Physical Work Environment, Shift Work, and Mental Workload as Determinants of Occupational Stress among Locomotive Depot Workers

Ainur Rochmah[1], Daru Lestantyo[1], Ida Wahyuni[1]
[1]Faculty of Public Health, Universitas Diponegoro, Semarang, Indonesia
Correspondence: **Ida Wahyuni**: Kampus Aceh Besar Jl. Soekarno-Hatta, Lagang, Aceh Besar, Indonesia; idawahyuni@lecturer.undip.ac.id

ABSTRACT
Locomotive depots are responsible for maintaining locomotives to ensure smooth railway operations. Inspection and maintenance workers play a direct role in this process and may be exposed to occupational stress due to various work-related factors. This study aimed to analyze factors associated with occupational stress among inspection and maintenance workers. A cross-sectional design was employed with total sampling of all 35 workers in the inspection and maintenance unit. Data were collected using the Work Stress Scale, physical work environment perception questionnaire, work relationship questionnaire, and NASA Task Load Index. Data were analyzed using the Spearman rank test. Most workers were middle-aged (65.7%), had good perceptions of the physical work environment (51.4%), and reported good work relationships (65.7%). More than half worked in shifts (57.1%) and had moderate mental workload (51.4%), while 34.3% experienced moderate levels of work stress, indicating that not all workers experienced stress. Significant associations were found between physical work environment perception ($p = 0.006$), shift work ($p = 0.012$), and mental workload ($p = 0.001$) with occupational stress. In conclusion, physical work environment, shift work, and mental workload are key determinants of occupational stress among locomotive depot workers. Effective management of these factors is essential to prevent adverse impacts.
Keywords: occupational stress; physical work environment; shift work; mental workload; locomotive depot workers

INTRODUCTION
Locomotive depots function as critical facilities responsible for the inspection, maintenance, and overall reliability of locomotives, which are the core components ensuring the safe and continuous operation of railway transportation systems. The effectiveness of railway services heavily depends on the operational readiness of locomotives; therefore, routine and systematic maintenance is essential to ensure that all mechanical and electrical components function properly. This is particularly important for the locomotive unit, which houses the primary engine responsible for generating the power required to move trains. As the demand for railway transportation continues to increase, the frequency and intensity of locomotive usage also rise, resulting in a greater need for maintenance activities at locomotive depots. Consequently, the performance and productivity of depot workers must be maintained at an optimal level, especially for those assigned to inspection and maintenance tasks, as they are directly involved in ensuring locomotive safety, functionality, and compliance with operational standards [1-5].

In carrying out locomotive maintenance activities, workers are exposed to a wide range of occupational hazards, including physical, mechanical, chemical, and psychosocial risks [6-10]. Among these, psychosocial hazards have gained increasing attention due to their significant impact on workers' mental health and overall well-being. Psychosocial risks often originate from both the physical and non-physical work environment, encompassing factors such as excessive workload, time pressure, shift work, interpersonal relationships, and organizational management practices. One of the prominent hazards identified in the physical work environment at the SMC Locomotive Depot is noise exposure. This noise is primarily generated by locomotive engines and supporting machinery operating within the depot area. Preliminary measurements conducted during peak working hours—particularly during daytime maintenance operations when worker activity is at its highest—revealed that noise levels exceeded 85 dBA. This level surpasses commonly accepted occupational exposure limits and may pose serious health risks to workers.

Exposure to excessive noise can lead to both audiometric and non-audiometric effects. Audiometric effects include hearing impairment or noise-induced hearing loss, while non-audiometric effects may manifest as physiological and psychological disturbances, such as fatigue, reduced concentration, irritability, and increased stress levels. These non-audiometric impacts are particularly important in high-risk work environments such as locomotive depots, where reduced concentration and impaired cognitive performance may increase the likelihood of workplace accidents and errors in maintenance procedures.

