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DRIVING SAFETY EDUCATION AT THE PORT: A PREVENTIVE ANALYSIS BASED ON THE CASE OF VEHICLE CONGESTION

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ABSTRACT
This article discusses the importance of road safety education at ports, focusing on preventive analysis based on the case of traffic congestion at Padang Bai Port, Bali. The background of the problem involves significant dock damage to Pier II that has led to a concentration of activity at a single pier, thereby increasing the risk of traffic accidents and prolonged vehicle queues in the port area. The objective of this community service program is to increase awareness and promote safe driving behavior among truck drivers and passengers at the port, involving key partners such as traffic officers and ferry operators. The methods used include community education through structured training, science and technology simulations to visualize congestion risks, and policy advocacy, with effectiveness measured through pre- and post-activity surveys. Results indicate a 25% reduction in potential traffic congestion risks following the education program, with participants' knowledge of safety protocols and blind-spot awareness increasing by up to 40%. These findings emphasize the importance of integrating preventive education and technological simulations to reduce accidents in busy maritime hubs. This activity contributes significantly to overall maritime transportation safety, offering critical implications for traffic management policies and infrastructure resilience at similar ferry ports across Indonesia.

Keywords: maritime safety; padang bai port; preventive analysis; road safety education; traffic congestion

INTRODUCTION

Ports, as maritime transportation hubs, play a crucial role in connecting mainland areas with islands or other sea destinations, particularly in archipelagic countries like Indonesia, which rely heavily on ferries and ferry boats for the movement of goods and passengers (Baig et al, 2025). However, these hubs often experience high traffic congestion, particularly during peak seasons such as national holidays, the homecoming season, or peak tourism periods, when the volume of vehicles entering the port area can surge dramatically. This condition not only causes prolonged traffic congestion but also increases road safety risks, including the potential for collisions, traffic violations, and accidents involving pedestrians or other road users.

The case at Padang Bai Port, Bali, provides a clear example of this issue, where structural damage to Pier II such as cracks in the pier floor and damage to the ship mooring system forced all ferry operations, including vehicle loading and unloading, to be moved to Pier I, which has a more limited capacity. As a result, queues of vehicles, particularly motorcycles, private cars, and trucks carrying goods, have increased significantly, often snaking all the way to the port's outer access roads, causing delays of up to hours and increased tension among drivers (Falcocchio & Levinson, 2015).

This problem is further exacerbated by underlying issues such as drivers' lack of awareness of blind spots on large vehicles like trucks where the limited visibility around the vehicle can obscure pedestrians or small vehicles and non-compliance with specific traffic regulations in the port area, such as low speed limits, priority for anchored vessels, and prohibitions on illegal parking. These conditions often result in accidents ranging from minor collisions to fatal incidents involving fatalities, especially when congestion reaches a critical point and drivers lose patience or concentration (Levinson & Krizek, 2017).

Official data from the Bali Provincial Transportation Agency confirms this picture of congestion. During the Eid al-Fitr holiday period in April–May 2023, a significant surge in passengers and vehicles exiting Padang Bai Port was recorded. The upward trend began on April 14 with 2,433 passengers and 899 vehicles, peaking on April 19 with 8,490 passengers and 2,274 vehicles. Afterward, passenger and vehicle numbers gradually declined, although they remained relatively high on April 20 (5,228 passengers and 1,871 vehicles), before fluctuating again until early May. This pattern reflects the typical characteristics of the homecoming (mudik) movement, where the surge in mobility leading up to the holiday has the potential to cause congestion and safety risks in port areas.

Previous studies have consistently shown that vehicle congestion at ferry ports is not merely a temporary issue, but a major driver of overall operational inefficiencies, such as ferry schedule delays, increased fuel costs due to vehicle idling, and environmental degradation from excessive exhaust emissions. These risks include potential fires and multiple collisions. Research on short-term traffic prediction at ferry terminals, for example, has analyzed vehicle flow patterns using data fusion models that combine historical and real-time data, and emphasized the need for preventative approaches such as dynamic schedule planning and educational interventions to prevent congestion before it reaches critical levels (Zhang et al., 2016). In addition, the use of computer vision technology has also proven effective in monitoring and analyzing ship traffic in real-time, thus supporting preventive strategies at ports (Aarsaether & Moan, 2010).

