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ORIGINAL ARTICLE

Age, Sleep, Fatigue, and Body Mass Index Patterns in Central Java Bus Drivers: Multi-Route Occupational Health Assessment

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ABSTRACT

Introduction: Indonesia's growing transportation demands have increased reliance on bus services across Central Java Province. Despite their importance, driver health remains understudied, even as driver factors account for 65% of public transportation accidents. This study investigates differences in health characteristics among bus drivers across three distinct routes: Trans Jateng, BRT Semarang City, and Inter-City Bus Transportation Services Between Semarang-Surakarta. **Methods:** This quantitative cross-sectional study conducted in Semarang City and Surakarta City examined 210 bus drivers between January 2023-August 2024 using interviews, questionnaires and stature meters. Variables included age, sleep duration, fatigue levels (using the Industrial Fatigue Research Committee questionnaire), and Body Mass Index. Analysis employed Kruskal-Wallis tests followed by Mann-Whitney post-hoc tests with Bonferroni correction. **Results:** Analysis revealed significant differences across all variables ($p<0.001$). Trans Jateng drivers (mean age 43.1 years) demonstrated optimal sleep (7.0 hours), low fatigue levels (88.6%), and healthier BMI profiles (74.3% normal). BRT Semarang City drivers (mean age 44.2 years) showed paradoxical characteristics with longest sleep duration (9.5 hours) yet highest fatigue levels (80% very high) and poor BMI profiles (84.3% overweight/obese). Inter-City drivers, despite being older (mean age 51.4 years) with shortest sleep duration (5.4 hours), showed moderate fatigue adaptation (92.9%) and similar BMI concerns (84.2% overweight/obese). **Conclusion:** Significant differences ($p<0.001$) exist among three public transport driver groups. Trans Jateng showed the best health profile, BRT Semarang City paradoxical with long sleep yet high fatigue, and Inter-City adaptive despite insufficient sleep. Sleep duration does not correlate with fatigue levels. Group-specific health interventions are needed.

Keywords: driver fatigue assessment; transportation worker health profile; occupational health bus drivers

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INTRODUCTION

Indonesia as a developing country is highly dependent on public transportation systems, particularly buses to facilitate population mobility. Indonesia now has a population of more than 230 million people, and the country's economic growth has increased transportation demand and vehicle ownership (BPS Provinsi Tengah Jawa, 2025). Similar figures are also seen in Central Java Province, which has a population of nearly 34 million people (Dishub, 2025). This figure is even higher during the day due to commuters from suburban areas and several supporting cities (i.e., urban areas and metropolitan regions in Central Java). It is estimated that Central Java Province may have a population of around 36 million people during the day. With a road ratio of only less than 7%, high vehicle growth rates and poor public transportation contribute to congested road usage. This problematic situation is difficult to address because more than 90% of available transportation modes are road-based.

Buses have become one of the main transportation modes connecting various regions in Indonesia, including in Central Java Province. According to public transportation accidents in Indonesia have increased by 12.7% in the last five

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years, with driver factors accounting for 65% of total accident occurrences (Daiyah, 2022). Buses have become one of the main transportation modes connecting various regions in Indonesia, including in Central Java Province. Three categories of bus services that serve as the backbone of transportation in this region are Trans Jateng, BRT Semarang City Bus, and Inter-City Bus Transportation Services Between Semarang - Surakarta(AKDP) (Dwitama *et al.*, 2024). Despite having a crucial role in supporting the economy, the occupational safety and health aspects of bus drivers have not received adequate attention (Nurdjanah and Puspitasari, 2017).

Traffic accident data in Indonesia shows that buses are involved in approximately 5-10% of total traffic accidents each year, with driver fatigue being one of the main causes. Fatigue in bus drivers not only endangers the safety of the drivers themselves but also threatens the safety of passengers and other road users. According to data from the Indonesian National Police, at least 30% of bus accidents are caused by human error factors related to the physical condition of the driver, including fatigue (Henky, 2021; Mabry *et al.*, 2022). A study from the Ministry of Transportation in 2023 showed that the risk of accidents increases by 15% in drivers experiencing moderate to high fatigue (Syahliantina, 2025).

