Journal of the Society of Automotive Engineers Malaysia
Volume 5, Issue 2, pp 235-243, May 2021
e-ISSN 2550-2239 & ISSN 2600-8092

The Development of an Automated Vehicle Simulator for On-Road Study

J. Karjanto*[1,2], N. Md Yusof[1,2], M. S. I. Azmi[1], M. Z. Hassan[2,3], A. F. H. Zulkifli[4], M. I. S. M. Nazar[4], A. A. Ab Rashid[5], Z. Mohd Jawi[5] and K. A. Abu Kassim[5]

[1]Faculty of Mechanical Engineering, Universiti Teknikal Malaysia Melaka (UTeM), Hang Tuah Jaya, 76100 Durian Tunggal, Melaka, Malaysia
[2]Centre for Advanced Research on Energy, Universiti Teknikal Malaysia Melaka (UTeM), Hang Tuah Jaya, 76100 Durian Tunggal, Melaka, Malaysia
[3]Faculty of Mechanical and Manufacturing Engineering Technology, Universiti Teknikal Malaysia Melaka (UTeM), Hang Tuah Jaya, 76100 Durian Tunggal, Melaka, Malaysia
[4]Synergies Technology Group, Advanced Technology Centre (ATC), Faculty of Engineering Technology, Universiti Tun Hussein Onn Malaysia (UTHM), 84600 Pagoh, Johor
[5]Malaysian Institute of Road Safety Research (MIROS), 43000 Kajang, Selangor, Malaysia

*Corresponding author: *juffrizal@utem.edu.my*

REVIEW **Open Access**

Article History:

Received
25 Aug 2020

Accepted
1 Feb 2021

Available online
1 May 2021

Abstract – *In the current development of Automated Vehicle (AV) technology, one of the challenges yet to be resolved is when the AV is driving in urban environments. There will be mixed traffic scenarios where the AV and Vulnerable Road Users (VRU) such as pedestrians, cyclists, and motorcyclists, will share the road infrastructures. In this study, an AV simulator is developed and will be used to study the interaction between an AV and motorcyclist when they encounter a specific situation on the real roads. The study begins with developing a test vehicle based on the three main systems: the vehicle's interior, outer appearance, and behavior. The vehicle's interior comprises four subsystems: data acquisition, sensor, monitoring, and power management system. The outer appearance system has a look-alike LiDAR system, while the driving style sub-system monitors the behavior system. Future improvement will include developing ghost drivers to be implemented together with this system to enhance this on-road simulator's saliency.*

Keywords: Automated vehicle, on-road simulator, Vulnerable Road User (VRU)

Journal homepage: www.jsaem.saemalaysia.org.my

1.0 INTRODUCTION

The rapid development of automated vehicles, also known as self-driving or autonomous cars, is underway. There are some urgencies for the transportation engineering profession to become actively engaged in dialogues and partnerships with various stakeholders, including software and systems developers, auto manufacturers, and regulatory bodies (Lutin et al., 2013). Hence, automated vehicle fieldwork is at the cusp of the transition from academic discovery to commercial goods. Google and Uber have tested their test vehicles on public roads, accumulating millions of miles of safe operation for several years (Mahadevan et al., 2018). The advantages of automated vehicles are well stated: they provide the ability to save precious driving time, provide a significantly safer passenger experience, and are available to people who cannot drive (Löcken et al., 2016). Incorporating automated vehicles into the surface transport network could improve traffic safety and reduce traffic congestion and the adverse effects on the environment (Bhavsar et al., 2017).

