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Systemic Model of Driver Fatigue on Extreme Routes: PLS-SEM Analysis of Supervisor Support and Organizational Justice

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Abstract. Driver fatigue is a critical safety concern for long-distance bus operations, particularly on the extreme route of Bima–Mataram. The study examines the impact of supervisor support and perceived penalty fairness on drivers' compliance with rest periods and levels of fatigue. Data from 114 drivers were analyzed using Partial Least Squares Structural Equation Modeling (PLS-SEM) and Importance–Performance Map Analysis (IPMA). The results indicate that supervisor support positively affects rest compliance ($\beta = 0.38$), which in turn decreases fatigue ($\beta = -0.35$); penalty fairness has a negative effect on fatigue ($\beta = -0.29$) directly. Accordingly, IPMA provides evidence that supervisor monitoring and penalty system consistency are high-impact yet underperforming priorities. These findings reveal that fatigue acts as a systemic variable developed by organizational and policy factors. The implications point out the necessity of improving supervisory capacity, penalty system reform to ensure fairness and transparency, and the integration of fatigue detection technologies to enhance safety interventions on high-risk routes.

Keywords: driver fatigue, extreme routes, long-distance buses, organizational justice, supervisor support.

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1. Introduction

Work fatigue is a critical problem in land transportation safety, especially in the long-distance transportation sector, with its shift work systems, time pressure, and unfavorable road conditions. According to the KNKT, more than 60% of land transportation accidents in Indonesia involve human factors, including driver fatigue as the main factor [1]. This condition worsens due to the absence of national regulations strictly regulating drivers' work and rest time limits, as in other modes of transportation, such as aviation and shipping [22].

Occupational fatigue refers to decreased effectiveness and endurance of performance of a certain duration, which may result in reduced concentration, alertness, and decision-making capability [2] [3]. An investigation conducted by Widyanti et al. found that 66.7% of bus drivers experienced occupational fatigue, 93% of whom also had symptoms of both physical and mental fatigue [2]. Contributing factors include sleep quality [4], nutritional status, driving duration, and mental workload [18].

Supervisor support and perceptions of penalty fairness are the two most important psychosocial variables affecting driver safety behavior. Empathetic and active supervisory involvement in the field enhances compliance with rest needs and mitigates psychological distress [5], [6]. On the other hand, a fair penalty system promotes compliance and less resistance to safety regulations [7] [9].

Msuya and Kumar [5] noted that supervisor support enhances safety behavior significantly in transport operations, while Kogler et al. [6] highlighted the benefits of transparency and procedural fairness in penalty systems in securing compliance and mitigating emotional distress.In Indonesia, Ahmad et al. [11] conducted a report revealing that the safety violation on inter-island routes has a close connection with irregular rest schedules and little engagement of supervisors in the field.

Although both international and national literature have explored these aspects separately, few studies have integrated supervisor support, penalty fairness, rest compliance, and subjective fatigue into a comprehensive structural model. This study, therefore, aims to analyze the effect of supervisor support on rest compliance, examine the influence of perceived penalty fairness on subjective fatigue, and assess the mediating role of rest compliance in the relationship between supervisor support and fatigue.

The Partial Least Squares Structural Equation Modeling approach was applied to explore causal pathways among latent constructs [[9] [10], while IPMA was employed to identify priority indicators requiring improvement to strategically mitigate fatigue risk [12]. By so doing, the study seeks to make a theoretical contribution to the development of psychosocial-based occupational safety models and also give practical recommendations to transportation managers in the elaboration of more effective and humane interventions.

In spite of the growing literature on occupational fatigue, integrative models considering psychosocial and systemic factors, as well as ergonomic elements, are still scant, especially in the context of extreme routes like Bima-Mataram. In fact, most studies have addressed separately the issues of supervisor support, organizational justice, and/or fatigue. This has resulted in limited knowledge regarding the extent to which these constructs interrelate in influencing compliance and safety outcomes. This study seeks to present a more holistic model of land transportation safety under extreme operational conditions by conceptualizing fatigue as a psychosocial and systemic construct.

The relationships between these constructs are summarized in Figure 1 below, which serves as the basis for formulating hypotheses and empirical testing.

