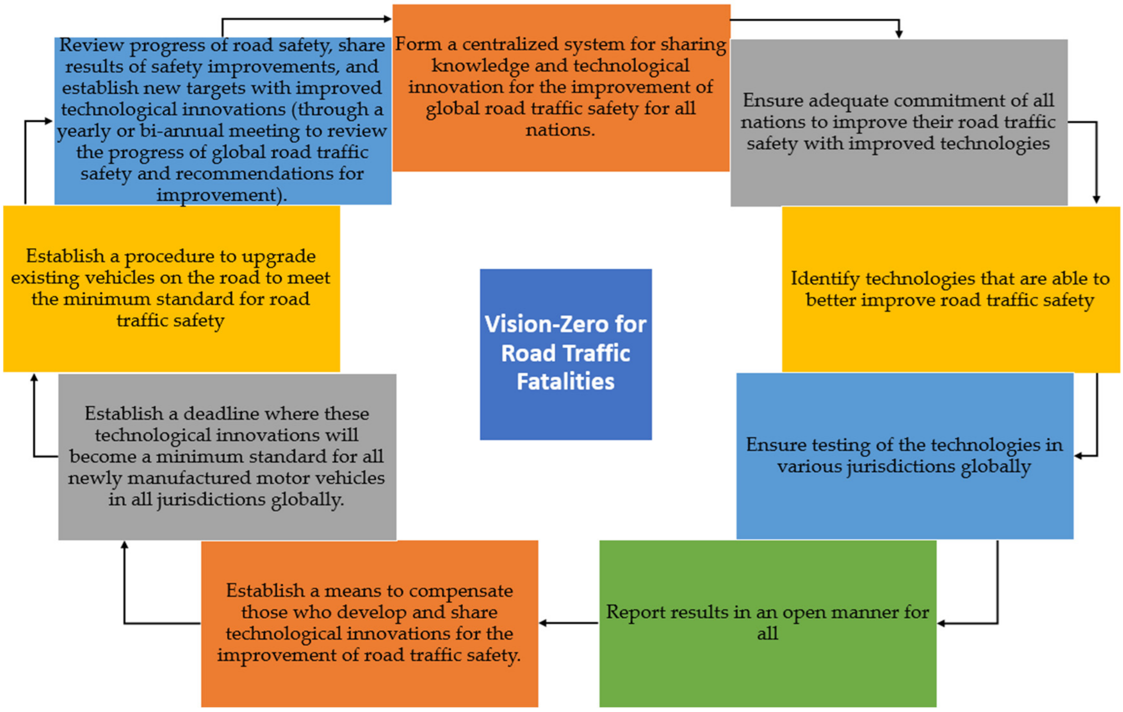

Figure 7. Model for continuous improvement of road traffic safety on a global scale.

4.9.3. Actionable Strategies towards the Achievement of Vison-Zero for Road Traffic Fatalities Globally

- Form a centralized system for sharing knowledge and technological innovation for the improvement of global road traffic safety for all nations.
- Ensure adequate commitment of all nations to improve their road traffic safety with improved technologies.
- Identify technologies that are able to better improve road traffic safety.
- Ensure testing of the technologies in various jurisdictions globally.
- Report results in an open manner for all.
- Establish a means to compensate those who develop and share technological innovations for the improvement of road traffic safety.
- Establish a deadline where these technological innovations will become a minimum standard for all newly manufactured motor vehicles in all jurisdictions globally.
- Establish a procedure to upgrade existing vehicles on the road to meet the minimum standard for road traffic safety.
- Review progress of road safety, share results of road safety improvements, and establish new targets with improved technological innovations (through a yearly or a bi-annual meeting to review the progress of global road traffic safety and recommendations for improvement).

The effort to eradicate road traffic fatalities should not be just a one-time thing in which some standards are legislated, with no action taken to improve on the minimum vehicle standards for many years. Efforts to improve vehicle standards should be an ongoing event until the world is able to achieve a state where there will be no more fatalities on the roads globally. The goal to achieve zero fatalities on the road also extends beyond improving the functionalities of the vehicle to complement human errors in driving. There is a need to attend to issues from all other factors that interact during the driving operation.