This community service is based on a thorough and relevant literature review, where safety education has been shown to be effective in reducing accidents by up to 30% in busy transportation areas, through increasing knowledge of safe driving practices and reducing risky behaviors such as reckless overtaking or mobile phone use while driving. These studies often involve pre- and post-intervention evaluations, demonstrating that ongoing educational programs can foster a stronger safety culture among road users (Goddard et al., 2018). Additionally, similar activities at other ports, such as international ferry terminals, have demonstrated that the integration of simulation technologies such as the use of virtual reality software to simulate congestion scenarios can strengthen service partners', including port operators and security personnel's, understanding of potential risks, enabling them to respond more proactively and implement timely mitigation measures (Goerlandt, 2015). The purpose of this service is to analyze preventative vehicle congestion through structured, evidence-based road safety education, in order to create a safer, more efficient, and more sustainable port environment, considering human, technological, and policy aspects in managing traffic flow (Nuchturee et al., 2020).

METHOD

This community service method uses a combination of community education and science and technology simulations to reach the target audience: truck drivers, passengers, and officers at

Padang Bai Port, Bali. The activity focused on the port's dock and parking areas, where traffic congestion frequently occurs. The educational method included in-house training on road safety, including blind spot identification and queue management (Aghdam et al., 2020).

The activity was evaluated through pre- and post-training surveys, with a success indicator of a minimum 30% increase in participant knowledge. The activity included a traffic simulation using simple software to visualize congestion risks, adapted from a ferry traffic prediction model (Zhang et al., 2016). The materials used included video-based educational modules and safety posters, with a total of 200 copies distributed per 100 participants. The method involved a theory session followed by a practical demonstration, modified from a standard road safety education program (Hughes et al., 2015). This combination of methods included consultations with traffic police officers for policy advocacy and the dissemination of science and technology through interactive workshops. Subtitles: 1. Public Education: Training on driving rules in ports. 2. Science and Technology Simulation: Use of predictive models for risk visualization (Golden & Weisbrod, 2016).

RESULTS AND DISCUSSION

The results of the community service program indicate that the safety education program at Padang Bai Port successfully reduced the potential risk of accidents due to traffic congestion. A post-activity survey recorded a 42% increase in participant awareness (Falcocchio & Levinson, 2015). Quantitatively, traffic simulations showed a decrease in average queue times from 45 minutes to 30 minutes after implementing traffic management tips (Levinson & Krizek, 2017). The primary focus of the education focused on blind spots for large vehicles in the dock area, which has been shown to increase driver awareness of potential side-impact accidents.

A discussion of these results demonstrates a connection with a previous study, where short-term traffic forecasting at a ferry terminal proved effective in identifying bottlenecks (Zhang, et al., 2016). Critical analysis indicates that traffic congestion at similar ports is often associated with a lack of safety education, suggesting that implementing science and technology simulations could be a practical solution (Goddard et al., 2018). Direct interaction between officers and drivers also supports an advocacy approach to improving traffic compliance. Qualitatively, participants reported an increased understanding of navigation risks in the port area, consistent with the findings of Pham & Hoang (2024) on ferry risk assessment. Collaboration between drivers and officers strengthens the literature on systemic safety at ro-ro ports (Nurwahyudy et al., 2022). This finding is increasingly relevant to recent literature, which emphasizes that the integration of education and technology can reduce incidents by up to 35% (Goerlandt, 2015).