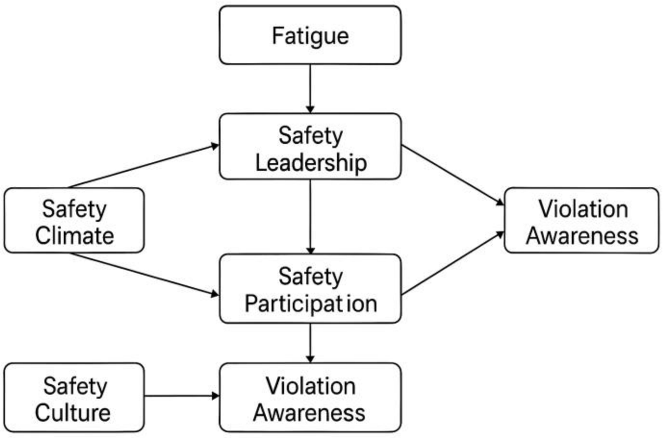

Figure 1. Conceptual Path Diagram of Driver Safety

Figure 1 shows the structure of the relationships between the main constructs in this study. Safety Leadership is the initial construct that influences two important aspects: Safety Climate and Safety Participation. Safety Climate is directly influenced by Safety Leadership, while Safety Participation is influenced by the combination of Safety Leadership and Safety Culture. Furthermore, Safety Participation has a direct influence on Volation Awareness, which is the main dependent variable in the model. On the other hand, Fatigue functions as a moderator construct that influences the strength of the relationship between Safety Participation and Volation Awareness. This moderator relationship is depicted by the dotted line from Fatigue to Volation Awareness.

Overall, this model represents a systemic approach to driver safety, where organizational factors (leadership and culture), work climate, active participation, and psychological conditions interact to shape awareness of violations. This model is designed to be empirically tested using PLS SEM and Multi-Group Analysis approaches, particularly in the context of extreme routes such as Bima–Mataram.

Based on the theoretical framework and research gap, the following hypotheses are proposed:

- H1: Supervisor support has a positive effect on rest time compliance.
- H2: Rest time compliance has a negative effect on subjective fatigue.
- H3: Supervisor support has an indirect effect on fatigue through rest time compliance.
- H4: Perceived fairness of the penalty system has a negative direct effect on fatigue.
- H5: Supervisor support has a stronger effect on rest time compliance in the high-fatigue group compared to the low-fatigue group.
- H6: Perceived fairness of the penalty system has a stronger effect on fatigue in the high-fatigue group compared to the low-fatigue group.

2. Method

This study employed an explanatory quantitative design to examine the causal relationships between supervisor support, perceived fairness of the penalty system, compliance with rest periods, and subjective fatigue among long-distance transport drivers. This approach is appropriate for analyzing complex phenomena involving interactions between psychosocial and behavioral variables in the context of land transport occupational safety [17].

The analytical method applied was Partial Least Squares Structural Equation Modeling (PLS-SEM), which is suitable for models with high complexity, moderate sample sizes, and non-normally distributed data [9] [10]. PLS-SEM also enables the testing of mediation effects and group comparisons through Multi-Group Analysis (MGA), which constitutes an important component of this study [23].

2.1. Research Location and Population

This research was carried out on the Bima–Mataram intercity and interprovincial (AKAP) bus route, which has a long duration of travel time and high work demands with a rotating night shift system. The route is considered a high-risk corridor because of the dominance of night driving and the very minimal rest facilities along the route [22]. The research population included all the active bus drivers of Bima–Mataram during 2024.

2.2. Sampling Techniques and Inclusion Criteria

The sampling technique used a purposive sampling approach, selecting respondents based on specific criteria relevant to the research objectives. Inclusion criteria included at least one year of work experience, involvement in alternating night and day shifts, and experience receiving company penalties in the past six months. A total of 114 drivers met the requirements and expressed their willingness to participate. Data completeness reached 95%, allowing all respondents to be included in the analysis.

The response rate was 95%, with incomplete questionnaires excluded from the analysis. Exclusion criteria encompassed drivers with less than one year of experience, those undergoing medical treatment for sleep disorders, and individuals who did not provide informed consent. Ethical clearance was obtained from the Tarumanagara University Research Ethics Committee, and all participants provided written informed consent before data collection.

2.3. Construction Instruments and Measurements

The research instrument was a structured questionnaire developed based on previous research and adapted to the local context. The questionnaire used a 5-point Likert scale (1=strongly disagree, 5=strongly agree) to measure respondents' level of agreement with statements representing latent constructs [17].

The four main constructs measured are: Supervisor Support (SUP), Perceived Penalty Fairness (PEN), Compliance with Rest Time (RST), and Subjective Fatigue (FAT). The SUP indicator is adapted from Msuya and Kumar [4], who emphasize the importance of supervisor support in improving driver work performance and well-being. The PEN construct refers to the study of Kogler et al. [5], which underlines the role of procedural justice in improving regulatory compliance. The RST indicator refers to Lee and Kim [18], who show that adherence to rest schedules plays a significant role in preventing fatigue accumulation. Meanwhile, the FAT construct refers to Van Hooff and Geurts [3] and Widyanti et al. [2], which measures fatigue in physical, emotional, and cognitive dimensions.