On a topic about complete street concepts and ensuring the safety of vulnerable road users, a scholar [89] mentioned various measures to improve road traffic safety for various factors that interact during motor vehicle driving operation (the road, the driver, the car, the environment, etc.). This report recommends a periodic meeting in a minimum of a 2-year interval to review global road traffic safety, examine what improvements in automobile technologies have yielded positive results, and what new improvements need to be implemented, to see better results. These meetings should be followed by new mandates to all car manufacturers to implement the suggested improvements in all automobiles. As there is an effort in improving the technology system for automobiles, it will also be good to see an agreement on a concerted effort to see improvement in the infrastructure systems for developing nations. Recall, good roads are also essential for road traffic safety everywhere.

5. Conclusions and Recommendations

With the trend in road traffic fatalities globally, the world is certainly overdue for an improvement in the minimum standards for vehicles on the road. This study provides a review of some human factors that result in road traffic crashes and recommends ways to achieve a positive turnaround in road traffic safety for various municipalities around the globe. In addition to the evaluation of results of the impact of human factors on road traffic fatalities, findings from previous literature were discussed to emphasize the reality of challenges with human factors in motor vehicle driving operations. This report also includes some recommendations that are hoped to help humanity at large achieve a breakthrough in the effort to reduce road traffic crashes and the associated property damage, injuries, and fatalities. Among other things, the discussion in this study illustrates human challenges with fatigue, sleepiness behind the wheel, distraction while driving, and driving under the influence of drugs and alcohol. From the review of human factors, it is evident that errors associated with human factors present a real challenge to improving transportation safety. This study supports the fact that challenges with human factors in driving operations present a real threat to improvement in road traffic safety. Hence, there is a need for a reasonable degree of automation to complement human efforts in driving operations.

It is known that a mixed opinion exists when it comes to the issue of the implementation of autonomous driving. Meanwhile, if it is known that certain technologies are able to help human drivers improve road traffic safety, it is reasonable that those technologies be given a fair chance for open evaluation and testing in various municipalities. This study defines a reasonable level of automation (to help human drivers reduce the chance of traffic crash) as the use of automatic technologies that has been adequately tested (in an open and unbiased way) in all weather conditions (including hazardous weather conditions, such as severe winter (extreme cold and snow), rain, fog, etc., and the safety capabilities have been verified to ensure the safety of people in their daily commute. A good reference on a research guide for using the efficiency of technological innovations in automobiles to establish unbiased policies for the improvement of minimum safety standards for driver-operated motor vehicles has been mentioned in the study. After a fair and unbiased evaluation of reasonable autonomous motor vehicle technologies, this study recommends a consensus effort to improve the minimum standards of motor vehicles in every jurisdiction to include innovative autonomous technologies that are found to be efficient. To ensure that everyone is carried along in the effort to improve traffic safety, the report provides a proposal to engage with the community, ensure public education, and use evidence-based research in making decisions to improve road traffic safety. A centralized system that is geared towards sharing knowledge of best practices for road safety improvements among all nations is recommended. Recognizing that the energy that supports transportation systems is a factor that may affect its acceptance, this study recommends that efforts be made to ensure that the presumed economic impact of certain technologies does not obstruct the effort to improve road traffic safety.

While there is news about notable achievements of reduction in traffic crashes with policy improvements in some municipalities, there is still a need to put in more effort to achieve more improvement in road traffic safety in all jurisdictions globally. This report noted that:

- A concerted effort is needed (cooperation between all nations on transportation (road traffic) safety).
- Open sharing of knowledge on what has resulted in positive achievements (improvement) in road safety in various municipalities will be beneficial.
- There is a need to legislate an increase to the minimum safety standard for all motor vehicles on the road. This should be a continuous effort until zero fatality is achieved on the roads globally.
- There is a need to create a sense of global accountability for road traffic safety for people in all jurisdictions. This should be strictly motivated by the intention to improve road traffic safety in all communities globally.
- There is a need to set a timeline for various nations to come up with adequate legislation, and enforcement of legislation that is aimed at improving road traffic safety.

The fact that traffic fatalities are still a big challenge in many parts of the world further corroborates the need to improve automation systems and ensure legislation that promotes the use of systems that are designed to ensure that human limitations in the driving of motor vehicles do not lead to negative consequences. After adequate testing of the innovative autonomous technologies that are aimed at improving road traffic safety, on a large scale in every community, this report supports the notion that technologies that are found to be efficient in improving road traffic safety be mandated as minimum standards for all motor vehicles on the road in all municipalities. The proposal presented to engage with the community in the effort to improve road traffic safety and to 'use research records as a defense for policy improvement' may be transferred to a world standard for managing road traffic safety. A periodic and consistent review of the status of transportation safety standards and subsequent improvements to the standards is recommended in every community globally.

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