One of the key psychological outcomes associated with adverse working conditions is occupational stress. Work stress is defined as a condition arising from an imbalance between an individual's abilities, needs, or expectations and the demands or conditions of the job. This condition can occur across various types of occupations and industries [11]. According to the World Health Organization (WHO), approximately 8% of countries worldwide report cases of depression attributable to occupational factors, highlighting the global burden of work-related mental health issues. In 2014, the Labor Force Survey conducted in the United Kingdom reported 440,000 cases of work-related stress, with an incidence rate of 1,380 cases per 100,000 workers. Furthermore, occupational stress contributes significantly to productivity loss, with an estimated 43% of working days lost due to stress-related conditions [12].

In Indonesia, mental health issues related to occupational and social factors are also a growing concern. Data from the 2018 National Basic Health Research (Riskesdas) indicated that approximately 19 million individuals aged over 15 years experienced emotional mental disorders [13]. At the regional level, data from Central Java in 2023 showed that approximately 25% of the population experienced mental health disorders, reflecting a substantial public health challenge [14]. Several studies conducted in Indonesia have further demonstrated the prevalence of occupational stress in railway-related occupations. For instance, research conducted at locomotive depots in Jember and Banyuwangi found that all maintenance workers experienced moderate to high levels of work stress. Similarly, a study among railway crossing gatekeepers in Semarang reported that 61.7% of workers experienced occupational stress [15]. These findings indicate that railway workers represent a high-risk occupational group for stress-related conditions.

The occurrence of occupational stress is influenced by multiple factors, which can generally be categorized into individual characteristics and workplace-related psychosocial factors. Work stress arises when there is a mismatch between an individual's capacity and the demands placed upon them, particularly in environments characterized by high workload, time constraints, and inadequate support systems. Psychosocial hazards in the workplace include aspects of the physical work environment (such as noise, temperature, and lighting) as well as non-physical factors, including interpersonal relationships, job demands, recognition and reward systems, and organizational policies [16]. A study conducted among

workers at PT Surgika Alkesindo demonstrated that occupational stress was significantly associated with organizational, environmental, and individual factors, emphasizing the multifactorial nature of this issue [12].

Occupational stress not only affects workers' mental and physical health but also has broader implications for their social functioning and quality of life, making it a significant public health concern [17]. In addition, work stress has a direct impact on employee productivity and performance. Workers experiencing high levels of stress often show decreased concentration, reduced efficiency, and increased absenteeism. Since productivity is a dynamic aspect that can fluctuate over time, organizations must provide adequate support and create a conducive work environment to maintain optimal worker performance. Several studies have confirmed the relationship between occupational stress and productivity. For example, research conducted among finishing unit workers in a plastic manufacturing company in Ungaran found a significant association between work stress and work productivity [18]. Similarly, a study among employees of PT KAI UPT Malang Station demonstrated that occupational stress negatively affects employee performance; lower stress levels are associated with improved performance, whereas higher stress levels lead to decreased performance [19].

Findings from a preliminary study conducted at the SMC Locomotive Depot further support the presence of occupational stress among workers. Interviews with six inspection and maintenance workers revealed that 83.3% perceived their work environment as unsafe due to the presence of multiple occupational hazards, which contributed to decreased concentration during work activities. Additionally, 66.7% of the workers reported experiencing symptoms associated with occupational stress, particularly sleep disturbances, which may further impair their work performance and overall well-being.

Given the complex interaction between individual and environmental factors in contributing to occupational stress, it is important to conduct a comprehensive analysis of these determinants. Therefore, this study aims to examine the role of age and work environment factors—including physical work environment perception, work relationships, shift work, and mental workload—in relation to occupational stress among inspection and maintenance workers at the SMC Locomotive Depot. By identifying key contributing factors, this study is expected to provide evidence-based recommendations for improving workplace conditions and reducing the risk of occupational stress among locomotive depot workers.

METHODS

This study employed a quantitative research approach using a survey method with a cross-sectional design to examine the correlation between independent and dependent variables. Data on both the dependent variable (occupational stress) and independent variables (age, perceived physical work environment, work relationships, shift work, and mental workload) were collected simultaneously at a single point in time [20]. The study was conducted at the Semarang Poncol Locomotive Depot (SMC Locomotive Depot) over a period from October 2023 to April 2024. The study population consisted of all workers in the inspection and maintenance units at the depot, comprising 20 inspection workers and 15 maintenance workers. A total sampling technique was applied, whereby all eligible workers were recruited as study participants, resulting in a total sample of 35 respondents.

