3rd International Conference on Engineering and ICT (ICEI2012)
Melaka, Malaysia
4 – 5 April 2012

BUS ACCIDENTS PREVENTION WITH AN INTEGRATED STEERING SYSTEM

V.K. Kher[1], Chee Fai Tan[1,a*] and Ranjit Singh Al Sarban Singh[2]

[1] Universiti Teknikal Malaysia Melaka/Fac. of Mechanical Engineering, Melaka, Malaysia.
[a]Email: cheefai@utem.edu.my
[2]Universiti Teknikal Malaysia Melaka/Fac. of Electronic and Computer Engineering, Melaka, Malaysia.

***Abstract*— This paper is focused on improving the drivability of busses for preventing accidents. Bus accidents are not as frequent as car accidents but each bus accidents puts at least forty human lives in risk which is equivalent to eight saloon cars with the maximum allowable passengers. While there are many parts of the busses which can be looked into for improving the safety this paper is focusing on the steering systems. Nowadays, many automobile manufacturers have integrated safety systems into the steering systems for saloon cars and the results shown are positive. They are proven to be effective as the manufacturers have successfully commercialised their technologies. Similarly, a framework will be developed to implement steering system integrated with safety systems for busses. The suggested framework will be focused on overcoming a specific emergency scenario which bus drivers will encounter most commonly.**

***Keywords*—**Power steering system; Safety systems; Bus accidents; Accidents prevention.

N. INTRODUCTION

Road safety has been an issue for both the government and public due to the implications that can arise shall there be any road accidents regardless of a minor or major accident. Therefore, the automobile industry has put in extensive research on enhancing the safety of vehicles because human beings often overestimated their driving skills and resulted in fatality [1]. An overview of safety systems implemented into cars would divide safety systems into two categories which are the *active safety systems* and *passive safety systems*. Basically active safety systems are more sophisticated safety systems like Anti Locking Brake System (ABS), Electronic Stability Control (ESC), Overtaking and Lane Changing Assistance and Road Departure Prevention which will react accordingly when the systems sense irregular car and driving behaviours [2]. Passive safety systems on the other hand are safety systems like safety belts, airbags and reinforced car structures which do not react like active safety systems but protect the passengers in the event of an accident [3]. Rapid advancement in technologies allows various parts of a car to be integrated with safety systems and in this paper discussions will be focussed on proposing a framework on integrating safety systems into busses' steering systems for accidents prevention.

A. *Evolvement of power steering systems*

Conventionally, vehicles are using power steering systems which operate with the assistance of a hydraulic pump. In fact, hydraulic power steering systems dated back to as early as the late 1870s but it was significantly looked into until the American automobile manufacturer, Cadillac started to commercialized the hydraulic power steering system during the late 1950s [4]. Hydraulic power steering system has been widely used until recent years where the Electric Power Steering System (EPS) has started to replace the hydraulic power steering gradually. The popularity of EPS is based on a few advantages over the hydraulic power steering and one of the most obvious advantage is the contribution of EPS towards a more efficient engine. This can be explained by the absence of a hydraulic pump which steals as much as 5 horsepower from the engine according to research[5]. The task of a hydraulic pump is being replaced with an electric motor which operates independently without the attachment to the engine anymore.

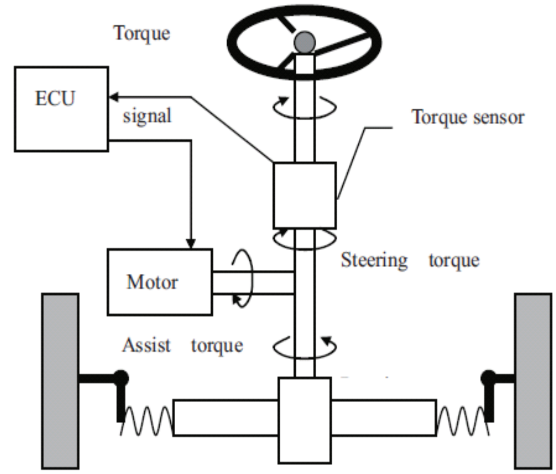

Figure 1. Electric power steering (EPS) schematic (photo reprinted from [18])