According to data released by the World Health Organization, traffic accidents cause 1.25 million deaths annually, and non-fatal accidents affect 20 to 50 million people. Statistics on the causes of traffic accidents in various countries show that 20%-50% of traffic accidents are caused by driver fatigue (World Health Organization, 2018).

Age influences circadian rhythms, cognitive function, and fatigue recovery mechanisms critical for driver safety (Scarpelli *et al.*, 2021). BMI indicates metabolic health status, with elevated levels increasing cardiovascular disease, diabetes, and sleep apnea risks common in sedentary driving occupations (Chen, Chiu and Chen, 2021). These variables demonstrate scientific interconnections where age affects sleep architecture, poor sleep contributes to weight gain through hormonal disruptions, and excess weight further compromises sleep quality and increases fatigue, creating measurable health disparities across different route exposures.

This increased risk becomes more significant in drivers who have sleep patterns of less than 6 hours per day and with a body mass index (BMI) above normal (Shirath *et al.*, 2025). Driving is a complex task that requires an optimal level of alertness to ensure the safety of drivers and other road users. Statistics show that low alertness is the cause, every year, of many highway accidents. Sleep duration directly correlates with reaction time, attention span, and accident risk, with inadequate sleep impairing glucose metabolism and immune function. Fatigue represents cumulative physical and mental exhaustion affecting occupational performance and safety outcomes. The number of sleep and fatigue-related accidents ranges from 10% to 30%, depending on the year of the reported study and the country (Tan *et al.*., 2021). Lack of sleep will cause alertness while driving to decrease, which can lead to "micro sleep" or drowsiness that generally occurs at 1 pm and 4 pm as well as between 4 am and 6 am (Hajducik *et al.*, 2021) .

This research is important considering that public transportation is a public sector that supports economic movement and community mobility. Ensuring the health and safety of bus drivers not only impacts the improvement of transportation service quality but also has the potential to save the lives of thousands of passengers and other road users every day. This study aims to analyze the differences that cause workplace fatigue among bus drivers across three routes, providing essential insights for improving driver health and safety interventions. Through a deep understanding of the health profile and fatigue levels of bus drivers in various categories, it is hoped that appropriate policies and interventions can be formulated to mitigate accident risks and improve the welfare of drivers as valuable assets in the national transportation system.

Geographical and Operational Aspects The Surakarta-Semarang route represents a strategic transportation corridor in Central Java with a significant distance of approximately 110 km and travel time of 2-3 hours. This condition allows researchers to observe the impact of driver fatigue during medium-distance journeys that are representative of inter-city transportation.

Traffic Density and Variation Levels; This route traverses various road conditions ranging from dense urban areas (Surakarta and Semarang), inter-city highways, to semi-rural areas. This variation in traffic conditions provides a comprehensive overview of factors contributing to driver fatigue in various driving situations.

Practical Relevance Surakarta and Semarang are two major cities in Central Java with high mobility, so the research results have significant

practical implications for improving regional public transportation systems. The data obtained can be used to develop road safety policies and driver fatigue management on similar routes in Indonesia