Each of these constructs was measured through items drawn from sources whose validity has already been established. Supervisor Support (SUP) included items such as "My supervisor monitors whether I take sufficient rest breaks," adapted from Msuya and Kumar [4]. Perceived Penalty Fairness (PEN) employed items from Kogler et al. [5], for example, "Penalties are applied consistently regardless of who commits the violation." Rest Time Compliance (RST) was measured through items adapted from Lee and Kim [18], for example, "I always follow the mandated rest schedule even under time pressure." Subjective Fatigue (FAT) was measured through questions inspired by Van Hooff and Geurts [3] and Widyanti et al. [2], such as "I often feel physically exhausted after long trips." Items were all measured on 5-point Likert scales anchored with 1 = strongly disagree to 5 = strongly agree.

2.4. Data Analysis Techniques

The data analysis was performed using SmartPLS software, version 4.0 [9]. Analysis of the data followed the three stages. First, the measurement model testing comprised the evaluation of the outer model in terms of the validity and reliability of the latent construct(s). With respect to convergent validity, the AVE for all constructs should exceed 0.50, while internally reliable constructs should show Composite Reliability (CR) values above 0.70 [10]. Finally, with regard to discriminant validity, HTMT should be less than 0.90 [10]. Table 1 shows the complete results of the measurement model, including factor loadings, cross-loadings, and VIF values for all items. All item loadings exceeded the threshold value of 0.70; all cross-loadings showed indicators that were distinct; and the VIF value for each was below 3.3, thus confirming no issues with multicollinearity.

The second step was to assess the structural model, that is, the inner model, in order to test the cause-and-effect associations among the latent constructs. In this respect, bootstrapping with 5,000 subsamples was used as a resampling technique to improve the precision of statistical significance estimates [9] [23]. Bias-corrected and accelerated (BCa) bootstrap confidence intervals were created using 5,000 resamples and 95% confidence intervals were reported for all path coefficients, ensuring robust significance testing of the paths.

These parameters were path coefficients, β; T-values; P-values; and mediation and moderation effects. The final step used the Importance–Performance Mapping Analysis to identify the indicators perceived to have a strong influence on the outcome variable while showing low performance [12]. As a consequence, IPMA enables strategic directions to build better interventions because it identifies those areas that need priority with the highest potential impact on drivers' fatigue. Performance scores were scaled from 0 to 100. Consequently, the scaling procedure of Sarstedt et al. [12] was followed to ensure transparency and comparability among the indicators.

In order to investigate distinctions between groups of respondents, MGA was performed with respect to levels of fatigue. The assignment of respondents to two groups was done according to the level of their fatigue: high fatigue (the FAT score was above 80) and low fatigue (up to 80). This analysis was necessary to test whether the effects of supervisor support and penalty fairness on rest compliance and fatigue levels significantly differ among the groups [23]. Before MGA, measurement invariance was tested by means of the Measurement Invariance of Composite Models (MICOM) procedure, and both configural and compositional invariance across the two fatigue groups were confirmed. The cutoff for dividing respondents into high- and low-fatigue groups is 80 points on the fatigue scale (fatigue is high if the score is above 80 and low for a score of 80 or less). IPMA enables the mapping of other relevant indicators that affect the outcome variable but for which the performance is low, which can therefore be taken into account when designing targeted intervention strategies according to priorities.

3. Results and Discussion

3.1. Measurement Model

Table 1. Measurement Model Results

Construct / Indicator	Loading	Cross-Loading Range	AVE	CR	VIF
Supervisor Support (SUP)			0.67	0.89	
SUP1: Supervisor monitors rest compliance	0.81	0.32–0.44			2.10
SUP2: Supervisor provides feedback	0.84	0.28–0.41			2.05
SUP3: Supervisor shows empathy	0.79	0.30–0.39			1.96
SUP4: Supervisor enforces rules fairly	0.83	0.29–0.42			2.18
Penalty Fairness (PEN)			0.65	0.87	

PEN1: Penalties applied consistently	0.80	0.34–0.46			2.11
PEN2: Penalties perceived as fair	0.82	0.33–0.45			2.04
PEN3: Penalties communicated transparently	0.78	0.31–0.43			1.92
PEN4: Penalties improve driver awareness	0.81	0.30–0.40			2.09
Rest Time Compliance (RST)			0.69	0.88	
RST1: Follows scheduled breaks	0.83	0.28–0.39			2.12
RST2: Uses rest facilities when available	0.85	0.27–0.36			2.07
RST3: Records accurate rest logs	0.81	0.29–0.37			2.01
Fatigue (FAT)			0.71	0.90	
FAT1: Feels physically exhausted	0.84	0.33–0.41			2.20
FAT2: Difficulty maintaining concentration	0.86	0.35–0.43			2.18
FAT3: Experiences emotional strain	0.82	0.34–0.42			2.09
FAT4: Feels cognitively drained	0.85	0.36–0.44			2.11