B. *Safety Systems Integrated into Saloon Cars' Steering System*

Safety systems have been integrated into the steering systems of saloon cars by many automobile manufacturers in the recent years BMW for instance has an active steering which is linked to its Dynamic Stability Control (DSC) [6]. Similarly, Audi also has its Dynamic Steering combined with the Electronic Stability Program (ESP) [7]. Peugeot also introduced its version which is called the Steering Stability Program (SSP). SSP is also coupled with the ESP because of the need for ESP to detect instability and activating the SSP [8]. Lexus has a Lane Keeping Assist (LKA) which is comprised of two functions. When lane departure is detected warnings in the form of audio-visual are emitted followed by steering wheel correction by the system [9]. Honda introduced its

Motion Adaptive Electric Power Steering in 2008 which detects instability during cornering and braking situations especially in slippery conditions. All these feedback will prompt the system to input corrective steering actions to assist the driver in handling the car [10]. Meanwhile, Toyota also has its Lane Departure Warning (LDW) where warnings are firstly provided by a buzzer and warning lamp before corrective steering force is being applied to the steering wheel [11].

II. Safety issues associated with busses

According to the statistics by Ministry of Works Malaysia in Table 1, busses have the least casualties compared to other more common forms of transportation [12]. Nevertheless, we should take note that each bus accident involves at least forty human lives. A simple comparison would means that the risk carried by each bus accident is equivalent to the risk of five saloon cars with five passengers each.

Table 1. Casualties according to types of transport [8]

Type	Casualties	Percentage (%)
Pedestrian	3, 523	7.49
Motorcycle	31, 222	66.41
Bicycle	1, 679	3.57
Car	7, 372	15.68
Van	824	1.75
Bus	*359*	*0.76*
Lorry	1, 032	2.20
4 Wheel Drive	585	1.24
Other	416	0.88
Total	47, 012	100

Furthermore, statistics in Table 2 have also shown that accidents that occured on straight roads and bends had recorded the highest percentage among all types of road being looked into.

Table 2. Amount of accidents according to road type [8]

Road Type	Fatal	Serious	Total	% age
Straight	*3,690*	*4,148*	*7,838*	*63.10*
Bend	*894*	*829*	*1,723*	*13.87*
Roundabout	23	28	51	0.41
Cross Junction	215	457	672	5.41
T/Y Junction	576	1,424	2,000	16.10
Staggered Junction	36	78	114	0.92
Interchanges	12	11	23	0.19
Total	5,446	6,975	12,421	100

The data from Table 1 and Table 2 can be further linked to bus accidents in Malaysia with the sources obtained from local newspapers [13-16]. Although the fatalities for each of the bus accidents presented in Table 3 did not reach the amount of forty but they are sufficient to prove that the consequences from each bus accidents that occurred are very serious because the fatalities are more than the passengers inside one saloon car. Moreover, road accidents are considered serious even if there is one fatality. Thus, there is a need for developing safety systems to prevent bus accidents because the statistics recorded by the Ministry of Works Malaysia and local newspapers have clearly shown that the bus accidents scenarios need serious attention and the appropriate steps to taken to curb the problems.

Table 3. Recent bus crashes in Malaysia [13-16]

Case	Casualties	How It Occurred
Bukit Gantang Bus Crash (2007)	> 20	Hit the guardrail before crashing
Perak bus Crash (2009)	10	Hit a road divider
Cameron Highlands Bus Crash (2010)	27	Negotiate a sharp bend but failed, hit a divider and overturned
Negeri Sembilan-Malacca Border Bus Crash (2010)	12	Crashed through a guardrail

A. *Common driving problems faced by bus drivers*

One of the major difference between busses and saloon cars is the size and layout of both vehicles. Busses are longer, taller and heavier compared to saloon cars. Thus, the center of gravity of busses is much higher and this would actually means that the handling characteristics of a bus is very much different from saloon cars because of the instability caused by higher center of gravity [17]. Logically, busses cannot be driven as fast as saloon cars and manoeuvring bends at similar speeds with saloon cars because the risk of losing control of the busses is very high.

Furthermore, the length of busses may cause bus drivers having limited visibility on their surroundings especially the rear and side of the busses. This would lead the bus drivers to drive in a "*self-predicting*" situation most of the time because they have to react according to their own judgement. Meanwhile, it has been proven that driver errors do exist and research has shown that drivers takes up to 0.5 seconds to interpret the emergency situation they are facing before they can react [17]. The duration of 0.5 seconds should not be underestimated because accidents do not need a few minutes to take place.

Combination of both the length and weight factors of busses, a large yaw-moment of inertia is created and this will lead to poor yaw response [17]. As a comparison to saloon cars, busses will not respond quick enough to a steering correction if the initial steering action is not producing positive feedback in the event of an emergency. To counter this problem, bus drivers will actually need to have more rapid response compared to saloon car drivers. [17].

