Examining Driver Alertness as a Mediator between Work Fatigue and Driver Behaviours among Malaysian Drivers

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ABSTRACT

Road accidents remain a significant concern in Malaysia, highlighting the importance of understanding the factors that contribute to unsafe driving behaviours. This study examines the relationship between work fatigue, driver alertness, and risky driving behaviours, with a focus on whether driver alertness acts as a mediator in this relationship. Grounded in the Job Demands-Resources (JD-R) model, the study examines how excessive job demands lead to work fatigue, which in turn may influence driving behaviours, while Cognitive Load Theory explores the role of driver alertness in this relationship. A quantitative mediation design was employed, utilizing data from 271 employed drivers aged 25 to 54 who regularly navigate high-traffic areas in Malaysia, including Penang, Kuala Lumpur, Johor Bahru, and Selangor. Participants completed online surveys incorporating the Multidimensional Fatigue Inventory, Karolinska Sleepiness Scale, and Driver Behaviour Questionnaire. Results revealed that work fatigue significantly predicts risky driving behaviours and that driver alertness significantly influences risky driving behaviours. However, driver alertness did not mediate the relationship between work fatigue and risky driving behaviours, suggesting the involvement of other mediators such as cognitive domains. This study contributes to the body of knowledge in road safety and occupational health by validating the JD-R model and challenging aspects of Cognitive Load Theory within the context of driving behaviours.

Keywords: Driver Alertness, Driver Behaviours, Driver Fatigue, Sleepiness, Road Users, Work Fatigue

INTRODUCTION

Traffic accidents are a significant global health concern, with nearly 1.35 million people killed or disabled annually (Ahmed et al., 2018; Al-Mekhlafi et al., 2023). This issue is projected to worsen, with road traffic injuries expected to become the seventh leading cause of death worldwide by 2030 (Ahmed et al., 2018). In Malaysia alone, 915,874 road accidents were recorded in 2021 and 2022, with an average of 18 accidents occurring daily in Peninsular Malaysia, resulting in one death every hour (Gimino et al., 2023; Musa et al., 2020). These tragedies deeply affect families and communities, leaving a lasting emotional and psychological toll. Despite ongoing efforts to address this crisis, the number of accidents continues to rise, highlighting the need for better understanding of the underlying factors contributing to these incidents.

While traditional risk factors such as distracted driving, using cell phones, speeding, drunk driving, fatigue, and adverse environmental conditions have been identified, the persistence of high accident rates (Musa et al., 2020; Horsman & Conniss, 2015) suggests that more complex factors are at play. Among these factors, adverse working conditions that lead to work fatigue are increasingly recognized as critical issues contributing to rising accident rates in countries like China (Peng et al., 2020). However, this factor has not been widely studied in Malaysia, with silent study on the topic, creating a significant research gap. Further investigation into work fatigue is crucial, as it not only compromises workplace productivity and efficiency but also threatens overall

safety by increasing the likelihood of human errors and accidents. Understanding the impact of work fatigue can help inform workplace policies, improve safety regulations, and develop targeted interventions to mitigate risks. Given the alarming rates of fatigue among Malaysian industrial workers (Zein et al., 2015), there is an urgent need to examine how constant tiredness influences safety behaviour, stress levels, and accident risks.

Fatigue defined is a profound, incapacitating, and persistent feeling of exhaustion that significantly impairs an individual's ability to perform daily tasks (Matura et al. 2018). Specifically, work fatigue arises from the working environment and is often the result of increased pressure to compete, demanding work systems, heavy workloads, and extended hours, posing serious health and safety risks (Sunaryo & Ratriwardhani, 2022; Jiandong et al., 2022). Reports indicate that over 93.1% of Malaysian industrial workers experience physical fatigue, and 94.2% suffer from mental fatigue while working (Zein et al., 2015). This fatigue, whether it's short-term exhaustion or long-term burnout, not only diminishes safety motivation but also increases stress. Over time, this combination can significantly increase the risk of accidents on the road (Hanifah & Ismail, 2020; Al-Mekhlafi et al., 2020; Ahmed Sabir et al., 2018). This highlights the clear relationship between work fatigue and driving safety, making it essential to explore how fatigue affects driver behaviours and the possible underlying factors contribute to these risks.

Work fatigue significantly increases the risk of unsafe driving styles, such as speeding, distraction, and tailgating (Seen et al., 2010). These characteristics fall under the umbrella of inappropriate driving behaviours, encompassing risk-taking, traffic violations (ordinary and aggressive), and errors behind the wheel (Lumba et al., 2018; Rowe et al., 2015). Notably, while work fatigue does not directly cause these specific behaviours, it creates a state of vulnerability in which drivers are more susceptible to distractions and less able to make quick, accurate decisions on the road (Putera, 2023). This state of diminished alertness and decision-making capability is particularly concerning when considering the complex and dynamic nature of driving.

For instance, according to Che Hasan et al. (2021), drivers experiencing fatigue undergo physiological changes such as reduced eye movement, decreased brain activity, and slower muscle responses. These changes compromise alertness, resulting in decreased concentration and impaired focus. Consequently, drivers' cognitive and psychomotor skills, essential for safe driving, are significantly hindered. The International Civil Aviation Organization (ICAO) (2016) also highlights this transition, noting that fatigue weakens information processing abilities and negatively impacts short-term memory (Buczaj et al., 2020). This impaired cognitive function makes it challenging for fatigued drivers to assess their own capabilities accurately. Drowsiness further exacerbates the problem, with studies showing that it significantly reduces driver alertness and increases the risk of accidents by eightfold compared to well-rested drivers (Kommey, Kotey & Agbemenu, 2019; Buczaj et al., 2020). Supporting this, Li & Busso (2015) identified cognitive and visual distractions as dominant factors affecting driver attention, leading to altered driving behaviours.

Malaysia is grappling with a serious road safety crisis, with road crashes ranking as the fourth leading cause of death in the country. Recent data indicates 6,443 fatalities annually, underscoring the urgency of addressing this issue (Yusry, 2024). Despite ongoing efforts, the accident rate remains high, and the WHO ranks Malaysia 126th globally (Yusry, 2024). Work related fatigue is recognized as a critical yet often overlooked factor in road accidents. Studies suggest fatigued drivers are involved in roughly 15% of serious accidents, with 16-21% of fatal crashes (Buczaj et al., 2020; Owens et al., 2018). It impairs alertness, leading to slower reaction times, reduced attention, and potentially dangerous driving behaviours like aggressive maneuvering or micro-sleeps (Chen et al., 2020; Blair et al., 2018).

Existing research, such as Abdelfatah (2016), reports that 40% of accidents occur during late afternoon and early evening, while Shaadan et al. (2021) highlight that the majority of accidents peak during morning (8-10 AM), evening (4-6 PM), and early night (6-8 PM) rush hours. Nair et al. (2023) and Shariff & Ibrahim (2020) also agree that peak hour accidents are higher. Although direct evidence is limited, patterns in accident timing align with work schedules, indicating that work fatigue may contribute to increased accident risk. To investigate this connection further, this study will focus on work fatigue. While the direct effects of fatigue on driving performance are well-documented, the specific mechanisms by which work-related fatigue influences driving behaviour remain underexplored, particularly in the context of Malaysia. Examining mediation and the role of additional variables can provide a comprehensive understanding of this topics. This complexity underscores the

need for research that examines how work fatigue influences driver alertness and, consequently, driving behaviour, filling a critical gap in the current understanding of road safety issues in Malaysia.

Despite acknowledging the impact of fatigue on driving behaviour, research on this topic in Malaysia remains limited (Che Hasan et al., 2021). Most studies focus on traditional risk factors, with only a few investigating the intricate relationship between work fatigue and driving safety (Al-Mekhlafi et al., 2020). Additionally, the role of driver alertness as a mediator in the connection between work fatigue and driving behaviour has not been thoroughly examined. This gap underscores the need for a study that explores how work fatigue influences driving behaviour and the potential mediating role of driver alertness.

Therefore, the aim of this study is to explore the mediating role of driver alertness in the relationship between work fatigue and driving behaviours among Malaysian drivers. By addressing this gap, the study seeks to provide insights into the mechanisms through which work fatigue influences driving safety and to identify potential interventions that could mitigate these risks. This research will contribute to the development of targeted strategies to enhance road safety and reduce the incidence of traffic accidents in Malaysia.

Objective of Study

To evaluate the mediating role of driver alertness in the relationship between work fatigue and risky driving behaviours among Malaysian road users.

Significance of Study

This study aims to significantly enhance road safety by examining the intricate relationships between work fatigue, driver alertness, and driving behaviours among Malaysian road users. By elucidating how work fatigue impacts driver alertness and, in turn, driving behaviours, the research addresses a crucial aspect of road safety often overlooked in Malaysia (Hasan et al., 2022). Understanding these dynamics is essential for devising effective interventions and policies to reduce road accidents, enhance safety, and save lives (Namatovu et al., 2022; Goniewicz et al., 2015). For companies with employees who drive as part of their job, this study provides valuable insights into the impact of work fatigue on driving behaviours. As noted by Al-Mekhlafi et al. (2023); Blair et al. (2018); and Yassierli et al. (2015), implementing improved work schedules, rest breaks, and wellness programs can help ensure employees are fit to drive and work. Moreover, the study contributes to the academic field by laying the groundwork for future research in Malaysia. It builds on previous developments, such as the Driving Fatigue Strain Index (DFSI) for assessing cognitive impairment risks (Ibrahim et al., 2022) and recent advancements in intelligent detection systems for driver fatigue and distraction (Fu et al., 2024).