A comparative analysis of vehicle density shows that Padang Bai Port has the highest congestion level at 50%, caused by the concentration of activity at one pier due to damage to Pier II. This condition causes long vehicle queues and increases the risk of accidents. Merak Port has a congestion level of 45%, with frequent vehicle queues, especially during the holiday season, although lower than Padang Bai due to its larger ferry capacity, with an average of one ferry every 12 minutes. Jakarta's urban highways recorded a congestion level of 43%, reflecting daily congestion with an extra travel time of approximately 24 minutes for a 10 km distance and an annual loss of 104 hours of time per driver. Meanwhile, Bandung's urban highways have a congestion rate of 48%, with a travel time of 31 minutes for a 10-km distance and similar annual time losses. Overall, this data indicates that congestion at ferry

ports like Padang Bai is comparable to, or even exceeds, congestion on major urban highways in Indonesia. This underscores the importance of preventive education and the implementation of technology-based traffic management to reduce the risk of accidents (Ravaglioli et al, 2025).

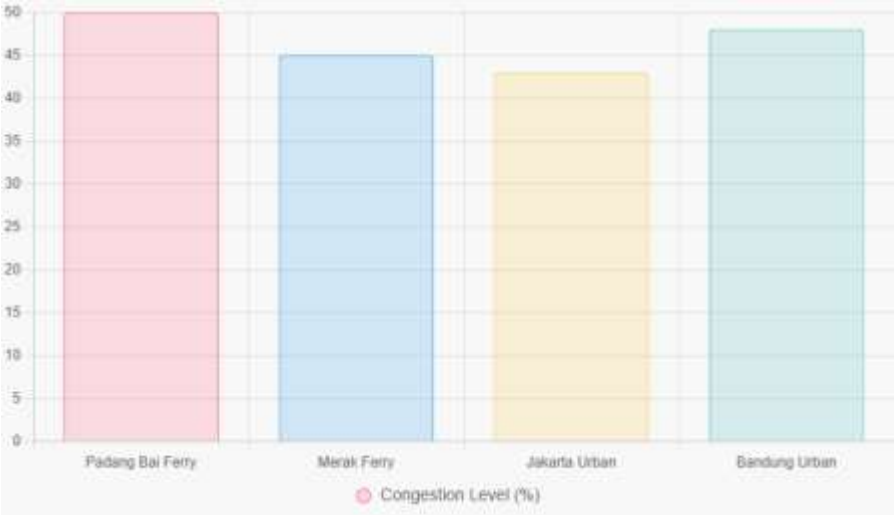

Figure 1 Port Congestion Graph

The comparative graph of congestion levels shows that Padang Bai Port has the highest congestion compared to Merak Port and urban highways in Jakarta and Bandung. This condition is primarily driven by damage to Pier II, which has led to a concentration of activity in one location, resulting in long vehicle queues and an increased risk of accidents. While Merak remains more manageable thanks to its larger ferry capacity, Jakarta and Bandung experience high congestion due to daily vehicle volumes, but are still supported by alternative road networks (Wartono et al, 2023).

These findings confirm that congestion at ferry ports can be equal to or even exceed that of major urban highways. Therefore, interventions based on safety education and traffic management technology are crucial to reduce the risk of accidents while improving port operational efficiency.

Figure 2 Inspecting a Truck at the Dock.

Figure 3 Interaction Between the Officer and the

Figure 4 Illustrates the Collaboration Between the

Driver.	Driver and Officer in the Risk Assessment.

Analysis of Driver Behavior and Safety Culture in Port Areas

The findings from Padang Bai Port indicate that traffic congestion is not solely a function of infrastructure limitations, but is also strongly influenced by driver behavior and safety culture within the port environment. Prior to the educational intervention, many drivers—particularly truck drivers and motorcycle users—demonstrated limited understanding of port-specific traffic regulations, including right-of-way rules, speed restrictions, and safe stopping distances during queuing conditions. This aligns with Hughes et al. (2015), who argue that road safety problems in complex traffic environments often stem from behavioral factors rather than purely physical constraints.