The dependent variable in this study was occupational stress. The independent variables included age, perceived physical work environment, work relationships, shift work, and mental workload. Data were collected directly from respondents using a structured questionnaire consisting of an identity form and several standardized instruments. Occupational stress was measured using the Workplace Stress Scale (WSS). Perceptions of the physical work environment were assessed using a physical work environment perception questionnaire. Work relationships were evaluated through a work relationship questionnaire, while mental workload was measured using the NASA Task Load Index. Shift work and age were obtained from respondent characteristics. Descriptive analysis was conducted to summarize the distribution of age, perceived physical work environment, work relationships, shift work, mental workload, and occupational stress among the workers. Bivariate analysis was performed to examine the relationships between independent variables and occupational stress using the Spearman rank correlation test, with a significance level (α) set at 0.05.

RESULTS

All participants were within the adult age range, with the majority classified as middle adulthood (65.7%). Slightly more than half of the workers (51.4%) reported a good perception of the physical work environment, which includes aspects such as noise, temperature, humidity, air circulation, and workplace organization. Similarly, most workers (65.7%) reported having good work relationships, indicating generally positive interpersonal interactions in the workplace. The 57.1% of workers were engaged in shift work, specifically those in the inspection unit, while the remaining workers in the maintenance unit followed regular working hours. In terms of mental workload, none of the workers reported a low workload; instead, the majority experienced a moderate level (51.4%), while the rest reported a high mental workload. For occupational stress, the largest proportion of workers fell into the moderate stress category (34.3%), and low stress (31.4%), indicating that while stress was present, it was not uniformly experienced at high levels across all workers (Table 1).

Table 1. Distribution of age, perceived physical work environment, work relationships, shift work, and mental workload

Variable	Category	Frequency	Percentage
Age	Early adulthood (19–30 years)	12	34.3
	Middle adulthood (31–45 years)	23	65.7
Perceived physical work environment	Good	18	51.4
	Poor	17	48.6
Work relationships	Good	23	65.7
	Poor	12	34.3
Shift work	Yes	20	57.1
	No	15	42.9
Mental workload	Moderate	18	51.4
	High	17	48.6
Occupational stress	Calm	4	11.4
	Low	11	31.4
	Moderate	12	34.3
	High	4	11.4
	Very high	4	11.4

Table 2 presents the results of cross-tabulation and Spearman rank correlation analysis examining the association between independent variables and occupational stress. Age was not significantly associated with occupational stress ($p = 0.394$), indicating that stress levels were relatively similar across age groups.

In contrast, perceived physical work environment showed a statistically significant association with occupational stress ($p = 0.006$) and a moderately strong positive correlation ($r = 0.459$). Workers who perceived their physical work environment as good did not report very high levels of stress, and most experienced low stress (44.4%). Conversely, among workers with poor environmental perceptions, 23.5% experienced very high stress. This suggests that poorer perceptions of the physical environment are associated with higher stress levels.

Table 2. Association between age, perceived physical work environment, work relationships, shift work, and mental workload with occupational stress

Variable	Category	Occupational stress										p	r
		Calm		Low		Moderate		High		Very high			
		Frequency	Percentage	Frequency	Percentage	Frequency	Percentage	Frequency	Percentage	Frequency	Percentage		
Age (adulthood)	Early	1	8.3	2	16.7	6	50.0	3	25.0	0	0.0	0.394	
	Middle	3	13.0	9	39.1	6	26.1	1	4.3	4	17.4		
Physical work environment	Good	3	16.7	8	44.4	6	33.3	1	5.6	0	0.0	0.006	0.459
	Poor	1	5.9	3	17.6	6	35.3	3	17.6	4	23.5		
Work relationships	Good	3	13.0	7	30.4	10	43.5	3	13.0	0	0.0	0.239	
	Poor	1	8.3	4	33.3	2	16.7	1	8.3	4	33.3		
Shift work	Yes	4	20.0	7	35.0	7	35.0	2	10.0	0	0.0	0.012	0.419
	No	0	0.0	4	26.7	5	33.3	2	13.3	4	26.7		
Mental workload	Moderate	4	26.7	7	46.7	3	20.0	0	0.0	1	6.7	0.001	0.547
	High	0	0.0	4	20.0	9	45.0	4	20.0	3	15.0		

Work relationships were not significantly associated with occupational stress (p = 0.239). However, descriptively, workers with good work relationships did not report very high stress, whereas a proportion of those with poorer relationships experienced higher stress levels, suggesting a potential but statistically unsupported trend.