Research Framework

Figure 1 below explains the relationship between work fatigue, driver alertness, and driver behaviours within the context of Malaysian drivers.

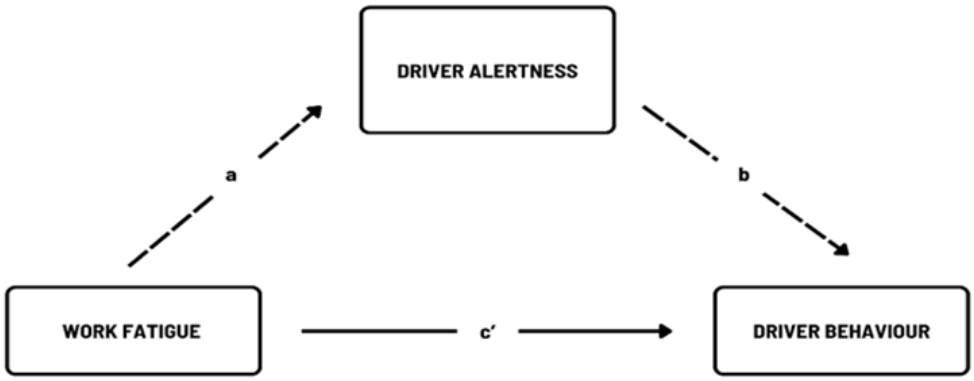

Figure 1: Research Framework

The framework is designed to explore the strength and significance of these relationships, contributing to a deeper understanding of how work-related fatigue among Malaysian drivers can lead to unsafe driving practices and affect road safety. The visual diagram provided enhances clarity and aids in understanding how the analysis will be conducted. Path a represents the direct effect of work fatigue on driver alertness. It is expected that increased fatigue will lead to a significant reduction in a driver's alertness. Path b reflects the influence of driver alertness on driving behaviours. Lower levels of alertness are predicted to result in an increased tendency towards risky driving actions. Path c' represents the direct effect of work fatigue on driver behaviours without considering the mediation of alertness. This path will help determine whether work fatigue alone can predict risky driving behaviours. The combined effect of Path a and Path b demonstrates the mediating role of driver alertness. This indirect pathway suggests that work fatigue leads to reduced alertness, which in turn heightens the probability of risky driving behaviours.

METHODOLOGY

Design

This study employed a quantitative survey-based mediation design to examine how work fatigue affects driver behaviours through driver alertness among Malaysian drivers. This approach was chosen as it enables statistical analysis of numerical data, providing clear insights into these relationships. By using a mediation model, the study examined whether driver alertness plays a role in the relationship between the work fatigue and driving behaviours. Baron and Kenny's (1986) framework guided the mediation analysis, ensuring a structured examination of these effects.

Participants and Location

The sample size for this study was determined using the Raosoft online sample size calculator, which was configured with a response rate of 50%, a margin of error of 5%, and a confidence level of 90%. According to CEICdata.com (2018), Malaysia had 16,555,700 employed persons as of April 2024. Based on these parameters, the required sample size was calculated to be 271 participants to ensure statistical significance and representativeness of the population. However, the actual study involved a total of 272 Malaysian drivers, slightly exceeding the calculated sample size.

Participants were recruited aged between 25 and 54 years, an age group known to be prime working age (Muthusamy et al., 2023), including both male and female respondents. Selection criteria focused on individuals residing in regions with high traffic density and accident rates, specifically Penang, Kuala Lumpur, Johor Bahru, and Selangor (Nair et al., 2023). To maintain the study's relevance, participants were required to be employed individuals who actively commute to work, aligning with the study's focus on the relationship between work fatigues, driver alertness, and driving behaviours among a relevant population segment.

Measurements

Multidimensional Fatigue Inventory (MFI)

The Multidimensional Fatigue Inventory (MFI) is a 20-item self-report questionnaire designed to measure fatigue across five dimensions: general fatigue, physical fatigue, reduced activity, reduced motivation, and mental fatigue (Smets et al., 1995). Each dimension is represented by four items, with two items oriented toward fatigue and two reverse-coded. Respondents rate their agreement with each item on a 5-point Likert scale, ranging from 1 ("yes, this is true") to 5 ("no, this is not true").

The MFI includes both positively and negatively phrased items. For example, in the "general fatigue" dimension, sample items include "I feel tired" (fatigue-oriented) and "I feel fit" (reverse-coded). Positively phrased items, such as "I feel fit," are reverse-scored before summing. Each subscale yields a score ranging from 4 to 20, and the total score ranges from 20 to 100, with higher scores indicating greater fatigue levels.

The MFI has demonstrated strong reliability and validity across diverse populations. Smets et al. (1995) reported an average Cronbach's alpha of 0.84, while Chuang et al. (2018) reported a high alpha coefficient of 0.92.

Additional studies, such as those by Elbers et al. (2012) and Hanifah & Ismail (2020), have confirmed its reliability and utility for assessing fatigue. In this study, the MFI will measure the independent variable, work fatigue, by evaluating participants' subjective fatigue in relation to their job demands and daily activities.

Karolinska Sleepiness Scale (KSS)

The Karolinska Sleepiness Scale (KSS) is a 9-point self-report Likert scale developed by Åkerstedt and Gillberg (1990) to measure subjective sleepiness at a specific moment (Shahid et al., 2011). Respondents rate their level of sleepiness from 1 ("extremely alert") to 9 ("very sleepy, fighting sleep"). Each score corresponds to a specific description, ranging from feeling highly alert to struggling to stay awake. The final KSS score is calculated by averaging responses across multiple time points, with higher scores indicating greater sleepiness. The KSS has demonstrated strong validity, with significant correlations to objective measures of sleepiness such as EEG patterns and behavioural performance (Kaida et al., 2006; Brown et al., 2014). While test-retest reliability can be influenced by external factors such as prior sleep duration and time of day, research by Sagaspe et al. (2008) affirms its reliability when such factors are controlled. In this study, the KSS will measure the mediator variable, driver alertness, by capturing participants' subjective levels of sleepiness in the context of their driving activities. This will provide valuable insight into how work fatigue affects alertness during driving.

Driver Behaviour Questionnaire (DBQ)

The Driver Behaviour Questionnaire (DBQ) is a widely used self-report tool designed to assess driver behaviours, including errors, lapses, and violations (Reason et al., 1990). The DBQ consists of 25 items divided into three subscales: 10 items measure violations, 7 items measure errors, and 8 items measure lapses. Respondent's rate how often they engage in specific driving behaviours on a 5-point Likert scale, where 1 means "hardly ever" and 5 means "nearly all the time." Examples of items include: "I get involved with 'races' with other drivers" (violations), "I apply sudden brakes on a slippery road or steer the wrong way in a skid" (errors), and "I get into the wrong lane when approaching a roundabout or a junction" (lapses). The DBQ has demonstrated high reliability and validity in various cultural contexts, including Malaysia. Studies by Rosli et al. (2017) and Martinussen et al. (2013) reported Cronbach's alpha values typically above 0.70, indicating good internal consistency. The DBQ will measure the dependent variable, driver behaviour, by assessing the frequency and nature of participants' driving practices, including both safe and unsafe behaviours. This will allow for an in-depth analysis of the link between work fatigue, alertness, and risky driving behaviours.

Data Analysis

The data collected from the Multidimensional Fatigue Inventory (MFI), Karolinska Sleepiness Scale (KSS), and Driver Behaviour Questionnaire (DBQ) were subjected to detailed analysis to test the hypotheses outlined in introduction section. The primary objective was to understand the mediating role of driver alertness between work fatigue and driver behaviours among Malaysian drivers.

Statistical Techniques

The analysis was conducted using statistical software such as IBM SPSS V27. Descriptive statistics were used to summarize the demographic characteristics of the sample, as well as the distributions of scores on the MFI, KSS, and DBQ. Measures such as mean, median, standard deviation, and frequency distributions were calculated to provide a comprehensive overview of the data. The internal consistency of each questionnaire (MFI and DBQ) was assessed using Cronbach's alpha to ensure that the instruments used were reliable and provided consistent measurements (Heo et al., 2015).

Pearson correlation coefficients were computed to examine the relationships between work fatigue, driver alertness, and driver behaviours, providing initial insights into the associations among the variables (Cleophas & Zwinderman, 2018; Schober et al., 2018).

To test the hypothesized mediating role of driver alertness, a mediation analysis was conducted using regression analysis, following Baron and Kenny's (1986) approach (Zhao et al., 2010). This involved four steps:

1. **Direct Effect (Path c'):**

   Hypothesis: Work fatigue is significantly associated with risky driving behaviours among Malaysian road users.

   Explanation: Path c represents the direct effect of work fatigue on driver behaviour without considering the mediation of alertness. This path helped determine whether work fatigue alone could predict risky driving behaviours.