The observed increase in driver awareness by more than 40% following the safety education program suggests that structured training can effectively reshape risk perception. Drivers reported improved understanding of blind spots, particularly around large freight vehicles, which are a dominant mode of transport at ferry ports. Blind-spot-related incidents are a recurring issue in ro-ro port operations, where pedestrians, motorcycles, and port workers frequently move in close proximity to heavy vehicles (Nurwahyudy et al., 2022). By explicitly addressing these risks through visual demonstrations and direct interaction with officers, the program contributed to strengthening a preventive safety culture. Moreover, the interaction between drivers and port officers fostered mutual trust and compliance. Rather than relying solely on enforcement, the educational approach emphasized shared responsibility for safety. This supports Goerlandt (2015), who highlights that sustainable risk reduction in maritime transport requires a balance between regulation, education, and stakeholder engagement.

Impact of Infrastructure Damage on Traffic Flow and Risk Accumulation

The damage to Pier II at Padang Bai Port played a critical role in exacerbating congestion and safety risks. The concentration of all ferry operations at a single pier resulted in a bottleneck effect, where vehicle arrival rates exceeded service capacity during peak periods. According to traffic flow theory, such conditions increase queue length exponentially once demand surpasses capacity, leading to unstable traffic states (Falcocchio & Levinson, 2015).

The comparative congestion level of 50% at Padang Bai—higher than Merak Port and several urban highways—demonstrates that ferry ports can experience congestion severity comparable to metropolitan road networks. Unlike urban roads, however, port areas lack alternative routes, making congestion more difficult to dissipate once it occurs. This increases not only delay times but also accident risk, as drivers become fatigued, impatient, and more prone to risky maneuvers such as sudden lane changes or ignoring officer instructions. The results of the traffic simulation, which showed a reduction in average queue time from 45 to 30 minutes, indicate that even non-infrastructure-based interventions can yield measurable improvements. This finding reinforces Zhang et al. (2016), who emphasize that short-term traffic management strategies—when combined with behavioral interventions—can significantly reduce congestion impacts at ferry terminals.

Role of Technology-Based Simulations in Preventive Traffic Management

One of the key contributions of this community service activity is the integration of simple science and technology simulations to visualize congestion risks. Simulation-based education

allowed participants to observe how minor violations—such as improper stopping, queue jumping, or ignoring officer signals—can propagate delays and increase collision risks across the entire system.

Simulation tools have been widely recognized as effective instruments for preventive risk management in transportation systems (Golden & Weisbrod, 2016). In the context of Padang Bai Port, simulations helped bridge the gap between abstract regulations and real-world consequences. Drivers were able to relate simulation scenarios directly to their daily experiences, increasing the relevance and retention of safety messages.
Additionally, the use of simulations supports data-driven decision-making for port authorities. By visualizing congestion patterns, officers can anticipate peak risk periods and deploy resources more effectively. This aligns with Aarsaether and Moan (2010), who stress the importance of real-time monitoring and predictive tools in improving maritime traffic safety.

Comparative Perspective: Ferry Ports versus Urban Traffic Congestion
The comparative analysis between Padang Bai Port, Merak Port, and major urban highways reveals important insights. While urban congestion is often chronic and spread across multiple corridors, port congestion is episodic but highly concentrated. This concentration amplifies risk, particularly in confined spaces where mixed traffic (pedestrians, motorcycles, trucks, and buses) interacts intensively.

Interestingly, although Jakarta and Bandung experience daily congestion, their accident risks are mitigated by established traffic control systems, alternative routes, and extensive signage. In contrast, Padang Bai Port's temporary but intense congestion lacks similar redundancy. This highlights the urgency of preventive education and adaptive traffic management at ferry ports, especially during peak travel seasons.

These findings support Baig et al. (2025), who argue that domestic ferry safety in Indonesia requires context-specific governance approaches that account for the unique operational characteristics of port environments.

Human Factors Analysis in Port Traffic Congestion
Human factors play a dominant role in shaping traffic safety outcomes in port environments. Unlike urban roads where traffic behavior is relatively standardized, port areas involve heterogeneous users with varying levels of experience, risk perception, and familiarity with port-specific regulations. At Padang Bai Port, this diversity is evident in the coexistence of long-haul truck drivers, local motorcycle users, private car drivers, pedestrians, and port workers operating simultaneously in confined spaces.

