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Monotonous Driving Environment along Highway and Driver Behaviour in Malaysia: A Review

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Abstract – *Driver alertness, behaviour, and performance are central aspects of road traffic safety to achieve sustainable mobility. In addition, the type of environment where mobility occurs tend to affect drivers. Typically, monotonous stretches along highway deteriorate drivers' vigilance thus leading to fatigue, drowsiness, and even crashes. Based on extensive review of related literature, this paper shall present the various issues of monotonous driving environment, countermeasures, as well as related research in Malaysia, aside from highway landscaping and other fatigue related road safety issues. Despite the significant amount of research on such issues, due to the current development trend and the highly motorised nature of Malaysia, there is need for more robust research especially in terms of countermeasure improvement and appraisal as well as development of monotony effect indices.*

Keywords: Monotony, environment, vigilance, safety, fatigue, landscape

1.0 INTRODUCTION

Since the number of vehicles globally is expected to increase threefold by 2050 (Shafaghat et al., 2016), the need to refocus attention on driver performance and road safety research is pertinent. Malaysia is well endowed with a road network that effectively covers the country. The provision of highway infrastructure is considered the "backbone" of social and economic development of the nation (Balubaid et al., 2015). Consequently, highways are kept very busy by the highly motorised population with over 25 million vehicles registered in 2014 (MIROS, 2017). The road is also dense at 70 vehicles per kilometre as well as a high vehicle ownership rate of 341 vehicles per 1,000 Malaysians (Mokhtar & Shimizu, 2017).

Furthermore, the government, whose target is to attain 36 million tourists and earn RM 168 billion by 2020, is still heavily investing in road infrastructure and facilities (Mokhtar & Shimizu, 2016). The demand for road movement shall continue to increase because Malaysia has enjoyed a high number of domestic tourists, out of which over 70% use private vehicles; in addition to the current 25.7 million international tourists who move within Malaysia by road, especially when the "fly-drive" holiday package is considered (Mokhtar & Shimizu, 2016).

When further consideration is given to the high number of land traffic to and from both Singapore and Thailand, then one may appreciate the ramifications of such huge volume of traffic (STB, 2014).

Thus, with this high level of motorisation and tourist road movement, there is both a high degree of service requirement as well as safety considerations. Out of the total of 894,274 crashes reported in 2015, there were 6,708 deaths and 11,552 injuries in Malaysia (MOT, 2016). Such high fatality and economic loss had been persistent for the last two decades despite the provision of facilities, expressways, higher quality vehicles, more intensive driver training and licensing (Zulhaidi et al., 2010; MIROS, 2017). Subsequently, this persistence of high road crash rates has been a major concern to policy makers and researchers. Driver behaviour, vehicle characteristics, and road environment have all been subjected to various research in order to improve road safety. Therefore, it is the objective of this paper to critically review the current research on highway driving performance and behaviour undermined by monotonous driving environment in Malaysia.

2.0 HIGHWAY DRIVING AFFECTED BY MONOTONY AND FATIGUE AND ITS COUNTERMEASURES

Driving is simultaneously a cognitive, intellectual, and emotional undertaking that requires constant and sustained alertness throughout the trip (Antonson et al., 2009). This requirement for constant attention makes driving a very fatiguing task (Oron-Gilad & Ronen, 2007), despite advancements in both vehicle and road design. Ironically, it is the very advances made in road and vehicle safety that are now posing as threats to road users. Through various innovations over the years, automobile manufacturers have ensured comfort and ease of driving in vehicles; while on the other hand, governments have provided improved road design and facilities (Fletcher et al., 2005; Larue et al., 2010b; Gastaldi et al., 2014). All of these have the combined effect of increased driver comfort, task under-loading, drastically increased speeds and monotony. The ultimate effect is that the drivers become disengaged from the road environment (Fletcher et al., 2005); and since the act of driving requires constant vigilance, preventing drivers from being disengaged from the road is paramount to safety.