While the continuous development of computing, sensing, and communication technologies will enhance automated vehicles' performance, the technologies may pose new challenges. For example, the interaction with other non-automated vehicles is one of the aspects that must be addressed before its implementation on the road (Bhavsar et al., 2017). The replacement of human drivers with automated control systems comes at the price of creating a void for social interaction. In addition to being a complex control activity, driving is a social phenomenon that involves communication between all road users involved to guarantee a better traffic flow and other road users (Rasouli et al., 2018). Automated vehicles face another dilemma in driving in complex scenes, such as urban environments, namely interacting with a pedestrian (Maurer et al., 2016). The interaction also ensures road users' safety, especially for pedestrians, cyclists, and motorcyclists. The new regional road health evaluation by the World Health Organization (WHO) reported that half of the 1.2 million deaths that occur per year on the world's roads concern by vulnerable road users (motorcycles, pedestrians, and cyclists) those most at risk in traffic (Constant, 2010). Pedestrians, who are the most vulnerable within the traffic hierarchy, often establish eye contact with drivers or wait for the drivers to give a clear signal to make sure they are noticed, and then executing crossing the road (Gough, 2016). Additional risks can still occur, for example, as vulnerable road users like the cyclists may not (yet) have accurate perceptions of automated vehicles' behavior and may react differently and inadequately to them (Hagenzieker et al., 2020).

There is not much research done for motorcyclists compared to pedestrians and cyclists in automated vehicles' research. Motorcyclists are the primary traffic users in South East Asia (Kitamura et al., 2018). Therefore, there is a need to study the effects of automated vehicle implementation on motorcyclists. Many motorcycle enthusiasts are justifiably concerned about the technology of automated vehicles. They wonder if the government will push to remove the human element entirely from the roads so the improved automated vehicles could serve as a precursor to an outright ban on public road motorcycles (Stock, 2016).

It is necessary to consider the variables that affect the interaction, especially the decision-making process, to understand what decisions are taken when a motorcyclist meets the automated vehicle. That is, the conditions that affect the mechanism can affect the outcomes (Dietrich, 2010). According to Dietrich (2010), one of the factors influencing decision-making is personal relevance or trust. Besides, the study done by Yusof et al. (2016) stated that a personal driving style also could be one of the factors that influence decision making. This exploration was done in a real-road context with an equipped car. An experimenter or a designated driver was used to stimulating an automated driving approach with a normal car instead of using an automated vehicle. Concerning appearance, it is a factor that can influence someone towards automated vehicles (Dey et al., 2017). Perception of the vehicle's sociability and power is also a significant role that vehicle appearance (Windhager et al., 2008).

External appearance is also one factor that can cause misunderstandings between vulnerable road users and automated vehicles. When vulnerable road users try to cross at the unsignalized junction, they have to determine whether to cross in front of the oncoming vehicle or wait until it has passed by (Dey et al., 2017). It can be presumed that their decision is affected by many factors: user-related factors such as agility, assertiveness, and likely context (being in a hurry or not, and position on the road) and vehicle-related factors, including behavioral (distance, speed, and acceleration) and appearance. Concerning appearance, characteristics such as size, color, design, and brand may influence people's expectations about whether or not the vehicle is likely to give the right of way (Dey et al., 2017).

A vehicle's appearance plays an essential role in the perception of the vehicle's sociability. It can influence the vehicle's perceived hostility or assertiveness or, opposite, its cuteness or friendliness (Windhager et al., 2008). A vehicle's presence also lends itself to assumptions about the kind of people who own it and their driving actions (Davies, 2009; Davies & Patel, 2005). For example, Volvo chose its first automated test vehicles to look unobtrusive and, like any other ordinary vehicle, to answer other road users' concerns invoking violent or bullying behavior (Connor, 2016). The well-known Google automated vehicle, by comparison, was deliberately built to look adorable to help pedestrians see it as a solid object, as well as to give the illusion that it is not a high-speed vehicle (D'Onfro, 2014; Korosec, 2016).

Therefore, the interaction between an automated vehicle and motorcyclists needs to be investigated, especially in the region where motorcycles are used as the main means of transportation. Early understanding of how a motorcyclist interacts and behaves when encounter an automated vehicle on circumstances where negotiation needs to be initiated, for example, at unsignalized junction, needs to be further investigated. To achieve that, an instrumented vehicle that mimics an automated vehicle is developed to study the critical factors that influence the communication between an automated vehicle and a motorcyclist. In this paper, the Automated Vehicle Simulator development, an instrumented car that imitates an automated vehicle and driving on the real road, was developed. Several essential setups such as the vehicle's interior, the outer appearance, and the behavior will be presented and discussed.