Table 1 depicts the measurement model assessment results for all latent constructs. All items demonstrated loadings well above the threshold of 0.70, which is indicative of strong indicator reliability. The cross-loading values supported the discriminant validity of the indicators, since all indicators had higher loadings on the respective constructs than on other constructs. The AVE values ranged from 0.65 to 0.71, thus above the minimum threshold level of 0.50, and all CR values ranged between 0.87 and 0.90, hence exceeded the standard threshold value of 0.70 and thus showed construct reliability. Each VIF score for all the indicators was well below the threshold value of 3.3, indicating no multicollinearity issues. Overall, these findings support that the measurement model has sound convergent validity, discriminant validity, and reliability and presents an appropriate base for subsequent analysis of the structural model.

3.2. Fatigue as a Systemic Variable in Transportation Safety

Research conducted by Xie et al. [24] and Zhang et al. [25] highlights technology-based approaches to detect driver fatigue in real time based on vehicle data and facial feature analyses that offer some substantial potential in enhancing early warning systems along with implementing data-driven safety interventions.

Work fatigue in land transportation cannot be viewed solely as a physiological condition but as a systemic variable that describes the general efficiency of safety management. This study found that over 60% of drivers operating the Bima-Mataram route reported high levels of fatigue, implying an accumulation of pressure at work, a lack of rest opportunities, and psychosocial support. This corresponds to the results of Van Hooff & Geurts [3], who denote that fatigue is cumulative and may result in burnout if not managed.

In extreme route conditions, fatigue should not be considered purely as the driver's private matter. It is a result of an interaction between high demands at work and poor recovery resources [6]. With a travel time of 12 to 14 hours, over a mountainous route, and with prevailing nocturnal operations, the Bima–Mataram route reflects very poor ergonomic and physiological conditions that maximize circadian rhythm disruption [21]. High levels of fatigue significantly lower the ability of drivers to anticipate road curves, stay focused on sharp uphill grades, and manage their vehicles through steep downhill grades.

Reports by WHO [22] and KNKT [1] have continuously indicated that fatigue is one of the major factors in land transportation accidents, especially at night and during long-distance drives. However, within the Indonesian context, in regard to safety management practices, fatigue is still often viewed as an individual problem rather than a systemic consequence of unsafe work conditions. As such, occupational safety strategies that do not deal explicitly with fatigue usually fail to deter rule violations and to decrease accident rates.

3.3. *The Role of Supervisor Support and Perceptions of Fairness in Reducing Job Burnout*

Results of this study point out the key findings, such as the fact that supervisor support influences adherence to rest periods ($\beta = 0.38$), which in turn decreases subjective fatigue ($\beta = -0.35$). Quantitative results are supported by the IPMA visualization shown in Figure 2, showing the gap in the importance-performance of each factor. Figure 2 presents a graphical representation, and from this, targeted interventions to minimize the risk for fatigue-related misconduct were identified.