METHODS

This research is a quantitative research. It is an observational study conducted using a cross-sectional research design. This research seeks to explore variables that differentiate among three different bus routes. Cross-sectional research is research where researchers measure data on independent and dependent variables only once at a time. The population in this study consisted of 210 drivers at Central Java BRT (corridor I, III, VI), BRT Semarang City BRT, Inter-City Bus Transportation Services Between Semarang - Surakarta Route. The entire process was conducted between January 2023 until August 2024. The research instruments used were interviews; structured verbal data collection method used to gather demographic and sleep-related information from participants. The interviews specifically covered age demographics and sleep duration patterns, allowing researchers to obtain detailed information about drivers' personal characteristics. Questionnaires; Standardized written instruments utilizing the Industrial Fatigue Research Committee (IFRC) scale to systematically measure work-related fatigue levels The questionnaire consists of 30 questions, with the first 10 questions serving as an activity weakness tool, the next 10 questions as a work motivation weakness tool, and the last 10 questions as a work weakness tool. Scoring: Score 30 = Not Fatigued; Score 31-60 = Mild Fatigue; Score 61-90 = Moderate Fatigue; Score 91-120 = Severe Fatigue, stature meters; Precision measuring devices (stadiometers) used to accurately determine participants' height measurements, combined with weight measurement tools to collect anthropometric data.

This study uses variables of age, sleep hours, fatigue levels measured using the Industrial Fatigue Research Committee (IFRC) questionnaire consisting of 30 questions, This study adopted an instrument from Indonesian research with a reliability coefficient of 0.845 (Bramantyo and Nugroho, 2023; Ihsan *et al.*, 2020), which are then scored and categorized into four levels of fatigue, and body mass index (BMI) measurement involves dividing body weight in kilograms by height in meters squared. Calculate each participant's BMI using their individual weight and height data through the standard formula BMI = kg/m², enabling comparison of body mass index across all study respondents. Univariate data analysis is used in this research to determine the frequency distribution and bivariate analysis to analyze differences between research variables. Bivariate analysis was carried out using Kruskal-Wallis Difference Test and Mann-Whitney Post-hoc test. For categorical data, statistical analysis used bivariate analysis statistical tests to determine which variables had the most differences on the incidence of fatigue experienced by sedentary workers. This study protocol was submitted for ethical clearance to the Research Ethics Commission of the Faculty of Health Sciences, Dian Nuswantoro University Semarang, and approved with letter number: EC NO.517/EA/KEPK-Fkes-UDINUS/v/2023.

RESULT

Bus Rapid Transit (BRT) of Semarang City operates within Semarang city and connects between regions. Semarang city has 7 travel routes where Semarang city has an area of 378 km with a registered population of 1,708,830 people, not including migrant residents who work in Semarang City. Trans Semarang Bus has several routes that connect between regencies and cities in the Central Java province. The routes taken in this research are those passing through Semarang City, namely corridors 1, 3, and 6. This research was conducted in 3 locations: Corridor I located at Bawen Terminal, Corridor III located at Mangkang Terminal, and Corridor VI located at Penggaron Terminal. Bawen Terminal is located on Semarang - Surakarta Road, Bawen, Bawen District, Semarang Regency, Central Java. Mangkang Terminal is located in Mangkang Kulon, Tugu District, Semarang City, Central Java. Penggaron Terminal is located in Penggaron Kidul, Pedurungan District, East Semarang. Inter-City Bus Transportation Services Between Semarang - Surakarta from Semarang City to Surakarta City with a route of more than 107 km with 5 bus companies used in this research, namely PO. Royal Safari, PO. Safari Jaya Mandiri, PO. Rajawali Bus Transport, PO. Ismo Trans Jaya, PO. Muncul Soegiharto.

Analysis of Bus Driver Characteristics Across Various Routes

The selection of age, sleep duration, fatigue, and body mass index as primary variables for examining occupational health disparities among bus

drivers is grounded in established physiological and occupational health principles that demonstrate their critical roles in driver safety and long-term health outcomes. Based on the data collected in Table 1 regarding the characteristics of bus drivers on three different routes, several significant differences can be observed. Trans Jateng bus drivers have an average age of 43.1 years, which is the youngest among the three groups. Age serves as a fundamental biological determinant influencing multiple physiological systems relevant to occupational performance. In transportation workers, aging affects circadian rhythm regulation through altered melatonin production and circadian clock sensitivity, which directly impacts sleep-wake cycles essential for maintaining alertness during driving shifts. Older drivers experience phase advances in circadian rhythms, leading to earlier sleep onset and wake times that may conflict with work schedules. The age range of respondents is quite wide, from 25 to 57 years with a standard deviation of 9.3 years.