2.0 OVERVIEW OF AUTOMATED VEHICLE SIMULATOR

The development of the Automated Vehicle Simulator was particularly inspired by the previous works (Baltodano et al., 2015; Karjanto et al., 2018; Rothenbucher et al., 2016; Sukardi et al., 2014). In their works, an instrumented vehicle was used to represent the automated vehicle to study the interaction between an automated vehicle and other road users. In this study, the Automated Vehicle Simulator system architecture can be grouped into three main elements: interior, external appearance, and behavior (see Figure 1). The interior system consists of four sub-systems that are data acquisition (DAQ) system, sensor system, monitoring system, and power management system (PMS). The DAQ is responsible for collecting and synchronizing all the data from the sensor system. In the sensor system's current setup, a tri-axial accelerometer is used to collect the vehicle's acceleration data. The monitoring system is implemented to capture all the events that are happening inside the vehicle. The data acquisition (DAQ) system, sensor system, and monitoring system are power-up using the Power Management System (PMS). The external appearance system consists of a look-alike Light Detecting and Ranging (LiDAR) system. This system is built to convince the Automated Vehicle Simulator people that this vehicle is fully automated. LIDAR is heavily associated with a fully automated vehicle shown on the Uber's and Google's version of the vehicle as seen on the mass and social media. The third system is the behavior system in which its purpose is to control the driving style of the Automated Vehicle Simulator. Using the driving style system, the way this vehicle is driven is controlled by assisting the designated driver in driving the Automated Vehicle Simulator according to the defined acceleration condition. The placement of the Automated Vehicle Simulator's architecture's main and sub-system is shown in Figure 2.