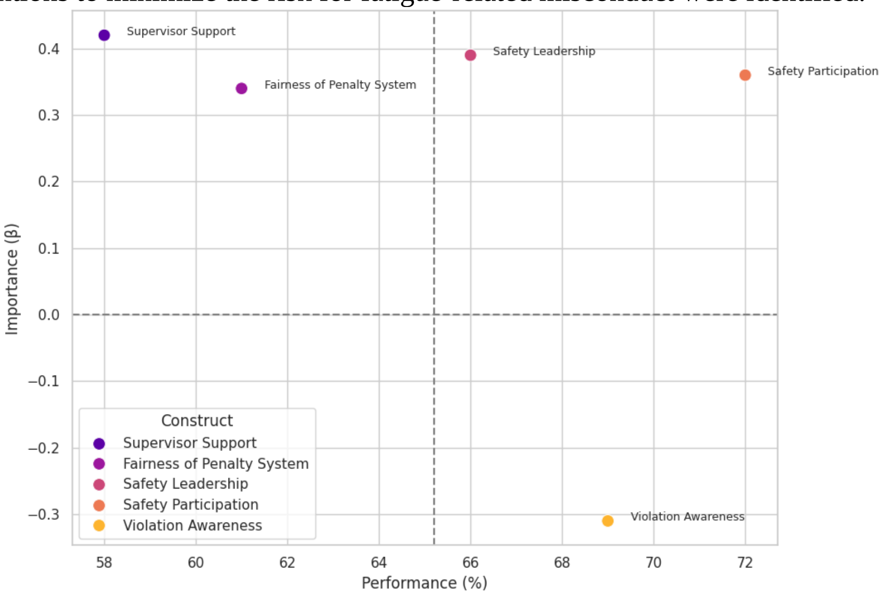

Figure 2. Importance-Performance of Construction Safety on the IPMA Chart

Figure 2 presents results that are in line with the JDR theoretical framework, which states that high work demands are better tolerated when combined with social support from supervisors [6]. In the context of extreme routes, this support goes beyond technical aspects to emotional recognition and motivational reinforcement and the capability to manage conflicts in the field [4]. In its turn, the Job Demands–Resources theoretical framework considers that job burnout occurs when work demands are not counterbalanced by adequate physical and psychosocial resources, a situation highly applicable to drivers who usually work under time pressure and with high workloads and lack of organizational support. On the other hand, Organizational Justice theory provides a conceptual framework under which an employee develops perceptions about an organization's fairness and encompasses procedural, distributive, and interactional dimensions. These justice perceptions influence drivers' levels of fatigue and their motivation to adhere to safety regulations.

These findings substantiate the Job Demands–Resources model, where supervisor support acts as a crucial job resource mitigating the negative impact of high job demands on fatigue. The indirect effect through rest time compliance illustrates how resources not only buffer demands but also enable adaptive behaviors aligned with safety protocols. Similarly, the direct effect of penalty fairness on fatigue reflects the principles of Organizational Justice theory, emphasizing that procedural and distributive fairness shape drivers’ stress appraisal and compliance motivation. Integrating both theories, the model demonstrates that systemic and psychosocial resources jointly regulate fatigue outcomes, thereby advancing theoretical understanding of safety behavior in high-risk transportation contexts.

Empirical evidence has established that supervisors actively and empathetically supporting an employee will increase adherence to rest protocols, which in turn decreases physical and mental fatigue. The result is also in line with the research of Msuya and Kumar [4], whereby it is established that supervisors being directly involved in the field operations improve the safety of drivers significantly. In a similar setting, Ahmad et al. [11] also found evidence in Bima–Mataram bus transportation that supervisors who actively monitor activities and provide interpersonal communication help in minimizing safety violations.

On the other hand, perceived fairness of the penalty showed a direct influence on fatigue: $\beta = -0.29$, independent of mediation through rest compliance. This supports the principles of Organizational Justice theory, especially on procedural and distributive fairness [7]. When the drivers perceive the penalty system as fair, consistent, and open, then the job stress is lessened and their compliance with safety regulations increases [5].

The mediation analysis confirms that rest time compliance partially mediates the effect of supervisor support on fatigue, indicating that supportive supervisors reduce fatigue not only directly but also indirectly by ensuring rest protocol adherence. In contrast, the moderation analysis shows that fatigue levels influence the strength of the relationship between organizational variables and compliance, suggesting that interventions may need to be tailored differently for high-fatigue and low-fatigue groups.

Education and learning-based penalty systems can increase perceptions of control and responsibility, ultimately reducing burnout and increasing compliance. Kogler et al. [5] showed that perceived fairness of organizational systems was linked to psychological recovery and work motivation. In extreme routes, perceptions of fairness become even more important, as high time pressure and risk exposure may further increase drivers' psychological strain when systems are perceived as nontransparent or inconsistent.

Supervisor support and perceived fairness of the penalty system have strategic positions as constructs of high importance but with low actual performance. The IPMA results suggested that indicators related to supervisor monitoring of rest compliance and consistent penalty enforcement are strong in producing effects on fatigue but have performances below 60% [12]. These results encourage these constructs to be made priorities in intervention strategies.

From an engineering perspective, these IPMA findings translate into concrete interventions. For example, strengthening supervisor monitoring can be operationalized through digital logging systems and GPS-based compliance trackers, while penalty system consistency can be supported by automated violation recording systems. Furthermore, fatigue detection technology such as real-time eye-tracking or vehicle telemetry analysis provides engineering solutions to complement psychosocial interventions, ensuring that fatigue management is data-driven and responsive to operational realities.

3.4. Fatigue Detection Technology as a Preventive Intervention

Technology-based approaches have been increasingly important for early detection and management of driver fatigue in recent years, with both extreme routes and driver workloads increasing in complexity. Xie et al. [124] proposed that vehicle-generated data can find fatigue patterns using the Attention BiLSTM model. Similarly, Zhang et al. [26] developed a fatigue detection system based on facial feature analysis, such as EAR and MAR, which provides real-time driver condition monitoring.