The yaw dynamics of busses are constantly changing due to the difference in mass, axle-weight distribution and moment of inertia everyday because the number of passengers being carried is not a fixed figure. The tasks of bus drivers will eventually become more hectic if they were to adapt to these changes daily [17]. Moreover, the working environment of bus drivers is closely associated with fatigue. It is known that fatigue will cause the bus drivers being not able to drive the bus in a safe manner and in the worst case losing control of the bus [17]. The discussions in this section is sufficient to justify the importance of developing saety systems to assist bus drivers adaptively during an emergency situation because it has been reported that driver assistance systems can reduce as much as 40% of road accidents [17].

III. FRAMEWORK TO DEVELOP STEERING SYSTEM INTEGRATED WITH SAFETY SYSTEMS FOR BUSSES

The discussions in previous sections have triggered the importance of developing safety systems for busses. While they are a vast amount of safety systems that can be developed, this paper will be focussed on developing a steering system integrated with safety system.

As seen in Fig. 2. a framework for an integrated steering system is presented. Initially, a driver's input is needed to trigger the entire system. A driver's input specifically means the steering angle. For instance, driving on a straight road does not require large steering angle. On the contrary, manoeuvring a bend requires larger steering angle. Due to some factors such as bus drivers being in a state of fatigue may cause the bus drivers performing irregular driving behaviour by inputting an inappopriate steering angle which the system interpret as potential to cause accidents.

Before the system interprets such signals, sensors act as the intermediating devices that bring the signals from the driver's input to the control module. The primary objectives of the sensors are to sense the line the bus should be taking and also any obstcales that are ahead or beside the busses. After gathering all these data the sensors will send the signals to the control module for the required interpretations and calculations to be done.

The control module's task is a crucial part of the system because the control module will be making decisions on whether to aware the bus driver or not to. These decisions are important because it is dangerous if a false alarm is being triggered and the awareness provided will actually interfere with the bus driving dangerously. Thus, the control module has to be developed smart enough to interpret the signals accurately. This system has high potential to curb bus accidents but meanwhile thorough considerations have to be taken before developing the control module or else this system will be harzardous to be implemented into busses.

Next, the decisions made will be sent to activate the actuator to provide awareness to the bus driver. This task once again has some considerations that are worth to be taken of. This is because the actuator is directly linked to the awareness alert system. Therefore, the behaviour of the actuator has to be tuned to aware the bus drivers adaptively instead of providing false alarm to them. If false alarm is provided, it will cause suprise and confusion to the bus drivers because the bus drivers would think that there are some mechanical failures which trigger the system since the bus drivers are actually driving in an appropriate manner. So these suprises and confusions if not being handled correctly will increase the possibilities of accidents insteading of reducing them.

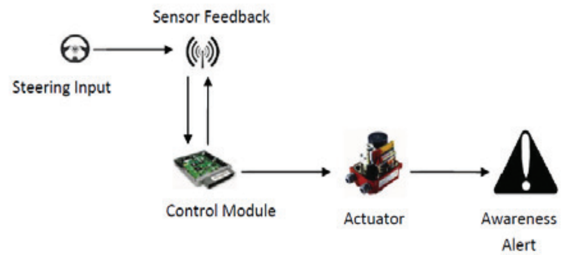

Figure 2. Framework to develop an integrated steering system

IV. CONCLUSIONS

The evolvement of automobile industry has been allow tremendous improvements and enhancement to be done on vehicles be it the performance of safety of the vehicles. Nevertheless, safety systems for busses has yet to be significantly looked into and evidences have shown the consequences that arise from each bus accident. Discussions in previous sections have proved that technology has permitted the steering systems in saloon cars to be integrated with safety systems and positive outcome has been achieved. It is worth to implement similar efforts on busses which have the higher casualties per accident ratio. Finally, the proposed framework is expected to provide sufficient assistance to the bus drivers and greatly reduce the possibilities of busses involving in accidents.

ACKNOWLEDGMENT

This project is funded by Universiti Teknikal Malaysia Melaka (UTeM) under the Short Term Research Grant. Special thanks are also expressed particularly to Ir. Dr Tan Chee Fai and Engr Ranjit Singh Al Sarban Singh for the continuous supervision and guidance provided.