Monotony, according to the Oxford dictionary, is the lack of variety and interest, tedious repetition and routine. “A monotonous task is often predictable and requires low activation of sensory perception,” as mentioned in Dababneh and El-Gindy (2015) and Mohd Tamrin et al., (2014). The mere fact that an act is repetitive constantly or has infrequent stimuli is deemed monotonous (Larue et al., 2010a). When exposed to monotony, the human central nervous system experiences a reduction in the level of cerebral activation which manifest in feeling weary, sleepy, decreased vigilance, disinterest in the task and decline in alertness (Larue et al., 2010b). While requiring constant attention, driving is intrinsically a monotonous task where the monotony can either result from carrying out the task itself or the environment around it. When monotony sets in on the driver, it leads to hypovigilance, inattention, highway hypnosis (white line fever), fatigue, drowsiness, microsleep and even deep sleep (Thiffault & Bergeron, 2003a; Larue et al., 2010a, 2010b, 2015; Dababneh & El-Gindy, 2015). Thus, monotony is a state that results in various other conditions mentioned above; which for the purpose of this paper shall collectively be referred to as either ‘inattention’ or ‘hypovigilance’. Note that the research does not separate which crash is caused by monotony, fatigue, drowsiness or sleep; and that they are all lumped together. The main indicators for assuming that an accident had occurred as a result of inattention are: a crash with either a stationary object or another vehicle, there are usually no skid or break marks indicating lack of control, and the driver is often alone (Larue et al., 2010b; Sahayadhas et al., 2012; Hossienpour et al., 2014). These particular type of road crashes have globally caused high injuries and deaths as well as huge economic loss; they range from 20% to 40% of crash fatalities (Gastaldi et al., 2014). Mohamed et al. (2012) reports 20% of such crashes in Malaysia, which is significant to warrant special attention.

There are several countermeasures aimed at impeding the effects of monotony, fatigue, distraction or sleep which include: (i) ensuring the driver is well rested before embarking on a trip; (ii) addressing other lifestyle issues such as drugs/alcohol, depression, domestic pressure and so on; (iii) keeping the time on task at optimum along with frequent stop over intervals; (iv) driving at the time of day that avoids sleep-susceptible periods such as mid-afternoon and midnight to dawn (Hosseinpour et al., 2014; Sahayadhas et al., 2012; Dababneh & El-Gindy, 2015); (v) the provision of landscaping, placemaking and locating the roads through scenic areas. Consequently, there is the consensus that the road environment is the most important factor in combating the effects of monotony (Thiffault & Bergeron, 2003; Fletcher et al., 2005); (vi) The manipulation of road geometry and alignment to increase driver stimuli is another major action in curbing monotony, since several studies have shown that straight and long road infrastructure is known to increase driver monotony than a winding and varied road (Thiffault & Bergeron, 2003; Larue et al., 2010a). (vii) Road furniture such as signage, markings, rumble strips, rails and reflectors are also important countermeasures. The positioning, size, colour intensity, shape, and the content of the sign and billboards are critical in enhancing visual stimuli (Bekdash et al., 2016; Ali et al., 2015). (viii) Other countermeasures taken by drivers on their own to create stimuli include rolling down the glasses to introduce wind and noise, playing the CD/radio loud, chewing gum or drinking coffee or engaging in conversation (Ting et al., 2008; Larue et al., 2010a). (ix) In-vehicle alert devices are now available in the market to alert a drowsy driver (Sahayadhas et al., 2012).

However, it is pertinent to note that there are currently no efficient countermeasures for combating the effects of monotony (Larue et al., 2010a, 2010b, 2015; Sallinen et al., 2014). All the measures stated above are *ad hoc* and short-termed; the drivers when experiencing drowsiness, boredom or feeling hypnotized should always stop and take a break (Larue et al., 2015).

3.0 RESEARCH ON HIGHWAY MONOTONY AND DRIVER BEHAVIOUR IN MALAYSIA

The research in Malaysia using the following keywords and phrases: monotonous driving environment, driver fatigue, driver performance/behaviour, highway stimulus, countermeasure for highway monotony, highway landscaping; was meticulously undertaken using the internet via Google Scholar, ScienceDirect, ResearchGate, Malaysian Institute of Road Safety Research (MIROS), and Ministry of Transport (MOT). Google Scholar search procedure was conducted as follows: under each of the keyword listed above, the first 10 pages are searched. Since each page contains 10 search items, all Malaysian research appearing within the first 100 items were selected. Furthermore, both Google Scholar and ScienceDirect portals offer the option of other related publications for each of the selected material, and this too had been fully exploited.