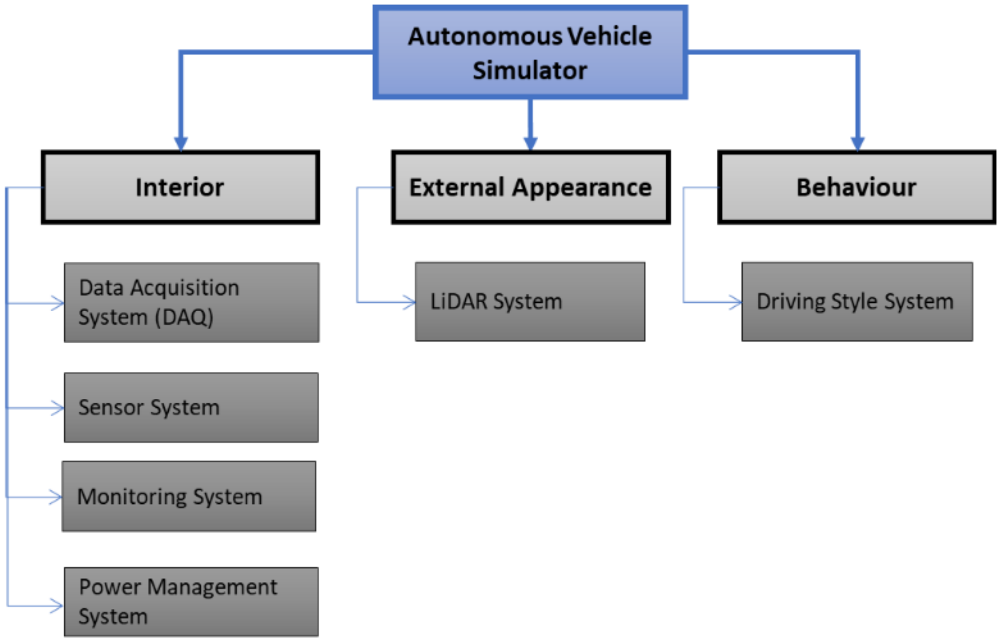

Figure 1: Architecture system of the Automated Vehicle Simulator

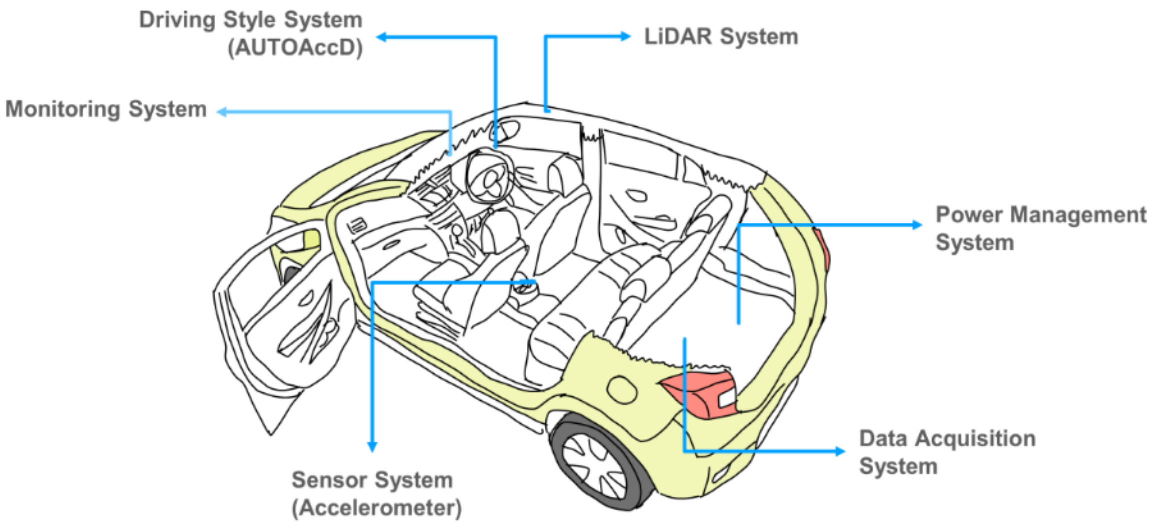

Figure 2: Placement of the main and sub-system at the Automated Vehicle Simulator

3.0 RESULTS AND DISCUSSION

3.1 Interior

The relation between the four sub-systems in the interior is shown in Figure 3. Synchronizing readings from all sensors and measuring instruments is a significant feature within the planned studies framework. For subsequent review, all data should have a precise timestamp with automated data logging. In this research, the National Instrument compactRIO-9030 (NI cRIO 9030) was introduced as the DAQ due to its ability to run real-time (RT) processor re-configurable field-programmable gate array (FPGA) programs. Besides, the NI cRIO 9030 is a powerful industrial-grade controller that can withstand and is ideal for an instrumented vehicle under real road conditions. The DAQ consists of NI 9205, a module with an inspecting rate of 250 kS/s. The sensor system consists of the accelerometer, ADXL335, which is a low force 3-axis accelerometer. The accelerometer was connected to near the middle console of the instrumented vehicle. ADXL335 has been utilized in multiple fields of examination, for example, detecting humans (Hollocher et al., 2009).

The monitoring system inside the Automated Vehicle Simulator comprises a high-definition web camera (c920; Logitech, 2018). The usage of this camera is to record all the activities inside or outside the vehicle. The driving style system will be explained further under the "Behavior" section. All the equipment that needs to be powered up electrically is done using a "Power Management System" or PMS (see Figure 4) and is particularly inspired by the work of Sukardi et al. (2014). In terms of power supply, the future planned studies are on the real road. Therefore, the Automated Vehicle Simulator requires to have two different energy sources. One is to power the vehicle's system (primary battery), and the other (secondary battery) is to power the equipment inside the vehicle, ranging from the DAQ, sensor, camera, to computer. A microprocessor automatically controls the battery separator. When the Automated Vehicle Simulator's engine is switched on, the battery separator enables the parallel charging of both primary and secondary batteries.