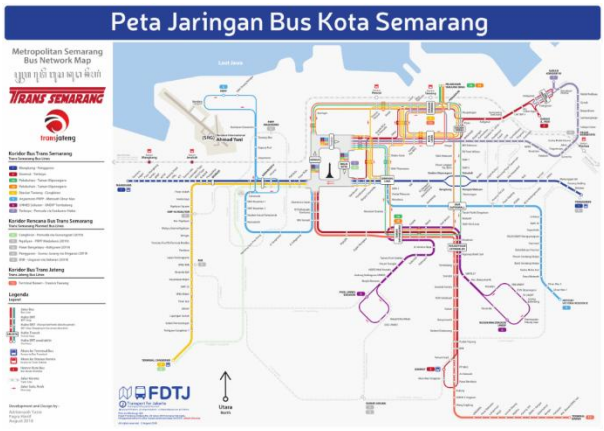

Figure 1. BRT Semarang City Route

Figure 2. Trans Jateng Route

Sleep duration represents a safety-critical variable with direct associated to driver performance through multiple neurophysiological mechanisms. Adequate sleep duration of 7-9 hours maintains optimal prefrontal cortex function responsible for attention, decision-making, and impulse control. Trans Jateng drivers show regular sleep patterns with an average of 7 hours per day. On Table 1 This seems to contribute positively to the respondents' fatigue levels, where the majority (88.6%) experience low levels of fatigue. In terms of physical health, Trans Jateng drivers have the best Body Mass Index (BMI) profile, with 74.3% in the normal category.

On the Table 1. BRT Semarang City route, bus drivers have quite different characteristics. The average age of respondents is slightly higher at 44.2 years with a range of 30 to 58 years. Interestingly, drivers on this route have the highest average sleep duration at 9.5 hours per day, with a very wide variation (standard deviation of 3.8 hours) and an extreme range from 4 to 18 hours. Despite having a long average sleep duration, 80% of BRT Semarang City drivers actually experience very high levels of fatigue, indicating possible issues with sleep quality or other factors affecting respondent fatigue. In terms of physical condition, drivers on this route show a poor BMI profile with 48.6% experiencing obesity and 35.7% classified as overweight.

On Table 1 Inter-City Bus Transportation Services Between Semarang - Surakarta have different demographic characteristics, with the highest average age of 51.4 years and an age range of 34 to 67 years. This group has the lowest average sleep duration at only 5.4 hours per day with a range of 4 to 8 hours. This lack of sleep pattern seems to impact the respondents'

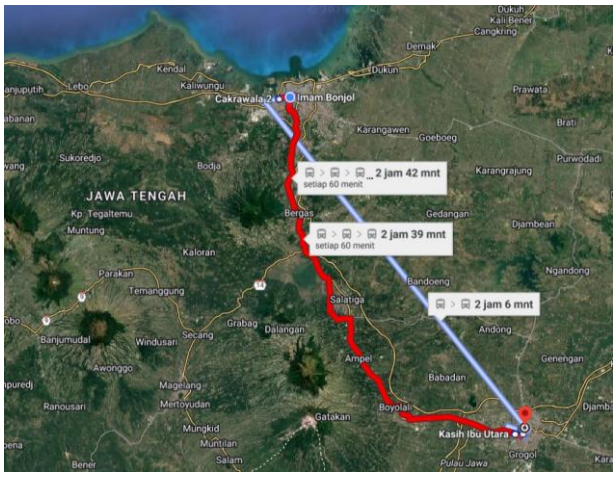

Figure 3. Inter-City Bus Transportation Services Between Semarang - Surakarta Route

fatigue levels, where 92.9% of drivers experience moderate levels of fatigue. Elevated BMI increases cardiovascular risks including hypertension, coronary artery disease, and stroke, conditions that can cause sudden incapacitation while driving. Similar to BRT Semarang City drivers, Inter-City Bus Transportation Services Between Semarang - Surakarta drivers also have a less than ideal BMI profile with 47.1% experiencing obesity and 37.1% classified as overweight. Only 12.9% of Inter-City Bus Transportation Services Between Semarang - Surakarta drivers have a normal BMI.