REFERENCES

[1] Isler. R. B., Starkey. N. J. and Sheppard. P. (2011). "Effects of Higher-Order Driver Training on Young, Inexperienced Drivers' On-Road Driving Performance." Accident Analysis and Prevention, vol 43, pp. 1818-1827.

[2] Held, G. (2008). "Inter- and Intra-Vehicle Communications." United States of America: Auerbach Publications, pp. 21-24.

[3] G.K. Ritcher. M., Pape. H. C., Otte. D. And Krettek. C. (2005) "Improvements in Passive Car Safety Led to Decreased Injury Severity – A Comparison Between 1970s and 1990s." Injury, vol 36, pp. 484-488.

[4] Linkletter. J. A. (1985). "Steering: A Century of Progress." Popular Mechanics, vol 162, pp. 52-59.

[5] Zeng, Q. and Huang, J. (2009). "Modeling and Simulation of the Electric Power Steering System." Pacific-Asia Conference on Circuits, Communication and System, IEEE. doi: 10.1109/PACCS.2009.67

[6] BMW. (2011). "BMW Technology Guide: Active Steering." BMW [Online]. Available at: http://www.bmw.com/com/en/insights/technology/technology_guide/articles/mm_active_steering.html (Accessed: 22 October 2011).

[7] Audi. (2011). "Dynamic Steering and ESP." Audi United Kingdom [Online]. Available at: http://www.audi.co.uk/new-cars/a8/s8/safety/esp.html (Accessed: 22 October 2011)

[8] Peugeot. (2011). "SSP: Steering Stability Program." Peugeot [Online]. Available at: http://www.peugeot.com/en/innovation/safety/avoid/ssp--steering-stability-program--.aspx (Accessed: 22 October 2011)

[9] Lexus. (2011). "Lane Keeping Assist." Lexus [Online]. Available at: http://www.lexus.eu/range/Ls/key-features/safety/safety-lane-keeping-assist.aspx (Accessed: 22 October 2011)

[10] Honda. (2011). "Honda Offers New Motion Adaptive Electric Power Steering Assist and Driving Stability Support Technology in Japan." Honda Worldwide [Online]. Available at: http://world.honda.com/news/2008/c080904Motion-Adaptive-EPS/ (Accessed: 22 October 2011)

[11] Toyota. (2011). "Lane Keeping Assist." Toyota Motor Corporation [Online]. Available at: http://www.toyota-global.com/innovation/safety_technology_quality/safety_techn ology/technology_file/active/lka.html (Accessed: 22 October 2011)

[12] Mohamad, N.M. (No Date). "Overview of Current Road Safety In Malaysia." United Nations Economic and Social Commision for Asia and The Pacific [Online]. Available at: http://www.unescap.org/ttdw/roadsafety/Reports2006/Malaysia_RSpaper.pdf (Accessed: 28 May 2011).

[13] The Star. (2007). "Twenty Die, Seven Injured in Bus Tragedy." The Star Online [Online]. Available at: http://thestar.com.my/news/story.asp?file=/2007/8/13/nation/20070813100234 &sec=nation (Accessed: 28 May 2011)

[14] Looi, S. and Loh, I. (2009). "10 Killed in Bus Crash; Perak MB Wants Night Express Buses Stopped." The Star Online [Online]. Available at: http://thestar.com.my/news/story.asp?file=/2009/12/26/nation/2009122609500 8&sec=nation (Accessed: 28 May 2011)

[15] Chan, L.L., Loh, I., Aruna, P. and Khairul, A.K. (2010). "27 Killed as Tour Bus Overturns in Cameron Highlands (Update 5)." The Star Online [Online]. Available at: http://thestar.com.my/news/story.asp?file=/2010/12/20/nation/2010122013504 4&sec=nation (Accessed: 28 May 2011)

[16] Sarban, S., Nathan, C.S., Carvalho, M. and Florence, A.S. (2010). "12 Killed in Horror Crash Near NS-Malacca Border" The Star Online [Online]. Available at: http://thestar.com.my/news/story.asp?sec=nation&file=/2010/10/11/nation/720 1269 (Accessed: 28 May 2011)

[17] Nan Yu. (2007). "Yaw-Control Enhancement for Busses by Active Front-Wheel Steering" (Phd Thesis), The Pennsylvania State University, The Graduate School, Department of Mechanical and Nuclear Engineering. United States.

[18] Wang, X.L., Zhao, Y. and Wang, H. (2009). "Non-conduct Steering Sensor for Electric Power Steering." International Conference on Information and Automation – ICIA 2009 (22-24 June 2009), pp. 1462-1467.