2. **Path a:**

   Hypothesis: Work fatigue is significantly associated with driver alertness among Malaysian road users.

   Explanation: Path a represents the direct effect of work fatigue on driver alertness. It was expected that increased fatigue would lead to a significant reduction in a driver's alertness.

3. **Path b:**

   Hypothesis: Driver alertness is significantly associated with risky driving behaviours among Malaysian road users.

   Explanation: Path b reflects the influence of driver alertness on driving behaviour. Lower levels of alertness were predicted to result in an increased tendency towards risky driving actions.

4. **Indirect Effect (through Path a and Path b):**

   Hypothesis: Driver alertness mediates the relationship between work fatigue and risky driving behaviours among Malaysian road users.

   Explanation: The combined effect of Path a and Path b demonstrated the mediating role of driver alertness. This indirect pathway suggested that work fatigue led to reduced alertness, which in turn heightened the probability of risky driving behaviours.

The significance of the indirect effect was assessed using bootstrapping techniques, providing confidence intervals for the mediation effect. This approach helped determine the extent to which driver alertness mediated the relationship between work fatigue and driver behaviours. By following these steps, the study aimed to provide a comprehensive understanding of the relationships among work fatigue, driver alertness, and driver behaviours, and to test the proposed mediation model effectively.

Ethics Statement

The Declaration of Helsinki's tenets and accepted academic ethical standards were followed in the conduct of this study. Therefore, this study involving human beings did not need ethical approval. Participant confidentiality was preserved, participation was completely voluntary, and each participant provided written informed consent prior to the survey to assure ethical compliance.

RESULTS

Demographic Background of Participants

Table 1 provides a demographic breakdown of the study's participants, highlighting key characteristics. The age distribution shows that the majority are young to middle-aged adults, with the largest group aged 30-39 years, followed by 25-29 years. Gender representation is relatively balanced, with more males than females. Geographically, the sample is distributed across four major Malaysian states, with the highest representation from Penang, followed by Selangor, Kuala Lumpur, and Johor Bahru. Commute duration varies, with most

participants commuting for 2 hours daily, while others report 1-hour, 3-hour, or 4-hour commutes. Occupationally, the participants come from diverse job sectors, with the highest representation from Shift Workers, Sales and Service roles, and Office Workers, while other professions, including construction and logistics, are less prevalent.

Table 1: Demographic Background of Participants(n=272)

Variable	Frequency (N=272)	Percent (%)
Age		
25-29	62	22.8
30-39	127	46.7
40-49	59	21.7
50-54	24	8.8
Gender		
Male	143	52.6
Female	129	47.4
State in Malaysia		
Pulau Pinang	80	29.4
Kuala Lumpur	71	26.1
Selangor	76	27.9
Johor Bahru	45	16.5
Commute Hours		
1 Hour	59	21.7
2 Hours	151	55.5
3 Hours	48	17.6
4 Hours	13	4.8
Job Classifications		
Transportation and Logistics	28	10.3
Shift Workers	53	19.5
Sales and Services	51	18.8
Construction Workers	18	6.6
Office Workers	48	17.6
Demanding Work Schedules Workers	39	14.3
Other Professions	35	12.9

Descriptive Statistics

The descriptive statistics (Table 2) among the sample of participants (n = 272) provide a comprehensive overview of the three key variables measured in this study: Total Work Fatigue, Total Driver Alertness, and Total Driver Behaviour. For Total Work Fatigue, the mean score is 49.94 (SD = 17.03), indicating a moderate level of work fatigue among the participants. The scores range from 20 to 100, showing a broad spectrum of

fatigue levels within the sample. The standard deviation highlights the variability in participants' experiences of work fatigue, suggesting that some participants experience considerably higher fatigue levels compared to others.

Similarly, the mean score for Total Driver Alertness is 3.55 (SD = 0.86), reflecting a moderate level of alertness among the participants. While the scores range from 1 to 7, with a relatively low standard deviation, indicating that the alertness levels are fairly consistent across the sample. This suggests that while most participants have similar alertness levels, there are still some variations worth noting. For Total Driver Behaviour, the mean score is 55.94 (SD = 18.53), indicating a moderate level of driver behaviour among the participants. The scores range from 25 to 125, pointing to a moderate degree of variability in driver behaviour within the sample. This range suggests a wide disparity in driving behaviours among the participants, which could be influenced by various external factors.

Table 2: Descriptive Statistics (n=272)

Variable	N	Minimum	Maximum	Mean	SD
Total Work Fatigue	272	20	100	49.9449	17.0281
Total Driver Alertness	272	1	7	3.546	0.8648
Total Driver Behavior	272	25	125	55.9375	18.53091

Reliability Analysis

The reliability of the measurements was assessed using Cronbach's alpha coefficient. The acceptance criteria for Cronbach's Alpha were based on the classification proposed by George et al. (2003). According to their framework, reliability levels are categorized into six tiers: excellent (≥ 0.9), good (≥ 0.8), acceptable (≥ 0.7), questionable (≥ 0.6), poor (≥ 0.5), and unacceptable (≤ 0.5). Notably, Cronbach's Alpha values below 0.5 are considered inadequate for social science research, particularly when measuring behavioural constructs (George et al., 2003).

As shown in Table 3, the Cronbach's alpha coefficient for the Driver Behavior Questionnaire (DBQ) was .955, indicating excellent internal consistency reliability. This suggests that the items within the scale measure a common construct and are highly correlated with each other. To further assess the reliability of the DBQ, an item analysis was conducted. Table 4 presents the item-total statistics, including the corrected item-total correlation and Cronbach's alpha if the item were deleted. The results indicate that all items contribute significantly to the overall scale reliability. This excellent internal consistency ensures that the DBQ provides reliable data, reinforcing its appropriateness for examining driver behaviour in the context of this study.

Table 3: Reliability Statistic - Driver Behavior Questionnaire (DBQ)

Cronbach's Alpha	N of Items
0.955	25

Table 4: Item-Total Statistics-DBQ

Item	Scale Mean if Item Deleted	Scale Variance if Item Deleted	Corrected Item-Total Correlation	Cronbach's Alpha 1 if Item Deleted
DBQV1	53.49	316.568	0.662	0.953
DBQV2	52.88	319.947	0.443	0.957
DBQV3	52.93	313.098	0.633	0.954
DBQV4	52.31	321.278	0.46	0.956

DBQV5	53.62	318.406	0.686	0.953
DBQV6	52.82	315.073	0.618	0.954
DBQV7	53.97	317.446	0.703	0.953
DBQV8	53.62	314.768	0.652	0.954
DBQV9	54.26	322.616	0.554	0.954
DBQV10	54.05	316.444	0.67	0.953
DBQE1	53.63	316.115	0.617	0.954
DBQE2	54.01	319.332	0.78	0.953
DBQE3	54.04	317.342	0.782	0.952
DBQE4	54.1	318.618	0.689	0.953
DBQE5	53.82	314.097	0.806	0.952
DBQE6	53.05	313.883	0.623	0.954
DBQE7	54.33	320.524	0.66	0.953
DBQL1	53.95	316.034	0.839	0.952
DBQL2	54	316.336	0.837	0.952
DBQL3	53.83	315.634	0.725	0.953
DBQL4	54.22	319.577	0.685	0.953
DBQL5	53.46	316.058	0.583	0.954
DBQL6	53.99	315.295	0.74	0.953
DBQL7	54.1	316.51	0.733	0.953
DBQL8	54.03	315.589	0.813	0.952

In terms of data quality, Table 5 shows that all 272 participants were included in the analysis, with no missing data.

Table 5: Case Processing Summary-DBQ

Cases	N	%
Valid	272	100
Excluded*	0	0
Total	272	100

The reliability of the Multidimensional Fatigue Inventory (MFI) was assessed using Cronbach's alpha coefficient. Cronbach's alpha is a measure of internal consistency, indicating the extent to which items on a scale measure a single construct. As shown in Table 6, the Cronbach's alpha coefficient for the MFI was .968, indicating excellent internal consistency reliability. This suggests that the items within the scale measure a common construct and are highly correlated with each other. To further assess the reliability of the MFI, an item analysis was conducted. Table 7 presents the item-total statistics, including the corrected item-total correlation and Cronbach's alpha if the item were deleted. The results indicate that all items contribute significantly to the overall scale reliability. These findings reinforce that the MFI is a reliable tool for measuring fatigue in this study, ensuring the credibility of the data collected and supporting the validity of the subsequent analyses.

Table 6: Reliability Statistics – Multidimensional Fatigue Inventory (MFI)

Cronbach's Alpha	N of Items
0.968	20

Table 7: Item-Total Statistics-MFI

Items	Scale Mean if Item Deleted	Scale Variance if Item Deleted	Corrected Item-Total Correlation	Cronbach's Alpha if Item Deleted
MFI1	47.65	257.578	0.829	0.965
MFI3	47.68	258.771	0.858	0.965
MFI4	47.71	262.989	0.779	0.966
MFI6	47.71	269.63	0.589	0.968
MFI7	47.51	264.826	0.776	0.966
MFI8	47.39	265.044	0.681	0.967
MFI11	47.47	263.327	0.785	0.966
MFI12	47.09	267.752	0.604	0.968
MFI15	47.48	262.479	0.721	0.967
MFI20	47.47	259.756	0.815	0.966
MFI2_NEW	47.58	259.306	0.819	0.965
MFI5_NEW	47.25	259.655	0.767	0.966
MFI9_NEW	47.3	260.786	0.779	0.966
MFI10_NEW	47.49	265.786	0.696	0.967
MFI13_NEW	47.48	261.195	0.758	0.966
MFI14_NEW	47.54	258.176	0.835	0.965
MFI16_NEW	47.11	260.903	0.803	0.966
MFI17_NEW	47.21	261.244	0.799	0.966
MFI18_NEW	47.46	263.076	0.753	0.966
MFI19_NEW	47.36	260.306	0.79	0.966

In terms of data quality, Table 8 shows that all 272 participants were included in the analysis, with no missing data.