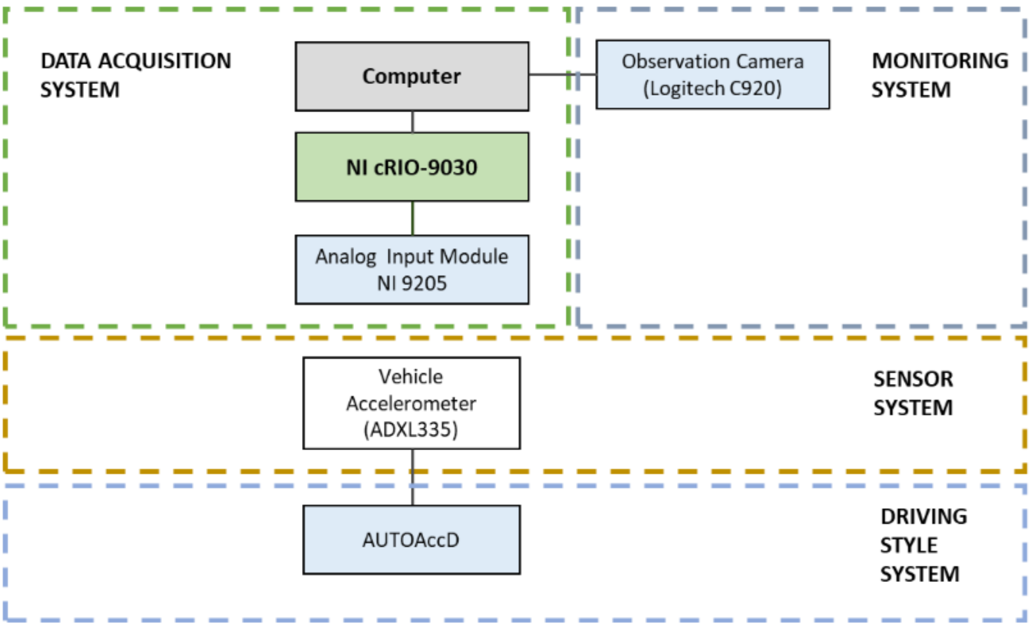

Figure 3: Relation between the four sub-systems inside the Automated Vehicle Simulator