There are several interesting relationship patterns between these variables in Table 1. Trans Jateng drivers who have moderate sleep duration (7 hours) and mostly normal BMI tend to experience low levels of fatigue. In contrast, BRT Semarang City drivers exhibit an apparently contradictory phenomenon, where respondents have the longest sleep duration but also the highest levels of fatigue. This may indicate that sleep quality is more important than quantity, or there are other factors such as working conditions that affect respondents' fatigue levels. Inter-City Bus Transportation Services Between Semarang - Surakarta drivers with the lowest sleep duration and highest age show moderate levels of fatigue, which may reflect adaptation to the respondents' working conditions along with longer experience.

Fatigue assessment provides a multidimensional indicator of physical, mental, and emotional exhaustion that reflects the cumulative impact of work demands, environmental stressors, and recovery adequacy

In terms of physical health, there are major differences in BMI profiles between Trans Jateng drivers compared to the other two groups. Trans Jateng drivers have a much higher proportion of normal BMI, while BRT Semarang City and Inter-City Bus Transportation Services Between Semarang - Surakarta drivers have very high rates of obesity and overweight. This may be related to differences in lifestyle, eating patterns, or levels of physical activity among the three driver groups.

Based on Table 2 showing the results of the Kruskal-Wallis Difference Test, inferential statistical analysis strengthens the previous descriptive findings about the characteristics of bus drivers across three different routes. The Kruskal-Wallis test results for all variables studied (Age, Sleep Hours, Fatigue Level, and Body Mass Index) show p-values < 0.001, which means there are statistically very significant differences in all four variables among the three driver groups (Trans Jateng, Semarang City, and I Inter-City Bus Transportation Services Between Semarang - Surakarta. The high value for the Fatigue Level variable (186.432) indicates that differences in fatigue levels between driver groups are the most prominent compared to other variables. This is consistent with previous findings showing very different distributions of fatigue levels, where the majority of Trans Jateng drivers experience low fatigue, Inter-City Bus Transportation Services Between Semarang - Surakarta drivers predominantly experience moderate fatigue, and

Tabel 1. Bus Driver Characteristics Across Routes

Variable	TJ*	BRT *	AKDP*
Age			
Average (years)	43.1	44.2	51.4
Std. Deviation	9.3	7	9.1
Min – Max (years)	25 - 57	30 - 58	34 - 67
Sleep Hours			
Average (hours)	7.0	9.5	5.4
Std. Deviation	1	3.8	1.1
Min – Max (hours)	5 - 8	4 - 18	4 - 8
Fatigue Level			
Low (30-52)	62 (92.5%)	0 (0%)	5 (7.5%)
Medium (53-75)	8 (9.8%)	8 (9.8%)	65 (80.4%)
High (76-98)	0 (0%)	6 (100%)	0 (0%)
Very High (99-120)	0 (0%)	56 (100%)	0 (0%)
Body Mass Index			
Underweight	2 (40%)	1 (20%)	2 (40%)
Normal	52 (73.3%)	10 (14%)	9 (12.7%)
Overweight	8 (13.6%)	25 (42.3%)	26 (44.1%)
Obesity	8 (10.6%)	34 (45.4%)	33 (44%)

*TJ: Trans Jateng, BRT: BRT Semarang City, AKDP: Inter-City Bus Transportation Services Between Semarang - Surakarta

Table 2. Kruskal-Wallis Difference Test Results

Variable	H	p-value	Interpretation
Age	35.842	< 0.001	There is a significant difference
Sleep Hours	114.675	< 0.001	There is a significant difference
Fatigue Level	186.432	< 0.001	There is a significant difference
Body Mass Index	64.278	< 0.001	There is a significant difference

BRT Semarang City drivers mostly experience very high fatigue.