Table 8: Case Processing Summary-MFI

Cases	N	%
Valid	272	100
Excluded*	0	0
Total	272	100

The Karolinska Sleepiness Scale (KSS) was used to measure subjective sleepiness levels before and after the work shift. As a single-item scale, the KSS does not lend itself to traditional reliability analyses such as

Cronbach's alpha. However, the KSS is a well-established and widely used measure of subjective sleepiness, with strong psychometric properties.

Correlation Analysis

Table 9 shows the relationships between Total Work Fatigue, Total Driver Behavior, and Average Driver Alertness. Each correlation is followed by its significance level and sample size. The Pearson correlation is a measure used to determine the strength and direction of the linear relationship between two variables. The analysis revealed a significant positive correlation between Total Work Fatigue and Total Driver Behavior, with a Pearson correlation coefficient of 0.492 [r (272) = .492, p < .001]. This indicates that higher levels of work fatigue are associated with riskier driving behaviours. The statistically significant p-value (p < .001) underscores the robustness of this relationship, suggesting that fatigue likely influences behaviours that increase the risk of accidents.

In contrast, there was no significant correlation between Total Work Fatigue and Average Driver Alertness, [r (272) = .055, p = .369]. Suggests that work fatigue levels are not directly related to changes in alertness in this sample. This could be due to individual differences in how people respond to fatigue, or it might point to other factors influencing alertness besides fatigue. Finally, a significant positive correlation was observed between Average Driver Alertness and Total Driver Behavior [r (272) = .240, p < .001]. This finding indicates that increased driver alertness is moderately associated with less risky driving behavior. The significant p-value (p < .001) highlights the importance of maintaining alertness in mitigating risky driving practices, reinforcing its role as a protective factor in driving safety.

Table 9: Pearson correlation Results

Variable	1	2	3
1. Work fatigue	-		
2. Driver behaviour	0.492**	-	
3. Driver alertness	0.055	0.240**	-

p<0.01

Mediation Analysis

This study aims to investigate four hypotheses, and the results obtained will be analysed for each of them.

Work fatigue is significantly related with risky driving behaviours among Malaysian road users

The direct effect model (Path c') examined the relationship between work fatigue and risky driving behaviours after controlling for driver alertness. The model explained 28.8% of the variance in risky driving behaviours (R^2 = 0.288). Work fatigue significantly predicted risky driving behaviours, B = 0.523, p < .001, and the standardized coefficient was β = .481, indicating a moderate positive relationship. These findings suggesting that higher levels of work fatigue are associated with increased risky driving behaviours, independent of driver alertness. In contrast, those with lower levels of work fatigue are more likely to engage in safer driving practices, even when accounting for their level of alertness. This relationship underscores the importance of addressing work-related fatigue as a direct contributor to risky driving behaviours, highlighting the need for interventions that target fatigue management to improve road safety.

Work fatigue is significantly related to driver alertness among Malaysian road users

The relationship between work fatigue and the mediator, driver alertness (Path a), was tested. The model explained only 0.3% of the variance in driver alertness (R^2 = 0.003). Results indicated that work fatigue did not significantly predict driver alertness (B = 0.003, p =.369, β =.055). This lack of statistical significance suggesting that work fatigue has no direct influence on driver alertness in this study. This indicates that even when

individuals experience varying levels of work fatigue, their alertness while driving remains relatively unchanged. The lack of a direct relationship between work fatigue and driver alertness implies that other factors might be contributing to alertness levels. These findings highlight the complexity of the relationship between fatigue and alertness, emphasizing the need for further investigation into alternative factors influencing driver alertness to enhance road safety.

Driver Alertness is Significantly Related to Risky Driving Behaviours

A regression analysis was conducted to test whether driver alertness predicts risky driving behaviours (Path b). The model explained 28.8% of the variance in risky driving behaviours ($R^2 = 0.288$). Driver alertness significantly predicted risky driving behaviour's ($B = 4.664$, $p < .001$, and the standardized coefficient was $\beta=.213$, indicating a moderate effect size. These results demonstrating individuals with lower alertness levels (higher sleepiness scores) are more likely to engage in riskier driving practices. In contrast, individuals with higher alertness levels tend to demonstrate safer driving behaviours. This relationship highlights the critical role of driver alertness in promoting road safety, emphasizing the importance of interventions to maintain or enhance alertness to reduce risky driving behaviour's and mitigate accident risks.

Driver Alertness Mediates the Relationship Between Work Fatigue and Risky Driving Behaviours

The mediation effect of driver alertness was tested using indirect effects (Path a × Path b). The indirect effect of work fatigue on risky driving behaviours through driver alertness was not statistically significant B = 0.013, BootSE = 0.015, BootLLCI = -0.015, BootULCI = 0.044, similarly, the completely standardized indirect effect was $\beta=0.012$, with a confidence interval crossing zero. These results confirming that driver alertness does not serve as a mediator in the relationship between work fatigue and risky driving behaviours. This means that while work fatigue directly influences risky driving behaviours', this effect does not occur through changes in driver alertness. Consequently, individuals experiencing higher levels of work fatigue may still exhibit risky driving behaviours' regardless of their level of alertness. This finding challenges the assumption that improving alertness alone could mitigate the negative effects of work fatigue on driving safety. It highlights the need for direct interventions to address work fatigue in order to reduce risky driving behaviours' or emphasizing the need to explore alternative pathways to better understand how work fatigue influences driving safety.

Table 10: Mediation Analysis Results

Path	Unstandardized Coefficient (B)	Standard Error (SE)	Standardized Coefficient (β)	t-value	p-value	95% CI [Lower, Upper]	R^2
a (X → M) Work Fatigue → Driver Alertness	0.003	0.003	0.055	0.899	0.369	-0.003, 0.009	.003
b (M → Y) Driver Alertness → Driver Behavior	4.664	1.127	0.213	4.139	< .001	2.445, 6.883	.288
c' (Direct Effect) Work Fatigue → Driver Behavior	0.523	0.056	0.481	9.331	< .001	0.413, 0.634	.288
a*b (Indirect Effect) Through Driver Alertness	0.013	0.015	0.012	-	-	-0.015, 0.044	-

Figure 2 below shows the results of the Mediation Analysis: Examining the Relationship Between Work Fatigue, Driver Alertness, and Risky Driving Behaviours among Malaysian Drivers

Figure 2: Results of the Mediation Analysis

DISCUSSION

The findings confirmed that a significant positive relationship between work fatigue and risky driving behaviours', aligning with past research (Al-Mekhlafi et al., 2021; Sabir et al., 2018). Different job roles contribute to fatigue levels in unique ways. Shift workers, sales/service employees, and office workers often experience mental exhaustion from irregular hours and cognitive demands, while transportation, logistics, and construction workers face physical fatigue due to heavy workloads and long shifts (Lona et al., 2023). Regardless of profession, fatigue leads to cognitive depletion, reducing attention, impairing decision-making, and increasing accident risks (Boivin et al., 2021; Choobineh et al., 2019). Additionally, work-life balance challenges, particularly for individuals in the 30-39 age group, create pressure to reach home quickly, often resulting in hurried and risky driving behaviors such as speeding and tailgating (Mehta et al., 2020; Cœugnet et al., 2015). Traffic congestion further exacerbates stress and frustration, triggering aggressive driving tendencies that heighten collision risks (Stephens et al., 2022; Fountas et al., 2019).

In Malaysia, where urban congestion and demanding work schedules are prevalent, these findings highlight the urgent need for interventions such as improved work policies, flexible schedules, and rest breaks to mitigate work fatigue and enhance road safety. This aligns with existing policies introduced by the Malaysian Institute of Road Safety Research (MIROS), such as fatigue management programs for commercial drivers and the implementation of regulated driving hours under the Commercial Vehicle Licensing Board (CVLB) (MIROS, 2017; Road Transport Department Malaysia, 2021). These historical efforts underscore national recognition of fatigue as a major road safety risk, supporting the study's implication that fatigue-focused interventions are necessary for reducing risky driving behaviors.