While the authors are not claiming full exhaustion of the research in Malaysia, they certainly can claim that the search had been reasonably thorough. Furthermore, in this paper, what constitutes a Malaysian research is that a publication either specifically states the study area, or that which the authors' affiliation is Malaysia. This endeavour yielded a total of 39 publications, ranging from 1990 to 2017, which are presented in Table 1 according to the traditional methodology of driver vigilance research. Thus the sequencing is as follows:

(a) 24 are direct driver vigilance research (items 1-24) which are further broken into:
    (i) 10 are driving simulator experiments (DSE) – items 1-10,
    (ii) 10 are subjective surveys (items 11-20),
    (iii) 4 are real world observations (RWO) – items 21-24;
(b) 10 are literature review (LR) on driver performance research (items 25-34);
(c) 3 are literature review (LR) on highway (items 34-36);
(d) 3 are direct research on the effect of highway landscaping (items 37-39).

Table 1: Research in driver performance, behaviour, and highway landscaping in Malaysia

LEGEND (*abbreviations and notes*)
DS (E): Driving Simulator (Experiments). **EEG**: Electroencephalography measures and records electrical activity of the brain. **ECG**: Electrocardiography measures the electrical activity of the heart. **EOG**: Electrooculogram measures eye blinks and movement. **EMG**: Electromyogram measurement for muscle activity. **SC**: Skin Conductance. **BP**: Blood Pressure. **BMI**: Body Mass Index. **LKA:** Lukas Knade Optical Flow Algorithm. **OSA**: Obstructive Sleep Apnoea. **SCA:** Salivary Cartisal Analysis tests the saliva for of stress. **RTS/C**: Road Traffic Safety/Crash. **SHECOP**: Safety Health and Environmental Code of Practice. **IDB**: inappropriate driving behaviour. **NSE:** North-south expressway. **LR**: Literature Review.

(Serial No.) Author	Theme/Objective	Methods	Findings
(1) Kee et al., 2010	Driver performance, physiological change subject to driving condition and environment in a prolonged session.	DSE, Physiological: EEG response to external environment; 250 occupational drivers as subjects.	Time-on-task and environmental factors significantly determined driver alertness and impaired driving performance in an extended driving period.
(2) Arun et al., 2012b	Developing a system to detect hypovigilance, drowsiness, and inattention.	DSE, Physiological: ECG, 15 subjects.	ECG is efficient in hypovigilance detection at 98% accuracy. Recommends fusion with behavioural measures.
(3) Sahayadhas et al., 2013	The various factors that cause driver drowsiness; and comparing DSE results with those of subjective measures.	DSE, Physiological and Subjective measures: ECG, EMG and ratings from drivers. 15 subjects.	Need to combine physiological, subjective, behavioural, and vehicle based measures to reliably detect drowsiness.
(4) Sahayadhas et al., 2015	Developing a system that can detect hypovigilance using ECG and EMG signals.	DSE, Physiological and Behavioural: ECG and EMG signals along with video recordings. 15 subjects.	- Merger of ECG and EMG signals provide better accuracy in the hypovigilance detection system. - ECG signals can be used to detect drowsiness and inattention. - Combined with other measures to develop in-vehicle alerting device.
(5) Abd Rahman et al., 2013	The effects of driving environment on the mental workload of train drivers.	DSE, Physiological: EEG, tests under clear sunny day, rainy day, and rainy night. 15 subjects.	Significant effect of driving environment toward driver mental workload.