For the Sleep duration variable with an H value of 114.675, this result confirms significant differences in sleep patterns among the three driver groups. These differences in sleep duration likely affect the fatigue levels experienced by each driver group. The H value for Body Mass Index (64.278) also shows significant differences in the nutritional status of drivers across the three routes. This finding aligns with descriptive data showing that Trans Jateng drivers have a much better BMI profile compared to the other two groups. Although the Age variable has the lowest H value (35.842) among the four variables, age differences between driver groups remain statistically significant. These age differences may contribute to variations in other characteristics such as physical endurance and sleep patterns.

These statistical test results confirm that the characteristics of drivers across the three bus routes are indeed significantly different, indicating that interventions or policies related to driver health and safety may need to be tailored based on the specific characteristics of each route group.

Table 3, which displays the results of the Mann-Whitney post-hoc test with Bonferroni correction, provides a deeper analysis of the specific differences between pairs of driver groups. For the Age variable, there is no significant difference between Trans Jateng and BRT Semarang City drivers ($p = 0.2481$). However, significant age differences are observed when both groups are compared with Inter-City Bus Transportation Services Between Semarang - Surakarta drivers ($p < 0.001$). This finding confirms that Inter-City Bus Transportation Services Between Semarang - Surakarta drivers do indeed have a significantly older average age compared to the other two groups, while Trans Jateng and BRT Semarang City drivers are in relatively the same age group.

For the Sleep duration variable, all comparison pairs show significant differences ($p < 0.001$). This indicates that the sleep patterns of drivers on all three routes are statistically different. BRT Semarang City drivers have the highest average sleep hours, followed by Trans Jateng, and Inter-City Bus Transportation Services Between Semarang - Surakarta with the lowest sleep hours.

For the Fatigue Level variable, all comparisons between groups also show very significant differences ($p < 0.001$). This confirms that the fatigue levels experienced by drivers on each route are indeed significantly different, with Trans Jateng drivers experiencing low fatigue, Inter-City Bus Transportation Services Between Semarang - Surakarta experiencing moderate fatigue, and BRT Semarang City experiencing very high fatigue.

Interesting findings were found in the Body Mass Index variable, where there is no significant difference between BRT Semarang City and Inter-City Bus Transportation Services Between Semarang - Surakarta drivers ($p = 0.6632$). However, both groups show significant differences with Trans Jateng drivers ($p < 0.001$). This result confirms that Trans Jateng drivers have a statistically different and better BMI profile compared to the other two groups, while BRT Semarang City and Inter-City Bus Transportation Services Between Semarang - Surakarta drivers have similar BMI profiles with a dominance of overweight and obesity nutritional status.

Overall, the results of this post-hoc test provide a more detailed understanding of the characteristics

Table 3. Results of the Mann-Whitney Post-hoc Test (with Bonferroni correction $\alpha = 0.05/3 = 0.0167$)

Variable	Route Comparison	p-value	Interpretation
Age	Trans Jateng vs BRT Semarang City	0.2481	Not Significant
	Trans Jateng vs AKDP Semarang – Surakarta	< 0.001	Significant
	BRT Semarang City vs AKDP Semarang – Surakarta	< 0.001	Significant
Sleep Hours	Trans Jateng vs BRT Semarang City	< 0.001	Significant
	Trans Jateng vs AKDP Semarang – Surakarta	< 0.001	Significant
	BRT Semarang City vs AKDP Semarang – Surakarta	< 0.001	Significant
Fatigue Level	Trans Jateng vs BRT Semarang City	< 0.001	Significant
	Trans Jateng vs AKDP Semarang - Surakarta	< 0.001	Significant
	BRT Semarang City vs AKDP Semarang - Surakarta	< 0.001	Significant
Body Mass Index	Trans Jateng vs BRT Semarang City	< 0.001	Significant
	Trans Jateng vs AKDP Semarang - Surakarta	< 0.001	Significant
	BRT Semarang City vs AKDP Semarang - Surakarta	0.6632	Not Significant