Shift work demonstrated a significant association with occupational stress (p = 0.012) and a moderately strong positive correlation (r = 0.419). The inspection unit implemented a three-shift system (morning, afternoon, and night shifts), each lasting eight hours, while the maintenance unit operated on a fixed daytime schedule. Workers engaged in shift work tended to experience higher levels of stress compared to those with regular working hours, indicating that irregular work schedules may contribute to increased stress.

Mental workload showed the strongest association with occupational stress (p = 0.001) and a strong positive correlation (r = 0.547). Workers with higher mental workload were more likely to experience higher levels of stress. This finding indicates a clear dose–response pattern, where increasing mental workload corresponds to an increased risk of occupational stress among inspection and maintenance workers.

Overall, these findings suggest that workplace-related factors—particularly physical work environment, shift work, and mental workload—play a significant role in influencing occupational stress, whereas individual factors such as age and work relationships were not statistically significant in this study context.

DISCUSSION

The findings indicate that the majority of inspection and maintenance workers at the SMC Locomotive Depot experienced occupational stress, with the most prevalent level being moderate stress. Occupational stress can be understood as a condition in which workers experience emotional pressure when facing high job demands and various workplace constraints that may affect both their physical and psychological well-being [21]. Based on the Workplace Stress Scale (WSS) used in this study, one of the contributing factors to stress among workers was the perception of insufficient appreciation or recognition for the work they had performed. This lack of perceived reward or acknowledgment may reduce motivation and increase emotional strain. However, it is important to note that occupational stress does not always produce negative outcomes; in some cases, a certain level of stress may enhance alertness and encourage workers to perform more optimally under pressure [22,23]. This dual nature of stress suggests that its impact depends on intensity, duration, and individual coping capacity.

Most workers in the inspection and maintenance units were categorized within the middle adulthood age group. Age is generally considered an important factor influencing individual capacity, as increasing age and work experience are often associated with greater responsibility, improved competence, and stronger confidence in task performance [24]. Previous research by Zulkifli et al. reported that age was significantly associated with occupational stress, with older workers showing a higher risk of experiencing stress [25]. However, the findings of the present study differ, as both early adulthood and middle adulthood groups showed a higher proportion of workers experiencing stress compared to those in a calm condition. This indicates that age was not significantly associated with occupational stress in this context. Similar findings were reported by Zavanya et al. in construction workers, where no relationship between age and work stress was identified [24], as well as by Yuliani et al., who also found no significant association between age and stress levels [26]. This lack of association may be explained by the relatively distribution of job tasks across age groups in the depot, where both younger and older workers carry similar responsibilities and workloads, leading to comparable stress exposure.

The perception of the physical work environment emerged as an important factor influencing occupational stress. In general, the quality of the work environment and the level of comfort experienced by workers depend largely on how individuals perceive their surroundings. Poor physical work conditions—such as excessive noise, inadequate ventilation, uncomfortable temperatures, and disorganized workspaces—can impair concentration, increase fatigue, and elevate stress levels, ultimately reducing productivity [21]. In this study, although slightly more than half of the workers reported a good perception of their physical work environment, all workers acknowledged that noise levels in the depot were high. The findings demonstrate that poorer perceptions of the physical work environment were associated with higher levels of occupational stress. This is consistent with research by Safitri et al., which found a positive correlation between workers' perceptions of their work environment and stress levels. Perception of the physical work environment reflects how workers evaluate the overall physical conditions, including infrastructure and workplace facilities, which in turn influence their attitudes and behaviors at work. Negative perceptions tend to amplify stress, whereas positive perceptions may serve as a protective factor that helps reduce stress levels [27].