(Serial No.) Author	Theme/Objective	Methods	Findings
(6) Wali et al., 2013	To determine classification of driver drowsiness level using EEG.	DSE, Physiological: EEG and SC with 50 subjects made to drive at constant 70 km/h over a long period in order to induce monotony.	4 levels or states of driver: awake, drowsy, high drowsy, and sleep.
(7) Mohd Tamrin et al., 2014	Comparing driving stress/ fatigue with driving error between complex and monotonous driving.	DSE, Physiological: EEG, and SCA. 100 subjects.	- All factors are significant. - Monotonous environment leads to driving stress and fatigue. - Complex environment leads to higher driving error.
(8) Awais et al., 2014a	Driving drowsiness detection using EEG, power spectrum analysis.	DSE, Physiological: EEG. 90 subjects.	- EEG is the most reliable method of drowsiness detection. - Detection of transition from alert to drowsy states. - Identification of the gradual changes in alertness.
(9) Awais et al., 2014b	To examine driver drowsiness using EEG.	DSE, Physiological: EEG; also use of topographic maps to visualize changes in brain signals. 22 subjects.	Location of the exact spot in the brain where changes are occurring: showing response to stimuli.
(10) Hassan et al., 2016	Determination of drivers' mental state by observing facial expression (the eye region).	DSE, Behavioural: LKA observations. 120 subjects observed 593 image sequences.	- Slight difference in the optical flow meters between the left and right eyes. - This method is capable of extracting temporal data from the eye region.
(11) Ameer Batcha et al., 2013	Prevalence of OSA among truck and express bus drivers in Malaysia, and efforts made to address OSA.	Physiological and Subjective: BMI, BP, neck circumference, and Polysomnography testing. Berlin questionnaire. 130 commercial truck drivers; and 292 express bus drivers.	- OSA affects drivers' performance and can cause crash. - Identification of high risk group. - Alarming prevalence of OSA among the truck and bus drivers. - Importance of constant screening. - OSA treatment may improve RTS.
(12) Abdullah & Von, 2011	Examining fatigue among bus drivers that lead to accident.	Subjective and Behavioural: questionnaire/interview. 60 bus drivers were sampled to establish relationships between fatigue factors and bus accidents.	Both working schedule and conditions significantly affect bus drivers and lead to accident.
(13) Bekdash et al. 2016	Driver alertness to different colours and intensities using brain visual evoked potentials	Observation and physiological: Visual and Graphic: checker-board stimulus design to measure visual responses of 20 subjects.	- Colour intensity levels play a major role in motivating the human alertness as higher responses are recorded when the intensity is increased. - Bright colours and high intensities are recommended to be used for traffic design rather than dim colours (blue and red).
(14) Khamis et al., 2014	Effect of driving fatigue among long distance heavy vehicle drivers in Klang valley.	Subjective: face-to-face inter-view and questionnaire. 60 heavy truck drivers.	- Long haul journey leads to driving fatigue. - Fatigue occurs after 2 hours of driving. Therefore, take a break every 2 hours. - Pain at shoulder and lower back is indicative of fatigue.

(Serial No.) Author	Theme/Objective	Methods	Findings
(15) Mohamed et al., 2009	Impact assessment of banning wee-hour express bus operation in Malaysia.	Subjective and Qualitative with questionnaire, interview combined with secondary crash data. - Profiling of existing operation scenarios, crashes involving public express buses and stakeholders' views. - Qualitative impact assessment analysis. Subjects include 16 bus drivers and 161 passengers.	- 75% of bus drivers had no preference for night or day travel. - Therefore, little difference in alertness between day and night. - No special sleep areas in the terminal for the long distance early morning drivers. - The ban will transfer excess traffic to the day time, hence more congestion and more risk and crash occurrences. - 68% of wee-hours passengers will switch modes and still travel at the wee-hours. 31.8% of them will drive their own private cars: this increases crash risks and defeats policy to encourage mass transit.
(16) Mohamed et al., 2012	Highlights the findings of the above 2009 study (above item 13).	Same as above.	- 55% of passengers travel more frequently during the night. - 54% disagree with the proposed ban. - 62% of passengers will not shift to daytime travel. - Ban will not solve the driver fatigue issue.
(17) Mohd Soid et al., 2017	Long distance bus drivers' attitudes towards traffic safety and IDBs.	Subjective: interview of 184 buses. Data was quantitatively analysed.	- Relatively positive relationship exists between long-haul bus drivers` IDB and attitude towards safety. - Being ticketed significantly affects IDB and safety attitudes.
(18) Mokhtar & Shimizu, 2016	Encouraging the self-drive tourist through improvements in tourist infrastructure.	Subjective: Online questionnaire survey of 103 Malaysian drivers.	- Very high potential in self-drive tourism. - Landscape reduces driving stress, provide visual and safety benefits. - Self-drive tourist desire comfort, beautiful natural environment and safety infrastructure.
(19) Mokhtar & Shimizu, 2017	Understanding the important factors influencing the Malaysian driving satisfaction during a tourist trip.	Same with the 2016 study, item 18 above.	- Encourage self-drive tourists to earn more revenue. - Road quality, safety and beautiful panorama attracts self-drive tourist.
(20) Hosseinpour et al., 2014	The effects of various roadway geometrical design, environment, and traffic on the frequency and severity of head-on collision.	Subjective: secondary data, 4 years' crash records (2007-2010) and data environment were collected on 543km of Malaysian federal roads with high crash rates.	- Road geometry variables were positively related to the frequency of head-on crashes. While speed and shoulder with had a negative impact. - Horizontal curvature, paved shoulder width, terrain type, and side friction were associated with more severe crashes; whereas access points, land use, and median reduced the probability of severe crashes.