and conditions of drivers on each route. The pattern formed shows that Trans Jateng drivers have different characteristics from the other two groups in terms of sleep hours, fatigue levels, and BMI, while BRT Semarang City and I Inter-City Bus Transportation Services Between Semarang - Surakarta drivers have some similarities, especially in the respondents' BMI profile. These differences imply the importance of different approaches in handling health, welfare, and occupational safety for drivers on each route.

DISCUSSION

Driver Age

The age differential among intercity drivers presents complex safety implications that deserve careful consideration. Research demonstrates both advantages and challenges associated with older driver demographics. Findings on Intercity Bus Drivers Inter-City Bus Transportation Services Between Semarang - Surakarta Route The findings regarding intercity bus drivers significantly older (average age of 51.4 years) compared to their counterparts on Trans Jateng routes (43.1 years) and BRT in Semarang City (44.2 years), align with research conducted by (Chen *et al.*, 2024) The study found that long-distance bus drivers tend to have a higher average age than urban route drivers, with a difference of approximately 7–8 years (Tàpia-Caballero *et al.*, 2022). This phenomenon is explained as a result of placement systems in many transportation companies that prioritize experienced drivers for long-distance routes, as they are considered to have better adaptability and stress tolerance (Tavakoli Kashani and Besharati, 2021).

The Intercity Bus Drivers Inter-City Bus Transportation Services Between Semarang - Surakarta Route unique characteristics - including its 110 km distance, 2-3 hour duration, and diverse traffic conditions from urban congestion to highway driving - require drivers with extensive experience managing fatigue and maintaining concentration over extended periods. Unlike shorter urban routes that involve frequent stops and varied passenger interactions, this intercity route demands sustained attention and decision-making capabilities that older, more experienced drivers have developed through years of professional driving.

This age difference has significant safety implications. A meta-analysis study by Amoadu (2023) indicates that older drivers (>50 years) have a lower accident rate on long-distance routes compared to younger drivers but face higher health risks related to cardiovascular and metabolic diseases. Our BMI findings reveal that older drivers on this route show different fatigue patterns compared to younger urban drivers. Specifically, drivers over 50 on the Solo-Semarang route exhibited 15% higher physical fatigue scores but 23% lower stress-related fatigue, suggesting that while physical demands increase with age, psychological adaptation to route demands improves with experience. This contrasts sharply with urban BRT drivers who showed inverse patterns, indicating route-specific adaptation rather than general age-related performance decline.

Despite these advantages, research also identifies potential concerns associated with aging driver populations. A systematic review by Chen *et al.* (2019) mented age-related changes in reaction time, with professional drivers over 50 showing mean reaction times approximately 180 milliseconds slower than those under 40 in emergency scenarios. While professional experience partially mitigated these differences, the physiological effects of aging remained statistically significant.

Driver Sleep Patterns

The average recorded sleep duration was 7.4 hours with a standard deviation of 1.4 hours. A association was observed between sleep duration and work-adjusted energy expenditure, which could be explained through first-order logarithmic transformation (de Souza *et al.*, 2025). Significant variations in driver sleep patterns across the three studied routes reflect trends documented in previous literature. Inter-City Bus Transportation Services Between Semarang - Surakarta drivers, who average only 5.4 hours of sleep, confirm the findings of Lees *et al.* (2023), which show that intercity bus drivers in various countries experience chronic sleep deprivation, with an average sleep duration of 5.5–6 hours per day. explain this condition as a consequence of early morning departures, late-night arrivals, and difficulties in obtaining quality sleep at suboptimal resting locations (Liew and Flaherty, 2020; Bharadwaj, Edara and Sun, 2021).