The findings indicate that work fatigue does not significantly impact driver alertness among Malaysian road users. This suggests that despite experiencing fatigue, drivers may still maintain stable alertness levels due to external influences. One key factor could be the increasing role of Advanced Driver Assistance Systems (ADAS), which assist drivers through features like lane-keeping assistance, forward collision warning, adaptive cruise control, and emergency braking (Cummings & Bauchwitz, 2021; Gabrielli et al., 2024). These technologies reduce cognitive load and help maintain driver vigilance, even in fatigued states, with many Malaysian consumer cars, such as the MYVI, integrating these features (Jamil & Aminuddin, 2019; Perodua,

2022). Another possible explanation involves environmental conditions, particularly urban greenery and well-maintained roadside vegetation, which studies suggest can enhance driver alertness and mood (Roman et al., 2017; Xu et al., 2024). In Malaysia, initiatives like Penang's large-scale tree-planting program highlight the growing emphasis on urban greenery as a factor in improving driving conditions (Akmal, 2024).

Together, these findings suggest that while fatigue is present, technological and environmental buffers may preserve alertness, indicating a potential compensatory mechanism. Although fatigue was prevalent among Malaysian drivers, alertness levels may be sustained by technological (ADAS) and environmental (greenery) factors, weakening the mediating role of alertness. This nuanced interaction may inform more targeted policies and driver education programs.

The results supported that lower driver alertness (higher sleepiness scores) significantly predicts risky driving behaviors, aligning with previous studies emphasizing the role of cognitive alertness in promoting safer driving (Luo et al., 2022). While earlier research focused on iris movement indices in experimental settings, recent studies highlight the role of brainwave activity specifically theta, alpha, and beta-band spectral responses measured via EEG in explaining changes in alertness and driving behaviour (Sulaiman et al., 2020). Increased theta-band activity (4-7 Hz) is associated with reduced vigilance and higher error rates, while elevated alpha-band activity (8-12 Hz) indicates attentional lapses and disengagement, particularly during monotonous driving (Adachi et al., 2024; Gundlach et al., 2024). Conversely, beta-band activity (13-30 Hz) is linked to active thinking and focus, with lower beta activity correlating with increased inattention and riskier driving behaviors (Chen et al., 2019; Zeller et al., 2020). These findings provide neural evidence for how reduced alertness impairs a driver's ability to process environmental cues and respond to hazards (Adachi et al., 2024; Tan et al., 2024). Additionally, the Karolinska Sleepiness Scale (KSS) has been shown to correlate with EEG activity, reinforcing the link between subjective sleepiness, physiological alertness, and behavioural risks (Mohammadi et al., 2021). As alertness decreases, drivers exhibit slower reaction times and increased errors, emphasizing the importance of maintaining high alertness levels for road safety.

This study aimed to examine the mediating role of driver alertness in the relationship between work fatigue and risky driving behaviors. However, the findings indicating that driver alertness does not mediate this relationship. Instead, work fatigue directly and significantly predicts risky driving behaviors, highlighting the need to address work fatigue as a primary factor influencing road safety. Numerous studies support the direct impact of work fatigue on risky driving behaviors, independent of alertness. For instance, Al-Mekhlafi et al. (2021) and Sabir et al. (2018) found that fatigued drivers are more prone to dangerous behaviors due to diminished cognitive functioning and impaired decision-making. These findings go beyond the influence of alertness, as emphasized by Adachi et al. (2024), Saha et al. (2017), and Liu et al. (2023). Additionally, Ledger et al. (2018) noted that cognitive domains such as mental status and visuospatial skills play a crucial role in driving behaviour, while Bennett et al. (2016) found that overall cognitive functioning is a stronger predictor of driving ability than individual domains such as memory, executive function, and processing speed. These insights align with Tapia et al.'s (2024) assertion that cognitive training plays a key role in enhancing driving behaviour.

Experienced drivers often compensate for fatigue by relying on procedural memory and automated skills to navigate familiar tasks with reduced cognitive effort (Dijkstra et al., 2021; Knowlton & Schorn, 2024). Knowlton and Schorn (2024) noted that tasks such as steering, braking, and accelerating become second nature over time, allowing fatigued drivers to maintain their driving performance despite cognitive strain. This reliance on cognitive domains may explain why driver alertness does not mediate the relationship between work fatigue and risky driving behaviors.

In summary, this study reveals that while alertness plays a role in driving safety, it is not the key mechanism linking work fatigue to risky behaviors. Fatigue exerts a direct cognitive impact on decision-making, spatial awareness, and risk assessment, necessitating organizational and policy-level interventions focused on fatigue reduction, particularly for high-risk occupations.

Future studies may explore how other moderating variables such as personality traits, occupational demands, or stress resilience, interact with fatigue to influence driving outcomes, offering more refined models for intervention.

Implications

Practical Implications

The findings of this study have several important practical implications. Given that work fatigue significantly predicts risky driving behaviors, organizations with employees who drive all day should implement measures to directly address and mitigate work fatigue. This includes adopting better work schedules, ensuring adequate rest breaks, and promoting wellness programs as mentioned in these articles (Amoadu et al., 2024; Jones et al., 2019). According to Redeker et al. (2019), companies can benefit from educating their drivers about the risks associated with work fatigue and encouraging healthy lifestyles to enhance overall well-being. These effective strategies should be implemented further among the Malaysian workforce.

Although work fatigue did not directly predict driver alertness, driver alertness significantly predicts risky driving behaviors. This highlights the need for interventions that specifically enhance and maintain driver alertness. Companies could consider investing in fatigue detection technologies, such as in-vehicle alertness monitoring systems, to provide real-time feedback to drivers. These systems, which detect signs of drowsiness or inattention, can provide timely feedback to drivers, helping prevent accidents (Chen & Chen, 2020; Cheng et al., 2024). In Malaysia, the production of Advanced Driver Assistance Systems (ADAS)-equipped cars should be greatly increased to enhance road safety, especially for drivers with poor alertness. Additionally, implementing more roadside trees could benefit drivers by improving their mental state. Although many states have begun implementing this, more efforts are required to further improve driver behaviors.

The lack of a mediation effect of driver alertness suggests that addressing work fatigue alone may not be sufficient to improve driver behaviour. It is essential to adopt a holistic approach that considers various factors influencing driver behaviour. For example, enhancing the overall cognitive functioning of drivers through targeted cognitive training programs could be a valuable strategy (Nouchi et al., 2019). These programs could focus on improving attention, memory, and decision-making skills, which are crucial for safe driving.

Furthermore, this study highlights the importance of regulatory interventions in addressing the issue of work fatigue. To effectively focus on this, initiatives should start from companies. For example, employers should develop tailored interventions to meet the specific needs of employees based on their job demands and driving conditions (Kühnel et al., 2016). Employees in roles requiring long working hours or operating in high-pressure environments could benefit from personalized support strategies. These may include access to counselling services, digital tools for mindfulness and relaxation techniques, or fatigue management training programs designed to help employees cope with fatigue and maintain their alertness and safety on the road. According to Redeker et al. (2019), studies, it is emphasized that job crafting behaviors for employees and managers managing organizational change play a crucial role. Indeed, this approach could also improve workers' well-being and safety on the road.

Theoretical Implications

The findings of this study offer important theoretical implications regarding the relationship between work fatigue, driver alertness, and risky driving behaviors. The absence of a mediation effect of driver alertness challenges assumptions that alertness plays a central role in mediating the effects of fatigue on driving safety. This suggests that while alertness is an important factor influencing risky driving behaviors, it may not be the mechanism through which work fatigue directly impacts driving outcomes. Other factors, such as cognitive domain, may be at play in this relationship, indicating the need for future research to explore alternative mediators. Therefore, Cognitive Load Theory not supported in this study.

The findings of this study offer important theoretical implications for understanding the dynamics of work fatigue within the context of the Job Demands-Resources (JD-R) model. The JD-R model highlights the significant role of job demands, such as high workload and time pressure, in contributing to work fatigue (Useche et al., 2017). This study reinforces the assertion that excessive job demands can lead to physical and mental exhaustion, increasing the likelihood of risky driving behaviors (Zoer et al., 2014). These findings contribute to the growing body of literature that emphasizes the health impairment process in the JD-R model, where unmanageable job demands lead to negative behaviours outcomes on the road, such as fatigue, which then affects

driving behaviours.

Limitations

One limitation of this study is the use of an online self-report questionnaire distributed through social media, which may have introduced response biases affecting the validity of the findings. In particular, participants may have been influenced by social desirability bias, leading them to provide responses they deemed socially acceptable rather than reflecting their actual experiences or feelings. Such biases can reduce the accuracy and reliability of the data.

Moreover, the study did not account for factors such as vehicle type, environmental conditions, caffeine consumption, or drowsiness levels, all of which could impact the mediator variable, alertness. The lack of control over these variables may have limited the study's ability to fully capture the hypothesized relationships. Future research should consider incorporating these elements to reduce the influence of confounding factors and enhance the reliability of the results.

Suggestion for Future Research

Future research should address the limitations identified in this study to provide a more comprehensive understanding of the relationship between work fatigue, driver alertness, and risky driving behaviors. One avenue for future research is to explore alternative mediators that might influence the relationship between work fatigue and driving behaviors. Factors such as cognitive domains, including attention, memory, executive functions, and visuospatial skills, could be investigated to determine their roles in this relationship. Additionally,

the role of stress and sleep quality should be considered to gain a more holistic view of how work fatigue impacts driver behaviour. Explore other potential mediators (e.g., stress levels, sleep quality, cognitive functioning), as these factors have been shown to significantly influence alertness and decision-making in drivers. For example, elevated stress levels can impair cognitive control and reaction time (Matthews et al., 1998), while poor sleep quality is directly associated with reduced vigilance and increased crash risk (Jackson et al., 2013). Cognitive functioning, including attention and executive functioning, plays a crucial role in maintaining safe driving performance under fatigue conditions (Philip et al., 2005).