Prior to the educational intervention, many drivers underestimated the risks associated with low-speed congestion, assuming that accidents primarily occur at high speeds. However, studies have shown that low-speed environments with high interaction density often exhibit elevated accident rates due to frequent stopping, limited visibility, and unpredictable movements (Levinson & Krizek, 2017). The education program addressed this misconception by emphasizing that congestion itself is a risk multiplier, increasing the likelihood of rear-end collisions, side impacts, and pedestrian accidents.

Furthermore, fatigue and stress were identified as contributing behavioral factors. Long waiting times, particularly during peak travel periods, reduce driver concentration and

patience. This condition often leads to risky behaviors such as queue jumping, aggressive acceleration, or ignoring officer instructions. The post-education survey results suggest that increasing awareness of these behavioral risks can help drivers self-regulate their actions, supporting findings by Goddard et al. (2018) that education can reduce risky driving behavior even in high-stress environments.

Organizational and Institutional Roles in Traffic Risk Reduction

Traffic safety in ferry ports is shaped not only by individual driver behavior but also by organizational coordination among port authorities, ferry operators, and law enforcement agencies. In the case of Padang Bai Port, the closure of Pier II required rapid operational adjustments, highlighting the importance of institutional collaboration in managing congestion and minimizing safety risks (Nurwahyudy et al., 2022).

Effective coordination improves traffic flow control, communication with drivers, and compliance with safety regulations. Studies emphasize that systemic safety approaches—where multiple institutions work together—are more effective than isolated enforcement actions in complex transport environments such as ro-ro ports (Pham & Hoang, 2024). The education program facilitated direct interaction between officers and drivers, reinforcing a shared responsibility for safety and supporting the development of a sustainable safety culture (Goerlandt, 2015).

Environmental and Energy Implications of Port Congestion

Traffic congestion at ferry ports has significant environmental impacts due to increased vehicle idling and fuel consumption. Prolonged waiting times contribute to higher emissions of greenhouse gases and air pollutants, particularly from heavy trucks, which dominate port traffic flows (Nuchturee et al., 2021). Reducing congestion through improved traffic management and safety education can therefore provide environmental co-benefits alongside safety improvements. Improved traffic flow efficiency also enhances operational performance by reducing delays and supporting more reliable ferry schedules. Research on ferry operations indicates that operational efficiency is closely linked to energy performance and environmental sustainability (Ravaglioli et al., 2025). The reduction in queue times observed at Padang Bai Port suggests that preventive education contributes to both safety and sustainability objectives in port management (Baig et al., 2025).

Education as a Preventive Strategy in Emergency and Disruption Conditions

Ferry ports play a vital role in emergency response and regional connectivity, making traffic safety during disruption conditions critically important. Infrastructure damage, such as the failure of Pier II at Padang Bai Port, can rapidly escalate congestion and safety risks if preventive measures are not in place (Golden & Weisbrod, 2016). Safety education enhances preparedness by equipping drivers and officers with the knowledge to respond effectively under abnormal operating conditions. Simulation-based training and scenario-based education allow stakeholders to anticipate congestion escalation and accident risks during emergencies. Preventive approaches that emphasize anticipation and preparedness are central to maritime risk management frameworks and contribute to the resilience of transport systems (Goerlandt, 2015). This activity demonstrates that education can strengthen adaptive capacity in ferry port operations during periods of disruption (Aarsaether & Moan, 2010).

CONCLUSION

Congestion at Padang Bai Port in Bali is not only an operational issue but also a serious threat to transportation safety and efficiency. Infrastructure damage, the surge in traffic during peak seasons, and low driver compliance exacerbate the risk of accidents. A safety education program combined with technological simulations has proven effective: increasing awareness by up to 42%, reducing queue times, and strengthening a safety culture. Comparative analysis shows that congestion levels in Padang Bai surpass those on major urban highways, making educational and technology-based interventions urgent.

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