(Serial No.) Author	Theme/Objective	Methods	Findings
(21) Khoo & Ahmed, 2015	Investigation of bus driver behaviour and passenger perception on the mountainous roads.	Behavioural, quantitative data for bus acceleration, speed and positioning using GPS and USB accelerometer. Qualitative data: passenger/ driver survey. 22 subjects in 27 trips.	- The ideal cruise speed limit is only 48 km/h compared the designated 70 km/h. - Geometric design can influence driver behaviour and road safety. - Driver familiarity with the road is significant to speed.
(22) Mohd Maksid & Hamsa, 2014	The relationship between road geometric design, speed, and road safety.	Observation of 100 passing vehicles whose spot-speed were measured with radar gun, sample of every 5th car under different road geometry, weather conditions, and time of day.	- Drivers drove faster on straight open road and speed reduced as conditions changed. - Introduction of curved road alignment along road network can reduce speed of the vehicles.
(23) Ahmad et al., 2017	Speeding among express bus drivers and inappropriate driving behaviour (IDB) during festive seasons. "Bus driver behaviour"	Behavioural and Observation: - GPS to track speed. - 270 buses were observed with checklist of eleven elements of IDB. - Observers were embedded in the buses with the bus drivers unaware of being studied.	- Bus drivers are more likely to drive above the speed limit at night. - Smoking and eating on the wheel were significantly associated with speeding.
(24) Osman et al., 2010	To evaluate the implementation of SHECOP among bus operations at wee hours, the bus speed profiles, and to analyse the relationship between speeding and IDB.	- Observational research with checklist of SHECOP elements which include: vehicle, journey, and driver management. - Random sampling of buses operating at night and travelling more than 4 hours/ trip. 14 companies and 55 buses.	- Low level of SHE-COP implementation. - 22% of the buses had average speed above the 90 km/h limit.
(25) Krishnan et al., 2017	Study of fatigue inducing factors among oil and gas tanker drivers in Malaysia.	LR: acquisition and use of secondary data.	There is a significant relationship between physiological risk factors and exhaustion among tanker drivers.
(26) Kamaliana et al., 2016	Review the methods of observing drowsiness and alertness of drivers.	LR assessing the current status of driver fatigue, performance, and detection technology research, 26 researchers were selected from electronic databases as from 1997 using the usual keywords of fatigue, drowsiness, alertness, sleepiness.	- Definitions, classification and tabulation of the 26 researchers. - Quick and easy to administer subjective scales. - Combination of the subjective scale and other objective method gives more reliable results. - Detailed discussion of the methods to include: measuring scale checklist, performance test, and questionnaire.