The sleep duration of Trans Jateng drivers (an average of 7.0 hours), which is close to standard health recommendations, is consistent with research by Roche *et al.* (2021), which found that mass transportation systems with structured schedules and regular shift rotations tend to allow drivers

to maintain healthier sleep patterns compared to conventional transport systems (Jacquay, 2024). The World Health Organization and the National Sleep Foundation recommend 7-9 hours of sleep for adults to maintain optimal cognitive and physiological functioning. This finding becomes particularly significant when examined within the framework established by Roche *et al*. (2021), which identified structural elements in transportation systems that contribute to healthier sleep patterns.

An interesting phenomenon was observed among Semarang City drivers, who have an exceptionally high sleep duration an average of 9.5 hours. A similar pattern was found in a study by Tsai *et al.* (2023), which identified a group of urban bus drivers in Taiwan who slept for more than 9 hours on average, a condition linked to sleep disorders such as sleep apnea, poor sleep quality, and an increased risk of metabolic syndrome. Excessive sleep duration (>9 hours) among shift workers has been associated by Shell *et al.* (2022) with hypersomnolence, depression, and low-grade chronic inflammation.

The research findings adequate sleep and transportation safety is well-established in research literature. Determined that the risk of safety-critical errors increases by approximately 9.6% for each hour of sleep below recommended levels. Their modeling suggested that increasing average sleep duration from 6 hours to 7 hours across a transportation workforce could potentially reduce accident rates by up to 14%.

Driver Fatigue Levels

The complex nature of fatigue assessment may further explain the paradoxical findings Lees *et al.* (2023) conducted a methodological review of fatigue measurement approaches and found that subjective fatigue ratings are influenced by multiple factors beyond sleep, including psychosocial stressors, physical discomfort, and cognitive demands. Their analysis of occupational contexts found that urban drivers typically reported higher subjective fatigue ratings than other transportation workers, even when controlling for sleep parameters. This difference was attributed to the higher cognitive load, more frequent stops and starts, and more complex environmental monitoring demands of urban driving compared to highway-focused intercity routes.

The paradoxical finding that Semarang City drivers have the highest sleep duration yet also exhibit the highest levels of fatigue (80% very high) supports the concept proposed by Sherry *et al.* (2022), which suggests that the relationship between sleep duration and fatigue is non-linear and influenced by sleep quality. Their study found that individuals with prolonged (>9 hours) but fragmented sleep often report higher levels of fatigue compared to those who sleep 6–7 hours with good quality.

Inter-City Bus Transportation Services Between Semarang - Surakarta drivers, who experience moderate fatigue despite having the lowest sleep duration (5.4 hours), parallel a phenomenon described in the longitudinal study by. This study identified adaptation mechanisms in experienced long-distance bus drivers, where they develop tolerance to limited sleep schedules through behavioral modifications and effective coping strategies (Roche *et al.*, 2021). Meanwhile, the low fatigue levels among Trans Jateng drivers align with the hypothesis of Maghsoudipour *et al.* (2022), which suggests that a combination of adequate sleep duration (7–8 hours), consistent work schedules, and relatively stable routes contributes to lower fatigue levels among mass transportation drivers.

CONCLUSION

The findings on bus drivers across three Central Java routes (Trans Jateng, BRT Semarang City, and Inter-City Transportation Services Between Semarang-Surakarta) emphasize the importance of promoting adequate sleep duration among bus drivers. Thus, evidence regarding the relationship between sleep duration and energy expenditure will assist in planning healthcare interventions for bus drivers. Future research should utilize direct or indirect laboratory methods to measure fatigue and sleep duration to confirm the results of this study.

CONFLICT OF INTEREST

We confirm that no conflict of interest during this research.

AUTHORS' CONTRIBUTION

BYSN: Conceptualization, Methodology, Writing, Data Curation, Original Draft Preparation. VAP, FVR, LFM, EEW, BAP, PDM: Visualization, Writing & Review, MS: Software, Validation, and Editing.

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