The integration of such technologies could be of great benefit in developing early warning systems and enhancing safety interventions, especially on high-risk routes like Bima-Mataram. Systemically, fatigue detection technology would complement psychosocial and structural interventions; it would also support data-driven decision-making processes among supervisors and operational management teams.

3.5. Importance-Performance Mapping and Its Implications for Adaptive Policy

The IPMA in Table 2 provides strategic insights at the level of constructs and their indicators that are highly influential in relation to driver fatigue yet demonstrate suboptimal performance in practice. At the construct level, Table 1 shows how IPMA was used to identify priority areas for intervention relating to subjective fatigue among long-haul drivers operating on extreme routes. Two central constructs were in particular focus in this analysis: supervisor support and perceived fairness of the penalty system.

The findings revealed that supervisor support has the strongest influence on fatigue, with a β-value of 0.42, while having the lowest performance level, which was 58%. It is therefore considered one of the highest priorities for intervention. These findings emphasize how reinforcing the role of supervisors in psychosocial and operational support to drivers can help reduce driver fatigue. Interventions are suggested in terms of micro-leadership training, two-way communication development, and the use of empathy-based monitoring mechanisms.

Perceptions of fairness in penalty systems also demonstrated a notable influence (0.34) with moderate performance (61%), placing them within the high-priority category. Ambiguity or inconsistency in sanction implementation can heighten work-related stress and contribute to burnout. Therefore, a more transparent, consistent, and communicative reformulation of penalty policies is needed.

Other constructs included safety leadership, 0.39; performance of 66%, and violation awareness, -0.31; performance of 69%, which respectively showed a medium relevance and were ranked as an ongoing intervention. Safety participation, 0.36, though at high performance, had a relatively lower influence on burnout; hence it was not emphasized for direct intervention.

Table 2. IPMA Results on Driver Violations

Build	Importance (β)	Performance (%)	Intervention Priorities
Supervisor Support	0.42	58	Tall
Criminal Justice System	0.34	61	Tall
Safety Leadership	0.39	66	At the moment
Safety Participation	0.36	72	Low
Awareness of Violation	-0.31	69	At the moment

At the indicator level, from Table 3, it can be observed that monitoring of compliance with rest by supervisors and the consistency of penalty systems show high influence scores (greater than 70) but performance levels less than 60%. This highlights the need to enhance supervisory capacity in monitoring and interpersonal communication along with reforming the penalty system to become more transparent and educational [5] [12].

Table 3. IPMA Priority Intervention Indicators

Indicator	Influence	Indicator
Supervisors monitor rest compliance	75	58
Supervisor provides physical attention	72	55
Transparent penalty system	70	60
Consistent penalty system	68	59

The IPMA analysis of specific indicators in Table 3 shows that four key elements have a high impact on long-distance driver fatigue, yet actual performance remains below the optimal threshold. These findings provide evidence-based interventions to improve occupational safety on extreme routes.

The indicator of supervisors monitoring rest period compliance ranked highest in terms of influence (75%) but showed low performance (58%). This indicates that monitoring rest periods is a crucial determinant in reducing fatigue, but has not been consistently implemented in the field. Interventions aimed at strengthening monitoring systems and training supervisors are crucial.

Supervisors' provision of physical attention showed an influence of 72% and performance of 55%, suggesting that direct physical support, such as health monitoring and rest facility provision, significantly contributes to maintaining work stamina but remains inadequately applied.

Two indicators related to penalty systems, namely transparency (70% influence, 60% performance) and consistency (68% influence, 59% performance), demonstrate that fairness perceptions in sanction enforcement substantially affect psychological strain and fatigue levels. Discrepancies between expectations and actual enforcement can intensify work pressure and compromise safety performance.

Taken together, these four indicators are positioned in the high-priority intervention zone and thus provide the empirical basis for a systemic approach integrating supervision, physical support, and penalty policy reform as effective and sustainable ways to reduce driver fatigue.

Indicators influencing scores above 70 but with performance scores below 60, such as supervisors' attention to drivers' physical condition and monitoring of rest schedule adherence, should be given priority. Therefore, transportation companies should develop supervisor competence, especially in monitoring and communicating effectively. Training programs emphasizing psychosocial support and fatigue management are effective long-term measures aimed at improving workplace safety.

3.6. Policy Implications: Designing Safety Systems for Extreme Routes

Safety policy approaches need to be adaptive and empirically based within these extreme routes like Bima–Mataram. The geographical and operational features of this route, which involves hill sections, long travel times, limited number of resting places, and high-frequency night driving, demand context-specific intervention strategies [22]. Figure 3 summarises the critical segments with long downgrades and sharp turnings that require specific attention from safety policy design, according to a route risk infographic compiled by the NTB Transportation Agency [22]. Four major kinds of risks drivers are exposed to underpin a geographical and temporal responsive safety strategy under real field conditions.