Work relationships, which represent social support from colleagues and supervisors, are generally considered a key psychosocial factor in the workplace. Establishing good work relationships requires effective communication and mutual understanding among workers and management. Such relationships can provide emotional support, foster a sense of belonging, and contribute to a healthier work environment [28]. However, the present study found no significant relationship between work relationships and occupational stress. There was no substantial difference in the proportion of workers experiencing calm conditions between those with good and poor work relationships. This finding contrasts with the study by Tumaruddin et al., which reported a negative relationship between social support and work stress, indicating that higher social support is associated with lower stress levels [29]. Similarly, Utomo et al. found that workers with poor relationships were 5.5 times more likely to experience occupational stress compared to those with good relationships [30]. Despite these contrasting findings, the results of the current study align with research by Lestari et al., which reported no significant relationship between interpersonal communication and work stress. In that study, interpersonal communication was defined as the ability of workers to exchange feedback effectively with supervisors and colleagues [31]. The

absence of a significant association in this study may suggest that other factors, such as workload and environmental conditions, play a more dominant role in influencing stress among these workers.

Interestingly, the findings related to shift work indicate that workers without shift schedules experienced higher levels of stress compared to those engaged in shift work. All workers without shift work reported experiencing some level of stress, whereas not all shift workers did. This may be explained by the structured nature of shift schedules at the depot, where inspection workers follow a rotating three-shift system (morning, afternoon, and night), each lasting eight hours. Such structured scheduling allows for adequate rest periods outside working hours, enabling workers to recover physically and mentally before returning to work. In contrast, maintenance workers who do not follow a shift system may experience a heavier and more continuous workload without equivalent task distribution. Additionally, shift-based work divides responsibilities across multiple teams, thereby reducing the burden on individual workers. A well-organized shift system can therefore support better workload management and reduce stress levels [32]. Conversely, workers without shift arrangements may face greater cumulative responsibilities, increasing their susceptibility to stress [33].

Mental workload was identified as the most influential factor associated with occupational stress. None of the workers reported a low level of mental workload; instead, most experienced moderate to high levels. The primary contributor to mental workload in this context is physical demand, as inspection and maintenance tasks require direct involvement in locomotive servicing, which is both physically and cognitively demanding. In addition to physical effort, workers must also integrate mental processes such as attention, decision-making, time management, and performance monitoring. Excessive and sustained mental workload can hinder task completion and reduce efficiency, as it may lead to decreased concentration and increased fatigue. This can ultimately affect the quality of work outcomes.

The findings of this study show that all workers with high mental workload experienced occupational stress, whereas among those with moderate mental workload, some workers remained in a calm condition. This suggests a clear trend in which increasing mental workload corresponds to a higher likelihood of experiencing stress. These results are consistent with the study by Choirunnisa, which found a relationship between mental workload and worker performance, with most workers experiencing moderate workload but not achieving optimal performance outcomes [34]. Furthermore, research by K. Trisminingsih among train drivers in PT KAI demonstrated a strong relationship between mental workload and occupational stress, where workers with higher mental workload were more likely to experience higher stress levels. In contrast, those with moderate workload did not experience high levels of stress [35].

Overall, these findings highlight that occupational stress among inspection and maintenance workers is a multifactorial issue, with mental workload, physical work environment, and work system arrangements (such as shift work) playing more prominent roles than individual characteristics like age or interpersonal relationships.

CONCLUSION

This study confirms that perceived physical work environment, shift work, and mental workload are key determinants of occupational stress among inspection and maintenance workers, while age and work relationships are not significant predictors. Workers with poorer perceptions of the physical environment, exposure to shift work, and higher mental workload tend to experience higher levels of stress. Although most workers reported moderate stress levels and not all experienced stress, these findings highlight the importance of workplace conditions as the main contributors to occupational stress. Therefore, improving physical work environment conditions, optimizing shift systems, and managing mental workload are essential to reduce the risk of occupational stress.

Ethical consideration, competing interest and source of funding

-This study received ethical approval from the Health Research Ethics Committee of the Faculty of Public Health, Universitas Diponegoro (KEPK FKM UNDIP), with approval number: 130/EA/KEPK-FKM/2024. All participants were informed about the purpose of the study, and their participation was voluntary. Confidentiality and anonymity of the respondents were ensured throughout the research process.
-There is no conflict of interest related to this publication.
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