(Serial No.) Author	Theme/Objective	Methods	Findings
(27) Mohd Ariffin et al., 2012	The role of driving DSs in research and training.	LR with details of different types of DS available globally and in Malaysia.	- Published information on DS availability and application in Malaysia is very limited. - DS for research available in three universities (UPM, UKM, and UTM). - DS for training is limited to the police and armed forces. - Use of DS in research is very necessary.
(28) Mohd Siam et al., 2017	Description of DS as a major data collection tool in driver behaviour research.	LR with full description of DS models, instrumentation, and usage depicted in pictures and flow charts (MIROS 2 degrees of freedom DS [MIDOF]).	DS benefits, challenges, and improvement areas.
(29) Sahayadhas et al., 2012	The measures of determining driver drowsiness; discussion of various ways of experiment-tally manipulating drowsiness.	LR combines definitions of drowsiness and sleep; full description of the drowsiness measures: vehicle-based, physiological, behavioural, and subjective.	Proposes the adoption of a hybrid measure that fuses the various measures.
(30) Arun et al., 2011	Driver hypovigilance, influencing factors and alerting devices.	LR consists of definition of terms, classification of previous research (global); full review of the measures and alerting techniques available for hypovigilance.	- Advantages and limitations of each measure. - Issues to consider when developing an efficient detection and alerting system. - Efficiency and precise timing of alert trigger. - De-termination of "acceptable limit" for driver distraction.
(31) Arun et al., 2012a	Subjective, vehicle-based, physiological and behavioural measures in detecting driver inattention and distraction.	LR consists of the usual definition of terms and classification of the measures. + Discussion and experiment manipulation methods, table categorizing 10 previous researches.	- Importance of designing a hypovigilance detection system that covers both drowsiness and distraction. - Visual or audio alerts should be in high, medium and normal intensities.
(32) Zulhaidi et al., 2010	The local environ-mental elements affecting driving and road safety.	LR and secondary data is used to present how the Malaysian environmental elements and weather affects driving.	- Drivers have to be vigilant against weather extreme conditions. - Visual impairment from use of dark glass tinted film. - Malaysian authority efforts in RTS via engineering, enforcement, and education.
(33) Ali et al., 2015	The review and analysis of traffic sign detection and recognition.	LR: Flow chart and graphic depiction of signals, signs and colours, and algorithms.	Making traffic signs easily detectable and recognizable is paramount to road safety.
(34) Williamson, 2003	Review of social effect of the NSE focusing on driver behaviour, landscape, speed and power.	LR.	- Detailed description of landscaping and policy attempts to counter highway monotony. - NSE facilities. - Speed, safety and motorisation in Malaysia.

(Serial No.) Author	Theme/Objective	Methods	Findings
(35) Ab. Rahman, 1990	Presentation of the "complete highway" design whose elements include: utility, economy, safety and beauty.	LR of highway landscape principles.	- Comments of NSE landscape, scenery and monotonous stretches. - Coordination between all professionals of built environment from the inception of highway plans. - Inclusion of scenic vistas to enhance driving experience into a "complete highway". - Reinforces prominence of landscape as a countermeasure for monotony.
(36) Jaal & Abdullah, 2012	The various highway landscape features that intrigue the users.	LR of highway landscape elements, characteristics, and character.	- Health, psychological and environmental benefits. - Distinct qualities and preferences of highway landscape. - The tie between culture and landscape.
(37) Jaal et al., 2013	Evaluation of highway users' preference of various landscape elements in the NSE.	Quantitative, questionnaire and photographic survey of 20 travellers.	- Highway users preferred the natural landscape elements the most. - The least preferred landscape element along the highway were towns, residential and industrial areas.
(38) Hosni et al., 2013	The reliability of expert assessment of visual landscape.	GIS, expert interviews, assessment of pictures of various landscapes along the highway.	- Preferences of natural and rural landscape over built up areas.
(39) Hussain & Abdul Aziz, 2016	The restorative effect and experiences of Malaysian recreational forest users.	Observation, interview and questionnaire of 413 respondents.	- Both qualitative and quantitative results show significant similarities in level of restorative experiences. - The prevailing preferences of natural environments for restoration persists.

In the DS experiments, the vigilance monitoring techniques adopted fall into the following categories, namely vehicle-based, behavioural, and physiological measures. (i) The vehicle based-measures include the use of metrics such as lane position deviation (lateral position), driver-car interface such as steering wheel movement, acceleration/speed – none was recorded here. (ii) The behavioural measures entail the observation of driver behaviour such as head position, yawning, blinking and closing of eyes as signals of drowsiness – among the researchers' item, 10 used this measure alone while 8 and 10 were mixed with physiological measures. (iii) The physiological measures include BMI, Bp, heartbeat, body temperature and other physiological signals (using medical instruments: ECG/EMG/EOG/EEG) to detect signals of drowsiness or stress (Larue et al., 2010a, 2010b; Sahayadhas et al., 2012, 2013). Except for item 1, all DSE researchers in Table 1 used the physiological measure. The researcher in item 3 combined physiological and subjective measures while 8 and 9 mixed behavioural and physiological measures. 90% of the researchers concentrated on the endogenous factors, with only 10% treating exogenous factors. This correlates with the global picture as Laure et al. (2015) asserted that there is a dearth in exogenous research on driver fatigue.