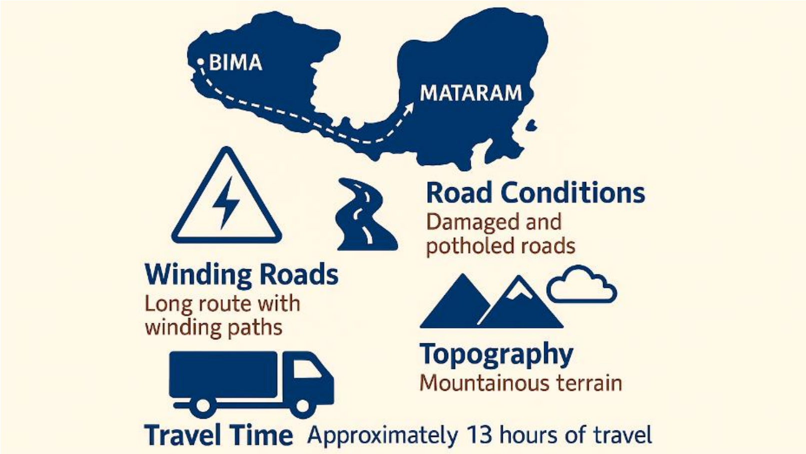

Figure 3. Bima–Mataram Route Risk Infographic

Figure 3 shows the significant four challenges that drivers on the Bima–Mataram route are facing: winding roads, poor surface conditions, long travel durations, and mountainous terrain that requires sustained concentration. These factors are not independent but interlink with one another, increasing the effects of fatigue on safety behavior. Therefore, in this study, the geographical and operational context becomes an integral part of the occupational safety model. Understanding the root causes of the issues, namely the ergonomic and environmental characteristics inherent in extreme routes like the Bima-Mataram route, will underpin the formation of contextual and evidence-based safety policies.

Table 4 summarizes the specific geographic and operational dimensions impacting driver fatigue and safety risk directly, serving as a reference for adaptive and field-responsive interventions.

Table 4. Characteristics of the Bima–Mataram Route and Ergonomic Risks

Route Characteristics	Impact on Drivers	Safety Implications
Duration 12 to 14 hours	Accumulation of physical and mental fatigue	Decreased concentration and alertness
Hilly roads and ravines	High cognitive load, visual stress	Risk of accidents due to anticipation errors
Minimal rest facilities	It's hard to recover from fatigue	Chronic fatigue and rest violations
Dominance of night travel	Circadian rhythm disorders	Decreased motor performance and reactions

3.7. Contextual Reflection: Inter-Island Transportation and Systemic Challenges

The work system of drivers operating the Bima–Mataram route, for example, is still mainly concerned with operational efficiency and time optimization, with a minimum concern for ergonomically grounded safety principles. Many firms continue to assign drivers to duty schedules without paying due attention to circadian rhythms, rest requirements, or even psychological fitness. Fatigue is often seen as an individual failing rather than the result of structural vulnerabilities in the design of work. In practice, however, fatigue arises from the interaction between excessive resource demands of a job and lack of adequate recovery resources [3].

In land transportation systems without strong regulatory frameworks that control work and rest hours, fatigue remains a chronic, difficult-to-mitigate hazard. Figure 4 depicts a systemic model with fatigue positioned as a key link in the occupational safety chain. The direct implication of this model is that safety interventions failing to address directly the issue of fatigue cannot succeed in the prevention of violations and accidents; therefore, occupational safety strategies must position the variable of fatigue at the core of policy formulation and intervention planning.