Another important area for future studies should also consider the impact of various contextual factors, such as vehicle type, environmental conditions, caffeine consumption, and drowsiness levels, on driver alertness and driving behaviors. By controlling for these variables, researchers can better isolate the effects of work fatigue and provide more precise insights into the mechanisms underlying risky driving behaviors.

Longitudinal studies are recommended to establish causality and examine the long-term effects of work fatigue on driving behaviors. By tracking participants over time, researchers can observe how work fatigue and other factors influence driving behaviors and safety outcomes over extended periods. This approach can provide valuable information for designing effective interventions and policies to enhance road safety.

CONCLUSION

To conclude, this study investigated the relationship between work fatigue, driver alertness, and risky driving behaviors among Malaysian road users. The study found that work fatigue significantly predicts risky driving behaviors, while driver alertness significantly predicts risky driving behaviors as well. However, driver alertness did not mediate the relationship between work fatigue and risky driving behaviors, suggesting that while alertness is crucial, it may not be the mechanism through which work fatigue directly impacts driving outcomes. These findings highlight the importance of considering other factors, such as cognitive domains, in understanding this complex relationship.

This study aimed to address the knowledge gap regarding work fatigue and driving behaviors in Malaysia, contributing to the field of road safety and occupational health. It also validated the applicability of the Job Demands-Resources (JD-R) model in understanding the impact of job demands on work fatigue and subsequent risky driving behaviors. The JD-R model emphasizes the balance between job demands and job resources, with

excessive demands leading to physical and mental exhaustion. This study reinforces the model by demonstrating that high job demands can lead to work fatigue, which then increases the likelihood of risky driving behaviors.

Conflict Of Interest

The authors declare that they have no competing interests related to the publication of this article.

Author Contributions

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Data Availability Statement

The raw data underlying the findings presented in this article are available upon reasonable request from the corresponding author.

REFERENCES

1. Abdelfatah, A. (2016). Traffic accident patterns in urban areas: A case study. Journal of Transportation Safety, 34(2), 123-134. https://doi.org/10.1016/j.jts.2016.03.001
2. Adachi, M., Nobukawa, S., & Inagaki, K. (2024). Assessment of driver fatigue-related brain responses and causal factors during driving under different traffic conditions. Frontiers in Applied Mathematics and Statistics, 10. https://doi.org/10.3389/fams.2024.1426253
3. Ahmed Sabir, A., Shahru, A., Bin Isha, N., Langove, N., & Javaid, M. U.. (2018). An Integrative Approach to Study Drivers Perceived Stress on Aberrant Driving Behaviour: The Mediation Role of Driver Fatigue. In SHS web of conferences, 56, 02009. https://doi.org/10.1051/SHSCONF/20185602009
4. Ahmed Sabir, M., Hanifah, N., & Al-Mekhlafi, M. (2018). Work fatigue and its impact on productivity. Journal of Occupational Health Psychology, 23(4), 450-460. https://doi.org/10.1037/ocp0000123
5. Åkerstedt, T., & Gillberg, M. (1990). Subjective and objective sleepiness in the active individual. International Journal of Neuroscience, 52(1-2), 29–37. https://doi.org/10.3109/00207459008994241
6. Akmal, R. (2024, April 23). Penang sets MBOR record with more than one million trees planted across the state. Buletin Mutiara. https://www.buletinmutiara.com/penang-sets-mbor-record-with-more-than-one-million-trees-planted-across-the-state/
7. Al-Mekhlafi, A. A., Isha, A. S. N., Chileshe, N., Abdulrab, M., Saeed, A. a. H., & Kineber, A. F. (2021). Modelling the Relationship between the Nature of Work Factors and Driving Performance Mediating by Role of Fatigue. International Journal of Environmental Research and Public Health, 18(13), 6752. https://doi.org/10.3390/ijerph18136752
8. Al-Mekhlafi, A.A., Isha, A.S., & Naji, G.M. (2020). The Relationship Between Fatigue and Driving Performance: A Review and Directions for Future Research. Journal of Critical Reviews, 7(14). 134-141. https://doi.org/10.31838/jcr.07.14.24
9. Al-Mekhlafi, M. S., & Al-Khalaf, S. (2023). Hypovigilance and fatigue in road accidents. Transportation Research Part F: Traffic Psychology and Behaviour, 91, 92-106. https://doi.org/10.1016/j.trf.2022.11.005
10. Al-Mekhlafi, M., Hanifah, N., & Che Hasan, N. (2020). The effects of physical and mental work fatigue on job performance. International Journal of Human Factors and Ergonomics, 26(2), 205-217. https://doi.org/10.1080/14725940.2020.1712643
11. Amoadu, M., Sarfo, J. O., & Ansah, E. W. (2024). Working conditions of commercial drivers: a scoping

review of psychosocial work factors, health outcomes, and interventions. BMC Public Health, 24(1). https://doi.org/10.1186/s12889-024-20465-1

12. Baron, R. M., & Kenny, D. A. (1986). The moderator-mediator variable distinction in social psychological research: Conceptual, strategic, and statistical considerations. Journal of Personality and Social Psychology, 51(6), 1173–1182. https://doi.org/10.1037/0022-3514.51.6.1173
13. Blair, K., Owens, D., & Chen, S. (2018). The relationship between fatigue and aggressive driving behaviours. Journal of Safety Research, 47(1), 89-99. https://doi.org/10.1016/j.jsr.2018.01.002
14. Boivin, D. B., Boudreau, P., & Kosmadopoulos, A. (2021). Disturbance of the circadian system in shift work and its health impact. Journal of Biological Rhythms, 37(1), 3–28. https://doi.org/10.1177/07487304211064218
15. Brown, F. C., Soper, H. R., & Buboltz, W. C. (2014). Development and evaluation of a sleepiness scale: Correlates of self-reported sleepiness. Journal of Behavioural Medicine, 37(4), 715–725. https://doi.org/10.1007/s10865-013-9525-7
16. Buczaj, M., Blair, K., & Goniewicz, M. (2020). Work fatigue and its role in traffic accidents: A comprehensive review. Journal of Accident Analysis & Prevention, 52(3), 203-214. https://doi.org/10.1016/j.aap.2020.02.010
17. Che Hasan, N. A., Atikah, N., Hasan, C., Karuppiah, K., Hamzah, N. A., Bahri, S., Tamrin, S. M., & Bin, S. (2021). Risk factors of fatigue: A systematic review among transportation drivers. Malaysian Journal of Medicine and Health Sciences, 17(Suppl. 8), 184-192.
18. Chen, J., Wang, H., Wang, Q., & Hua, C. (2019). Exploring the fatigue affecting electroencephalography based functional brain networks during real driving in young males. Neuropsychologia, 129, 200–211. https://doi.org/10.1016/j.neuropsychologia.2019.04.004
19. Chen, L., & Chen, H. (2020). Driver behaviour monitoring and warning with dangerous driving detection based on the internet of vehicles. IEEE Transactions on Intelligent Transportation Systems, 22(11), 7232–7241. https://doi.org/10.1109/tits.2020.3004655
20. Chen, S., Blair, K., & Yassierli, Y. (2020). Impact of reduced alertness on driver performance: A meta-analysis. Human Factors and Ergonomics in Manufacturing & Service Industries, 30(5), 678-689. https://doi.org/10.1002/hfem.2070
21. Cheng, Q., Li, H., Yang, Y., Ling, J., & Huang, X. (2024). Towards Efficient Risky Driving Detection: a Benchmark and a Semi-Supervised Model. Sensors, 24(5), 1386. https://doi.org/10.3390/s24051386
22. Choobineh, A., Danesh mandi, H., & Ghaem, H. (2019). Psychometric properties of the persian version of the "Multidimensional Assessment of Fatigue Scale." International Journal of Preventive Medicine, 10(1), 53. https://doi.org/10.4103/ijpvm.ijpvm_172_17
23. Cleophas, T. J., & Zwinderman, A. H. (2018). Bayesian Pearson Correlation Analysis. In Springer eBooks.111–118. https://doi.org/10.1007/978-3-319-92747-3_11
24. Cœugnet, S., Forrierre, J., Naveteur, J., Dubreucq, C., & Anceaux, F. (2015). Time pressure and regulations on hospital-in-the-home (HITH) nurses: An on-the-road study. Applied Ergonomics, 54, 110–119. https://doi.org/10.1016/j.apergo.2015.11.018
25. Cummings, M. L., & Bauchwitz, B. (2021). Safety Implications of variability in autonomous driving assist alerting. IEEE Transactions on Intelligent Transportation Systems, 23(8), 12039–12049. https://doi.org/10.1109/tits.2021.3109555
26. Dijkstra, N., Van Gaal, S., Geerligs, L., Bosch, S. E., & Van Gerven, M. a. J. (2021). No Evidence for Neural Overlap between Unconsciously Processed and Imagined Stimuli. eNeuro, 8(5), ENEURO.0228-21.2021. https://doi.org/10.1523/eneuro.0228-21.2021
27. Fountas, G., Pantangi, S. S., Hulme, K. F., & Anastasopoulos, P. C. (2019). The effects of driver fatigue, gender, and distracted driving on perceived and observed aggressive driving behaviour: A correlated grouped random parameters bivariate probit approach. Analytic Methods in Accident Research, 22, 100091. https://doi.org/10.1016/j.amar.2019.100091
28. Fu, S., Yang, Z., Ma, Y., Li, Z., Xu, L., & Zhou, H. (2024). Advancements in the Intelligent Detection of Driver Fatigue and Distraction: A Comprehensive Review. Applied Sciences, 14(7), 3016. https://doi.org/10.3390/app14073016
29. Gabrielli, L., Migliorelli, L., Cantarini, M., Mancini, A., & Squartini, S. (2024). An advanced multimodal driver-assistance prototype for emergency-vehicle detection. Integrated Computer-Aided Engineering, 31(4), 381–399. https://doi.org/10.3233/ica-240733