The subjective research includes self-reporting by drivers, interviews and questionnaire surveys on driver vigilance and habits (Kamaliana et al., 2016). Items 11 to 20 in Table 1 are all subjective research. Subjective and other measures include verbal interviews and questionnaire administration to drivers to determine drowsiness

The Real World Observation (RWO) of driver behaviour and vigilance entails the observer being positioned in the vehicle out on the road either: with a checklist observing and recording all the drivers' actions – items 21, 23 and 24; or with all the measuring gadgets used in the DS – not available; or the observer is positioned outside the vehicle tracking, and measuring with GPS, speed-guns and other devices – item 22.

Among the 24 vigilance research reviewed, about 34% used the mixed-mode method (3, 4,6,11, 12, 13, 21 and 23) where any combination of the above techniques was used. This according to Sahayadhas et al. (2012, 2013) and Kamaliana et al. (2016) provide more reliable results. However, the review confirms the claim by Mohd Ariffin et al. (2012) that most (58%) of the research in Malaysia are based on survey and observation.

The research themes and objectives revealed that as much as 40% of researchers based their experiments on commercial/professional long distance drivers, while the rest were on general drivers. This supports the claim by Ameer Batcha et al. (2013) that since bus and lorry drivers record up to 53% fatigue related crashes, they do deserve special research attention. Almost all the researchers had looked at either or both the time-on-task, and the time-of-day, with Khamis et al. (2014) specifically recommending a short break every 2 hours to combat fatigue. While Mokhtar and Shimizu (2016, 2017) in both their papers concentrated solely on tourist drivers; Abd Rahman et al. (2013) uniquely looked at vigilance versus workload and how they were influenced by weather conditions and time of day. Hossienpour et al. (2014), in a detailed report explored highway head-on collision in Malaysia (accounting for 12% of crashes). The reason for including this is because most head-on collision were caused by sleepiness and distraction (Larue et al., 2015).

Generally, findings of the researchers reviewed all corroborate the global research findings. Regarding the literature reviews (LR) on driver vigilance, they have all been presented with adequate coverage, clarity, and diction. Except for items 27 and 32 which had some material on Malaysia, all were global in outlook. There was no exclusive LR on driver vigilance research in Malaysia; which supports Soid et al.'s (2017) assertion that "*In Malaysia, research regarding stress and driving performance is not as much as those in other countries with similar transport characteristics"* (Soid et al., 2017). The research on highway landscaping in Malaysia reviewed here supports the restorative and stimulus effects of landscape and scenery on both drivers and travellers. Item 34 reviewed both drivers' behaviour and landscaping in the NSE; while 35 and 36 exclusively dealt with highway landscape. The research on highway landscape and scenery as exhibited by items 18, 19, 37, 38, and 39, are all impressive works investigating perceptions of drivers, tourist, passengers, and experts. The pioneering work by Ab. Rahman (1990) (in items 35) is broad-based and well presented. Also worthy of mention is the Road Engineering Association of Malaysia (REAM) in its "Guide on geometric design of roads" which specified that topography, physical features, and land use are three important elements in highway design and construction (REAM, 2002), which is in line with both the global and local research.

5.0 CONCLUSION

Having recognized that environmental monotony has a significant impact on driver vigilance and consequently safety, this paper has reviewed the factors affecting highway driver performance and countermeasures or stimuli against monotonous driving environment. A number of recent research in Malaysia on both highway driver performance and landscape have been reviewed; and have been found to be insufficient considering the countries high level of motorisation, transport characteristics, and level of development. Specific research is required in developing monotony indices for assessing the highways. Moreover, since the current literature suggests that there are no absolutely effective countermeasures for highway monotony effect; there is room for further research both locally and globally.

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