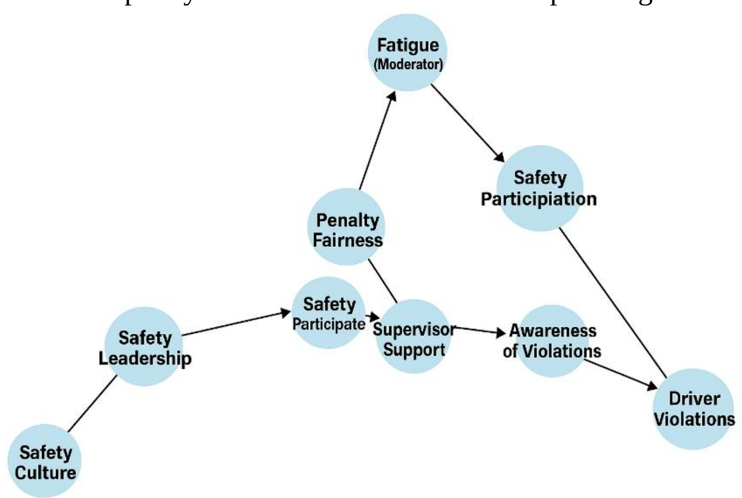

Figure 4. Systemic Model of Fatigue in Land Transportation

Figure 4 conceptualizes driver fatigue as the result of interactions among organizational structures, ergonomic working conditions, and psychosocial stressors. The model emphasizes that fatigue must not be regarded solely as an isolated incident but as part of an integrated work system; thus, interventions also need to be holistic and systemic. Possible measures range from work schedule optimization with respect to drivers' biological rhythms and improvement in both the quality and availability of facilities for rest to training for supervisors in identifying and acting on early signs of fatigue. Collectively, these measures can help develop a safer and more viable environment in the land transportation industry.

3.8. Integration of Key Constructs in the Conceptual Model of Land Transportation Safety

To summarize the relationships among the main constructs analyzed in this study, Figure 4 shows a conceptual path diagram that includes four key variables: supervisor support, perceived fairness of the penalty system, compliance with rest periods, and subjective driver fatigue levels. This diagram not only depicts the direct relationships among the variables but also reflects the mediating and moderating mechanisms identified through the PLS-SEM approach.

Overall, Figure 5 serves as a visual synthesis of the study's key findings and forms the basis for developing policy recommendations that are more responsive to drivers' operational and psychological dynamics.

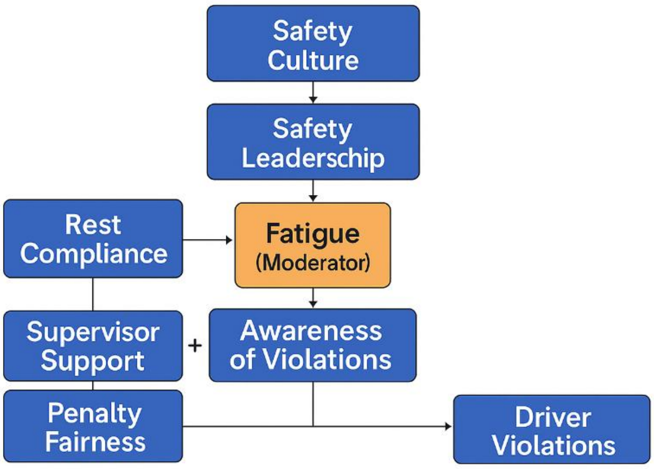

Figure 5. Conceptual Path Diagram of Driver Safety

igure 5 shows the structural relationships among the key variables of interest in the conceptual model. The results showed that supervisor support had a significant direct effect on driver rest period compliance, which then served as a mediator in lessening subjective fatigue levels. On the other hand, perceptions of the equity of the penalty system had a direct effect on fatigue independent of the rest period compliance pathway, indicating that risk perception and job stress involve different psychological mechanisms.

Furthermore, this diagram shows how fatigue also acts as a moderating variable in influencing the magnitude of relations between constructs, especially under certain route conditions such as the Bima–Mataram route. This interaction thus underlines the need to consider both psychosocial factors and operating conditions simultaneously when occupational safety policy is designed. An integrative and contextual approach is thus central to both the management of risk for fatigue and the improvement of compliance with safety protocols. In general, occupational safety in land transportation cannot be separated from the psychological condition of the driver, especially the fatigue aspect. Fatigue is not only a risk factor for the individual but also a systemic variable that influences the effectiveness of all safety interventions. Therefore, the occupational safety approach needs to be holistic, adaptive, and evidence-based, with the aspects of fatigue being at the forefront in policy design [6] [22] [23].

4. Conclusion

This study confirms that supervisor support significantly enhances drivers' rest time compliance ($\beta=0.38$), which in turn reduces subjective fatigue ($\beta=-0.35$), while perceived penalty fairness directly reduces fatigue levels ($\beta=-0.29$). These findings establish fatigue as a systemic variable shaped by organizational justice and supervisory practices, rather than solely an individual responsibility. Theoretically, this research combines Job Demands–Resources and Organizational Justice frameworks to explain how psychosocial resources and systemic fairness jointly influence fatigue outcomes in high-risk transport operations. Methodologically, it shows the combined use of PLS-SEM, IPMA, and MGA in evaluating complex psychosocial–behavioral models under extreme-route contexts. Practically, the findings point out the requirement for strengthening supervisory monitoring, penalty systems to be revised to ensure greater fairness and transparency, and the implementation of fatigue detection technologies as engineering-based interventions. Future research could expand this framework by adopting a longitudinal or multi-country study approach integrating biometric fatigue monitoring and evaluating organizational interventions beyond bus transport systems in order to enhance the generalizability of the findings.

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