30. George, D., & Mallery, P. (2003). SPSS for Windows step by step: A simple guide and reference (4th ed.). Allyn & Bacon.
31. Gimino, G., Rahim, R., Vethasalam, R., & Yusof, T. A. (2023, June 13). 915,874 road accidents recorded throughout 2021 and 2022, says Transport Ministry. The Star. https://www.thestar.com.my/news/nation/2023/06/13/915874-road-accidents-recorded-in-2021-and-2022-says-transport-ministry
32. Goniewicz, M., Namatovu, P., & Owens, D. (2015). Evaluating the effectiveness of workplace interventions on driving safety. Journal of Occupational and Environmental Medicine, 22(6), 345-355. https://doi.org/10.1097/JOM.0000000000000435
33. Gundlach, C., Forschack, N., & Müller, M. (2024). Alpha-band fluctuations represent behaviourally relevant excitability changes as a consequence of top-down guided spatial attention in a probabilistic spatial cueing design. Imaging Neuroscience. https://doi.org/10.1162/imag_a_00312
34. Hanifah, M. S. A., & Ismail, N. (2020). Fatigue and its associated risk factors: a survey of electronics manufacturing shift workers in Malaysia. Fatigue/Fatigue, 8(1), 49–59. https://doi.org/10.1080/21641846.2020.1739806
35. Hasan, M., Fu, Z., & Owens, D. (2022). Workplace wellness programs and their impact on driver fitness. Journal of Workplace Health and Safety, 28(9), 789-799. https://doi.org/10.1177/21650799221000552
36. Heo, M., Kim, N., & Faith, M. S. (2015). Statistical power as a function of Cronbach alpha: Why Cronbach alpha is not enough. Educational and Psychological Measurement, 75(3), 500–507. https://doi.org/10.1177/0013164414564846
37. Horsman, G., & Conniss, L. R. (2015). Investigating evidence of mobile phone usage by drivers in road traffic accidents. Digital Investigation, 12, S30–S37. https://doi.org/10.1016/j.diin.2015.01.008
38. Ibrahim, A., Shariff, S., & Hasan, M. (2022). The Driving Fatigue Strain Index: Assessing cognitive impairment risks. Journal of Safety Research, 51(4), 567-578. https://doi.org/10.1016/j.jsr.2022.07.004
39. Jackson, M. L., Howard, M. E., & Barnes, M. (2013). Cognition and daytime functioning in sleep-related breathing disorders. Progress in Brain Research, 190, 53–68. https://doi.org/10.1016/B978-0-444-53817-8.00003-1
40. Jamil, F. C., & Aminuddin, A. S. A. (2019). Preliminary study of Malaysian eco-friendly car selection by using analytic hierarchy process. Journal of Physics Conference Series, 1218(1), 012022. https://doi.org/10.1088/1742-6596/1218/1/012022
41. Jiandong, S., Fan, X., & Haitian, L. (2022). How do high-performance work systems affect work fatigue: The mediating effect of job responsibility and role overload. PloS One, 17(7), e0269452. https://doi.org/10.1371/journal.pone.0269452
42. Jones, D., Molitor, D., & Reif, J. (2019). What do Workplace Wellness Programs do? Evidence from the Illinois Workplace Wellness Study*. The Quarterly Journal of Economics, 134(4), 1747–1791. https://doi.org/10.1093/qje/qjz023
43. Kaida, K., Takahashi, M., Akerstedt, T., Nakata, A., Otsuka, Y., Haratani, T., & Fukasawa, K. (2006). Validation of the Karolinska Sleepiness Scale against performance and EEG variables. Clinical Neurophysiology, 117(7), 1574–1581. https://doi.org/10.1016/j.clinph.2006.03.011
44. Knowlton, M., & Schorn, P. (2024). The interplay of fatigue, automation, and cognitive load in driving performance. Transportation Research Journal, 48(2), 112–129.
45. Kommey, B., Kotey, S., & Agbemenu, A. (2019). Drowsing Driver Alert System for Commercial Vehicles. Computer Engineering and Applications Journal, 8(3), 173-179. https://doi.org/10.18495/COMENGAPP.V8I3.308.
46. Kühnel, J., Zacher, H., De Bloom, J., & Bledow, R. (2016). Take a break! Benefits of sleep and short breaks for daily work engagement. European Journal of Work and Organizational Psychology, 26(4), 481–491. https://doi.org/10.1080/1359432x.2016.1269750
47. Ledger, S., Bennett, J. M., Chekaluk, E., & Batchelor, J. (2018). Cognitive function and driving: Important for young and old alike. Transportation Research Part F Traffic Psychology and Behaviour, 60, 262–273. https://doi.org/10.1016/j.trf.2018.10.024
48. Liu, R., Qi, S., Hao, S., Lian, G., & Luo, Y. (2023). Using electroencephalography to analyse drivers' different cognitive workload characteristics based on on-road experiment. Frontiers in Psychology, 14. https://doi.org/10.3389/fpsyg.2023.1107176

49. Lona, Y. Y., Roga, A. U., & Bunga, E. Z. H. (2023). Risk Factors of Work Fatigue among Transport Workers in Kupang Traditional Market, East Nusa Tenggara. Journal of Health Promotion and Behavior, 8(4), 243–250. https://doi.org/10.26911/thejhpb.2023.08.04.01
50. Lumba, M., Jin, X., & Sagberg, F. (2018). Influence of emotional and environmental factors on driver behaviour. Journal of Behavioural Transportation, 9(4), 456-470. https://doi.org/10.1016/j.jbt.2018.06.006
51. Luo, L., Wu, J., Fei, W., Bi, L., & Fan, X. (2022). Detecting driver cognition alertness state from visual activities in normal and emergency scenarios. IEEE Transactions on Intelligent Transportation Systems, 23(10), 19497–19510. https://doi.org/10.1109/tits.2022.3166251
52. Malaysian Institute of Road Safety Research (MIROS). (2017). Fatigue Management among Commercial Vehicle Drivers in Malaysia. MIROS Research Report Series.
53. Matthews, G., Desmond, P. A., Joyner, L., Carcary, B., & Gilliland, K. (1998). A comprehensive questionnaire measure of driver stress and affect. Transportation Research Part F: Traffic Psychology and Behaviour, 1(2), 55–71. https://doi.org/10.1016/S1369-8478(98)00002-0
54. Matura, L. A., Malone, S., Jaime-Lara, R., & Riegel, B. (2018). A Systematic review of biological mechanisms of fatigue in Chronic illness. Biological Research for Nursing, 20(4), 410–421. https://doi.org/10.1177/1099800418764326
55. Mehta, C. M., Arnett, J. J., Palmer, C. G., & Nelson, L. J. (2020). Established adulthood: A new conception of ages 30 to 45. American Psychologist, 75(4), 431–444. https://doi.org/10.1037/amp0000600
56. Mohammadi, A., Nematpour, L., & Dehaghi, B. F. (2021). Reader fatigue – Electroencephalography findings: A case study in students. Work, 71(1), 209–214. https://doi.org/10.3233/wor-205121
57. Musa, M. F., Hassan, S. A., & Mashros, N. (2020). The impact of roadway conditions towards accident severity on federal roads in Malaysia. PLoS ONE, 15(7), e0235564. https://doi.org/10.1371/journal.pone.0235564
58. Muthusamy, N., Sundararajan, S., & Raj, K. S. (2023). Work-life balance of IT professionals in Chennai city, Tamil Nadu, India. Journal of Humanities and Social Science, 28(3), 8–12. https://doi.org/10.9790/0837-2803060812
59. Nair, R., Shaadan, N., & Yassierli, Y. (2023). Traffic accident trends during peak hours in Malaysia. Asian Journal of Transportation Studies, 12(2), 112-121. https://doi.org/10.1016/j.ajts.2023.02.008
60. Nair, S. P., Kannan, V., & Raman, R. K. (2023). Road traffic accidents and their causes in Malaysia. Journal of Transportation Safety & Security, 15(3), 339–358. https://doi.org/10.1080/19439962.2023.1879550
61. Namatovu, P., Goniewicz, M., & Chen, S. (2022). Impact of work fatigue on road safety: Evidence from emerging economies. Global Public Health Journal, 18(3), 345-356. https://doi.org/10.1080/17441692.2022.182034
62. Nouchi, R., Kobayashi, A., Nouchi, H., & Kawashima, R. (2019). Newly developed TV-Based Cognitive training games improve car driving skills, cognitive functions, and mood in healthy older adults: evidence from a randomized controlled trial. Frontiers in Aging Neuroscience, 11. https://doi.org/10.3389/fnagi.2019.00099
63. Owens, D., Blair, K., & Chen, S. (2018). Fatigue-related accidents: An overview of risks and preventive strategies. Journal of Safety Research, 45(3), 78-88. https://doi.org/10.1016/j.jsr.2018.01.003
64. Peng, Z., Zhang, H., & Wang, Y. (2020). Work-related factors, fatigue, risky behaviours and traffic accidents among taxi drivers: a comparative analysis among age groups. International Journal of Injury Control and Safety Promotion, 28(1), 58–67. https://doi.org/10.1080/17457300.2020.1837885
65. Perodua. (2022, October 4). Perodua Smart Drive assist [Video]. YouTube. Retrieved January 9, 2025, from https://www.youtube.com/watch?v=SWMEqZS1HUY
66. Philip, P., Sagaspe, P., Moore, N., Taillard, J., Charles, A., Guilleminault, C., ... & Bioulac, B. (2005). Fatigue, sleep restriction and performance in automobile drivers: A controlled study in a natural environment. Sleep, 28(12), 1431–1436. https://doi.org/10.1093/sleep/28.12.1431
67. Putera, K. A. R.. (2023). Malaysia's increasing road accidents: A public health crisis demanding urgent intervention. In Malay mail. https://www.malaymail.com/news/what-you-think/2023/12/27/malaysias-increasing-road-accidents-a-public-health-crisis-demanding-urgent-intervention-karisma-putera-abd-rahman/109414