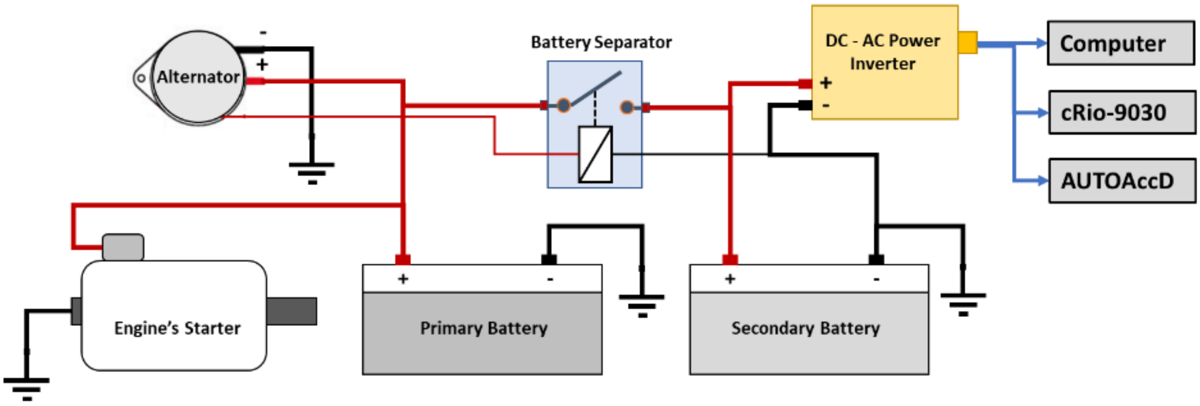

Figure 4: Power Management System inside the Automated Vehicle Simulator

3.2 External Appearance

For the Automated Vehicle Simulator's external appearance, a look-alike Light Detecting and Ranging (LiDAR) was developed to replicate a typical presentation of a fully automated vehicle. In a real automated vehicle, a LiDAR is a device that rotates 360 degrees to scan and record the surrounding entities. The design of the look-alike LiDAR was done using the computer-aided design (CAD) program of AutoDesk SolidWorks 2016 (see Figure 5). The look-alike LiDAR consists of a few parts that will later be printed using the Fused Deposition Modelling technique. Besides, a mechanism consisting of high speed and low torque 12 volts-motor, and a potentiometer will rotate the look-alike LiDAR to enhance its saliency.

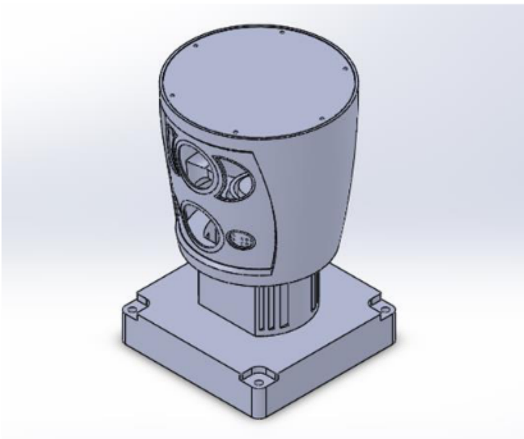

Figure 5: CAD rendering of the look-alike LiDAR

3.3 Behavior

The same accelerometer used to measure the vehicle's acceleration is used to connect to the Automatic Acceleration and Data controller (AUTOAccD), shown in Figure 6. AUTOAccD has been developed by Karjanto et al. (2017) to guide the designated driver or experimenter to accomplish selected accelerations and act as instrumented processors to measure and display the vehicle dynamics data. AUTOAccD allows for the maximization of driving consistency, which needs to be produced by the designated driver or experimenter.

Using the AUTOAccD, which is placed on the top right side of the inside windshield, a driving style can be consistently controlled as different driving styles will provide higher dispersion in the horizontal accelerations, as found in a study done by eight drivers in the same car (Griffin & Newman, 2004). Based on the earlier study by Yusof et al. (2016), regardless of the driving styles a person has, one is more likely to accept the more defensive automated driving style in a fully automated driving/riding experience. A similar study was done by Basu et al. (2017) using a car simulator also found a comparable result. For the driving style of the Automated Vehicle Simulator, the "defensive automated driving style" settings were implemented based on Karjanto et al. (2017), on which the lateral acceleration was aimed to be at around 0.29 g or 2.84 ms^{-2}. Besides, the designated driver or the experimenter needs to drive the Automated Vehicle Simulator with a constant rate of acceleration and deceleration, and without jerking to mimic a driving style of a real fully automated vehicle (Baltodano et al., 2015).

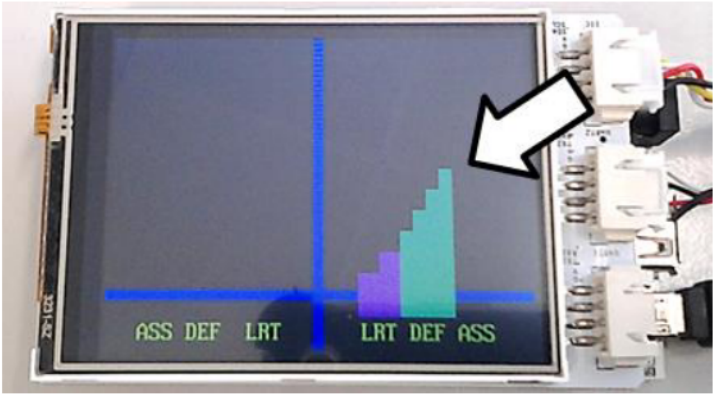

Figure 6: AUTOAccD's view indicating the defensive automated driving style

4.0 CONCLUSION AND FUTURE WORKS

In this paper, we present the development of the Automated Vehicle Simulator. This instrumented test vehicle was developed to study the communication between an automated vehicle and vulnerable road users, especially motorcyclists. The development of the Automated Vehicle Simulator focuses on three main systems: the vehicle's interior, the outer appearance, and the vehicle's behavior.