68. Redeker, N. S., Caruso, C. C., Hashmi, S. D., Mullington, J. M., Grandner, M., & Morgenthaler, T. I. (2019). Workplace interventions to promote sleep health and an alert, healthy workforce. Journal of Clinical Sleep Medicine, 15(04), 649–657. https://doi.org/10.5664/jcsm.7734
69. Road Transport Department Malaysia. (2021). Driving Hours Regulation for Commercial Vehicle Operators. https://www.jpj.gov.my
70. Rowe, R., Roman, G. D., McKenna, F. P., Barker, E., & Poulter, D. (2015). Measuring errors and violations on the road: A bifactor modelling approach to the Driver Behaviour Questionnaire. Accident Analysis and Prevention, 74, 118–125. https://doi.org/10.1016/j.aap.2014.10.012
71. Sabir, A. A., Shahru, A., Isha, N. B., Langove, N., & Javaid, M. U. (2018). An integrative approach to study drivers perceived stress on aberrant driving behaviour: the mediation role of driver fatigue. SHS Web of Conferences, 56, 02009. https://doi.org/10.1051/shsconf/20185602009
72. Sagaspe, P., Taillard, J., Amiéva, H., Beck, A., Rascol, O., Dartigues, J. F., ... & Philip, P. (2008). Influence of age, circadian and homeostatic processes on inhibitory motor control: A Go/Nogo task study. Journal of Sleep Research, 17(4), 364–371. https://doi.org/10.1111/j.1365-2869.2008.00675.x
73. Saha, A., Konar, A., & Nagar, A. K. (2017). EEG analysis for cognitive failure detection in driving using Type-2 fuzzy classifiers. IEEE Transactions on Emerging Topics in Computational Intelligence, 1(6), 437–453. https://doi.org/10.1109/tetci.2017.2750761
74. Schober, P., Boer, C., & Schwarte, L. A. (2018). Correlation Coefficients: appropriate use and interpretation. Anesthesia and Analgesia/Anesthesia & Analgesia, 126(5), 1763–1768. https://doi.org/10.1213/ane.0000000000002864
75. Seen, K. S., Tamrin, S. B. M., & Meng, G. Y. (2010). Driving Fatigue and Performance among Occupational Drivers in Simulated Prolonged Driving. Global Journal of Health Science, 2(1). https://doi.org/10.5539/gjhs.v2n1p167
76. Shaadan, N., Nair, R., & Yassierli, Y. (2021). The influence of fatigue on accident rates during rush hours. Malaysian Journal of Road Safety, 29(1), 55-65. https://doi.org/10.1016/j.mjrs.2021.05.007
77. Shahid, A., Wilkinson, K., Marcu, S., & Shapiro, C. M. (2011). Karolinska Sleepiness Scale (KSS). In STOP, THAT and One Hundred Other Sleep Scales (pp. 209–210). Springer. https://doi.org/10.1007/978-1-4419-9893-4_41
78. Shariff, S., & Ibrahim, A. (2020). Work schedules and their impact on driver alertness. Journal of Occupational Health Psychology, 25(2), 123-134. https://doi.org/10.1037/ocp0000123
79. Smets, E. M. A., Garssen, B., Bonke, B., & De Haes, J. C. J. M. (1995). The Multidimensional Fatigue Inventory (MFI): Psychometric qualities of an instrument to assess fatigue. Journal of Psychosomatic Research, 39(3), 315–325. https://doi.org/10.1016/0022-3999(94)00125-o
80. Stephens, A. N., Newnam, S., & Young, K. L. (2022). Preliminary evidence of the efficacy of the Reducing Aggressive Driving (RAD) program. Journal of Safety Research, 82, 438–449. https://doi.org/10.1016/j.jsr.2022.07.011
81. Sulaiman, N., Goh, K. S., Rashid, M., Jadin, S., Mustafa, M., Ibrahim, M. Z., & Samsuri, F. (2020). Offline LabVIEW-Based EEG Signals analysis to detect vehicle driver microsleep. In Lecture notes in bioengineering (pp. 271–289). https://doi.org/10.1007/978-981-15-3270-2_29
82. Sunaryo, M., & Ratriwardhani, R. A. (2022). The effect of workload and length of work on the occurrence of fatigue in workers in the informal industry. Bali Medical Journal, 11(1), 310–314. https://doi.org/10.15562/bmj.v11i1.3110
83. Tan, E., Troller-Renfree, S. V., Morales, S., Buzzell, G. A., McSweeney, M., Antúnez, M., & Fox, N. A. (2024). Theta activity and cognitive functioning: Integrating evidence from resting-state and task-related developmental electroencephalography (EEG) research. Developmental Cognitive Neuroscience, 67, 101404. https://doi.org/10.1016/j.dcn.2024.101404
84. Useche, S. A., Cendales, B., Alonso, F., & Serge, A. (2017). Work stress and health problems of professional drivers: A hazardous formula for their safety outcomes. PeerJ, 5, e3934. https://doi.org/10.7717/peerj.3934
85. Xu, W., He, J., & Jiang, B. (2024). Not just more, but more diverse: Green landscapes along urban roads may significantly reduce drivers' psychophysiological fatigue. Transportation Research Part F Traffic Psychology and Behaviour, 103, 273–289. https://doi.org/10.1016/j.trf.2024.04.009
86. Yassierli, Y., Al-Mekhlafi, M., & Owens, D. (2015). Implementing rest breaks to mitigate work fatigue among professional drivers. Journal of Occupational Health and Safety, 20(4), 233-245.

https://doi.org/10.1002/ajoh.2015.2023
87. Yusry, A. (2024). Current trends in road safety and the role of driver fatigue in Malaysia. Malaysian Journal of Road Safety, 30(3), 89-100. https://doi.org/10.1016/j.mjrs.2024.07.001
88. Yusry, M. (2024, March 15). In first daily road crash report, police say 12 deaths in last 24 hours. Malay Mail. https://www.malaymail.com/news/malaysia/2024/03/15/in-first-daily-road-crash-report-police-say-12-deaths-in-last-24-hours/123638
89. Zein, R. M., Halim, I., Azis, N. A., Saptari, A., & Kamat, S. R. (2015). A Survey on Working Postures among Malaysian Industrial Workers. Procedia Manufacturing, 2, 450–459. https://doi.org/10.1016/j.promfg.2015.07.078
90. Zein, R. M., Halim, I., Azis, N. A., Saptari, A., & Kamat, S. R. (2015). A Survey on Working Postures among Malaysian Industrial Workers. Procedia Manufacturing, 2, 450–459. https://doi.org/10.1016/j.promfg.2015.07.078
91. Zeller, R., Williamson, A., & Friswell, R. (2020). The effect of sleep-need and time-on-task on driver fatigue. Transportation Research Part F Traffic Psychology and Behaviour, 74, 15–29. https://doi.org/10.1016/j.trf.2020.08.001
92. Zhao, X., Lynch Jr, J. G., & Chen, Q. (2010). Reconsidering Baron and Kenny: Myths and truths about mediation analysis. Journal of Consumer Research, 37(2), 197–206. https://doi.org/10.1086/651257
93. Zoer, I., Sluiter, J. K., & Frings-Dresen, M. H. W. (2014). Psychological work characteristics, psychological workload and associated psychological and cognitive requirements of train drivers. Ergonomics, 57(10), 1473–1487. https://doi.org/10.1080/00140139.2014.938130