For future works, the "Ghost Driver" method developed by Rothenbucher et al. (2016) to study the communication between an AV and pedestrians in the USA and later implemented by Dey et al. (2017) in the Netherlands will be adapted to be used with the Automated Vehicle Simulator. This method involves concealing a human driver behind a specially fabricated seat to create an illusion that the Automated Vehicle Simulator is driven by itself.

ACKNOWLEDGEMENTS

The authors fully acknowledged Universiti Teknikal Malaysia Melaka (UTeM) and ASEAN NCAP for the approved fund that makes this important research viable and effective (No. ANTARABANGSA-ANCHOR/2020/FKM-CARE/A00030). This research is fully supported by an international grant ASEAN NCAP III entitled "Naturalistic and observational study on communication in mixed traffic scenarios: Autonomous vehicle vs. motorcyclist" (No. A3-C392).

REFERENCES

Baltodano, S., Sibi, S., Martelaro, N., Gowda, N., & Ju, W. (2015). The RRADS platform. Proc. of the 7th Intl. Conf. on Automotive User Interfaces and Interactive Vehicular Applications – AutomotiveUI 15, 281–288.

Basu, C., Yang, Q., Hungerman, D., Singhal, M., & Dragan, A. D. (2017). Do you want your autonomous car to drive like you? Human-Robot Interaction 17, 417–425.

Bhavsar, P., Das, P., Paugh, M., Dey, K., & Chowdhury, M. (2017). Risk analysis of autonomous vehicles in mixed traffic streams. Transportation Research Record, 2625, 51–61.

Connor, S. (2016). First self-driving cars will be unmarked so that other drivers don't try to bully them: Volvo fears that other road users could drive erratically in order to take advantage. The Guardian. Retrieved from https://www.theguardian.com/technology/2016/oct/30/volvo-self-driving-car-autonomous

Constant, A. (2010). Protecting vulnerable road users from injury. PLoS Medicine, 7(3), 1–4.

D'Onfro, J. (2014). Why Google made its self-driving car look so cute. Retrieved from www.businessinsider.com/google-self-driving-car-why-its-so-cute-2014-12

Davies, G. M. (2009). Estimating the speed of vehicles: the influence of stereotypes. Psychology, Crime & Law, 15(4), 293-312.

Davies, G. M., & Patel, D. (2005). The influence of car and driver stereotypes on attributions of vehicle speed, position on the road and culpability in a road accident scenario. Legal and Criminological Psychology, 10(1), 45-62.

Dey, D., Martens, M., Eggen, B., & Terken, J. (2017). The impact of vehicle appearance and vehicle behavior on pedestrian interaction with autonomous vehicles. AutomotiveUI 2017 - 9th Intl. ACM Conf. on Automotive User Interfaces & Interactive Vehicular Applications, Adjunct Proceedings, 158–162.

Dietrich, B. C. (2010). Decision making: Factors that influence decision making, heuristics used, and decision outcomes. Inquiries Journal, 2(02).

Gough, M. (2016). Machine smarts: how will pedestrians negotiate with driverless cars? Guardian Sustainable Business, The Guardian.

Griffin, M., & Newman, M. (2004). An experimental study of low-frequency motion in cars. Proc. of the Institution of Mechanical Engineers, Part D: Journal of Automobile Engineering, 218(11), 1231–1238.

Hagenzieker, M. P., van der Kint, S., Vissers, L., van Schagen, I. N. L. G., de Bruin, J., van Gent, P., & Commandeur, J. J. F. (2020). Interactions between cyclists and automated vehicles: Results of a photo experiment. Journal of Transportation Safety and Security, 12(1), 94–115.

Hollocher, D., Zhang, X., Sparks, A., Bart, S., Sawyer, W., Narayanasamy, P., … Yang, K. (2009). A very low cost, 3-axis, MEMS accelerometer for consumer applications. Proceedings of IEEE Sensors, 953–957.

Karjanto, J., Md. Yusof, N., Terken, J., Delbressine, F., Hassan, M. Z., & Rauterberg, M. (2017). Simulating autonomous driving styles: Accelerations for three road profiles. MATEC Web of Conferences, 90, 01005.

Karjanto, J., Yusof, N. M., Terken, J., Delbressine, F., Rauterberg, M., & Hassan, M. Z. (2018). Development of on-road automated vehicle simulator for motion sickness studies. International Journal of Driving Science, 1(1), 1–12.

Kitamura, Y., Hayashi, M., & Yagi, E. (2018). Traffic problems in Southeast Asia featuring the case of Cambodia's traffic accidents involving motorcycles. IATSS Research, 42(4), 163–170.

Korosec, K. (2016). How to design a car when you're not a car designer. Retrieved from https://fortune.com/2016/10/12/google-yoojung-ahn-car-designer/

Löcken, A., Heuten, W., & Boll, S. (2016). Autoambicar: Using ambient light to inform drivers about intentions of their automated cars. AutomotiveUI 2016 - 8th Intl. Conf. on Automotive User Interfaces and Interactive Vehicular Applications, Adjunct Proceedings, 57–62.

Logitech (2018). Logitech HD Pro Webcam c920. Retrieved from http://support.logitech.com

Lutin, J. M., Kornhauser, A. L., & Masce, E. L. L. (2013). The revolutionary development of self-driving vehicles and implications for the transportation engineering profession. Institute of Transportation Engineers. ITE Journal, 83(7), 28.

Mahadevan, K., Somanath, S., & Sharlin, E. (2018). Communicating awareness and intent in autonomous vehicle-pedestrian interaction. Conference on Human Factors in Computing Systems – Proceedings, 2018-April, 1–12.

Maurer, M., Gerdes, J. C., Lenz, B., & Winner, H. (2016). The interaction between humans and autonomous agent. Autonomous Driving: Technical, Legal and Social Aspects, 1–706.

Rasouli, A., Kotseruba, I., & Tsotsos, J. K. (2018). Understanding pedestrian behavior in complex traffic scenes. IEEE Transactions on Intelligent Vehicles, 3(1), 61–70.

Rothenbucher, D., Li, J., Sirkin, D., Mok, B., & Ju, W. (2016). Ghost driver: A field study investigating the interaction between pedestrians and driverless vehicles. 25th IEEE International Symposium on Robot and Human Interactive Communication, RO-MAN 2016, 795–802.

Stock, K. (2016). Self-driving cars will improve motorcycle safety. Retrieved from https://www.detroitnews.com/story/business/autos/2016/10/11/self-driving-cars-motorcycle-safety/91910968/

Sukardi, A., Ibrahim, M. K. A., & Ariffin, M. Q. M. (2014). Enhancement of instrumented car design for driver behaviour research. Journal of Asian Scientific Research, 4(7), 314–319.

Windhager, S., Slice, D. E., Schaefer, K., Oberzaucher, E., Thorstensen, T., & Grammer, K. (2008). Face to face. Human Nature, 19(4), 331-346.

Yusof, N. M., Karjanto, J., Terken, J., Delbressine, F., Hassan, M. Z., & Rauterberg, M. (2016). The exploration of autonomous vehicle driving styles. Proc. of the 8th Intl. Conf. on Automotive User Interfaces and Interactive Vehicular Applications - AutomotiveUI 16, 245–252.