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FACTORS INFLUENCING DOMESTIC FERRY CASUALTIES IN LANGKAWI, MALAYSIA

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ABSTRACT

Domestic ferry services played a vital role in providing essential transportation for local communities and supporting tourism activities in Langkawi, Malaysia. Ferry operations were exposed to various safety risks that might result in casualties and operational disruptions. This study examined the influence of human factors, environmental conditions, mechanical failures, organisational factors and technical knowledge on domestic ferry casualties in Langkawi. A quantitative research approach was adopted, and data were collected from 186 ferry operators using a structured questionnaire through purposive sampling. The data were analysed using descriptive analysis, Pearson correlation analysis, and multiple linear regression analysis using Statistical Package for the Social Sciences (SPSS) version 29. The correlation results indicated that all independent variables had positive and statistically significant relationships with domestic ferry casualties, with environmental conditions recording the strongest correlation ($r = 0.601$, $p < 0.001$). Multiple linear regression analysis revealed that environmental conditions were the only factor with a statistically significant effect in influencing domestic ferry casualties. Human factors, mechanical failures, organisational factors and technical knowledge did not demonstrate significant predictive effects in the regression model. The findings highlighted the dominant influence of environmental conditions such as tidal variations, sea state, and weather patterns on ferry casualties in Langkawi. The study provided valuable insights for maritime authorities, ferry operators, and policymakers to strengthen weather-related risk management, improve operational decision-makingdecision-making, and enhance preventive safety measures for domestic ferry operations. Future research was recommended to expand the geographical scope, utilise mixed research methods, and further incorporate qualitative insights to improve understanding of domestic ferry casualty risks in Malaysia.

Introduction

In Malaysia, 351 vessel accidents were reported in Malaysian waterways between 2018 and 2024 (MMD, 2025). This indicated that marine accidents continued to occur annually despite ongoing efforts to enhance safety standards and enforcement actions. Langkawi, a district within the state of Kedah in northern Peninsular Malaysia, was one of Malaysia's most popular tourist destinations (Imran Hilmy, 2025). The

tourism sector contributed significantly to Kedah's gross domestic product. Langkawi's tourism industry generated RM 1.7×10^9, representing 6.5% of the state's Gross Domestic Product in 2019 (LADA, 2021). During the COVID-19 pandemic, visitor arrivals to Langkawi declined sharply in 2020, with ferry passenger numbers decreasing from 2,206,498 to 1,199,155 (LADA, 2025) before showing a modest recovery to 1,341,289 by 2024. Langkawi consistently recorded nearly twice as many visitors as Pangkor Island between 2018 and 2024, highlighting its continued importance as a major domestic ferry destination in Malaysia.

Langkawi provides a unique laboratory for maritime safety research due to its extreme hydrographic challenges, including narrow navigational channels, significant siltation (Ian McIntyre, 2022) and high tidal variations (CruiseMapper, 2022) that create a high-pressure environment for ferry operators. Unlike many open-sea routes, the Langkawi mainland corridor is characterised by exceptionally high ferry density and intense tourism pressure (Osman, 2026), making it a critical case study for examining the evolution of maritime risk in highly regulated and high-traffic corridors.

Recent events have further highlighted safety concerns within Langkawi's ferry sector. A fire incident at Bukit Malut Jetty, Langkawi on 19 January 2026 involved three passenger ferries, resulting in two vessels being approximately 80% damaged and drifting offshore while another sustained minor damage of about 5% (Azman, 2026). Such incidents emphasise the ongoing risks faced by domestic ferry operations in the region. The significance of the ferry sector extends beyond mere mobility, it is the island's primary economic lifeline with approximately 70% (BERNAMA, 2026) of all visitors relying on sea transport to reach the island. Consequently, maritime casualties or operational disruptions not only represent human tragedies but also trigger immediate and severe socio-economic fallout such as a decline in tourist confidence and direct income loss for small traders and residents. It was crucial to identify the underlying causes of ferry casualties to improve safety measures, strengthen operational reliability, and ensure sustainable ferry services in the region (Onsongo, 2017). Ferry casualties are linked not only to technical and operational issues but also to crew members' psychological states such as stress, risk perception, adherence to safety procedures and decision-making under uncertainty and emergencies.

Literature Review

This study was underpinned by Heinrich's domino theory as the primary theoretical framework, with Bird's domino theory and Systems theory serving as supporting frameworks. Heinrich's domino theory explained accident causation as a sequential chain progressing from underlying causes to unsafe acts or conditions, and then to accident and injury (Heinrich, 1931). This theory was appropriate for the present study because domestic ferry casualties developed progressively through the interaction of human factors, mechanical factors, organisational factors, technical factors, and environmental factors rather than occurring as isolated events. Bird's domino theory extended this framework by emphasising management control as the root cause of unsafe acts and unsafe conditions within organisations (Bird, 1974). This perspective highlighted how weaknesses in safety management, supervision, training provision and resource allocation created operational conditions that increased ferry casualty risk. Systems theory further supported the framework by viewing ferry operations as interconnected systems in which disturbances in one component could affect the overall system performance (Miles, 1973). Environmental conditionsconditions such as adverse weather, sea state, visibility, and tidal variation interacted with human factors and mechanical elements, thereby increasing the likelihood of ferry casualties. The integration of these theories provided a comprehensive explanation of domestic ferry casualties by linking sequential accident causation with system-wide interactions within ferry operations.

Drawing on prior empirical studies, this study proposed five hypotheses to examine the factors influencing domestic ferry casualties in Langkawi. Human factors such as fatigue, lack of concentration, inadequate training, stress and communication barriers were frequently identified as major contributors to ferry accidents (Che Ishak *et al*., 2019). Within Heinrich's domino theory, these factors corresponded to the fault of the person, reflecting individual deficiencies that increased the likelihood of unsafe acts and subsequently increased the risk of casualty occurrence. Environmental conditions were also recognised as critical determinants of ferry safety, as adverse weather, rough sea conditions, poor visibility, submerged objects, and night operations increased navigational difficulty and operational risk (Golden & Weisbrod, 2016.)

From a systems perspective, these environmental disturbances amplified existing human factor and mechanical weaknesses, making ferry operations more vulnerable to failure. Mechanical failures were commonly associated with ferry casualties, particularly when preventive maintenance was inadequate, and faults remained undetected (Anthony, 2008). Such failures increased casualty risk when combined with adverse environmental conditions or human error during ferry operations. Organisational factors influenced ferry safety indirectly through management priorities, safety culture, supervision, and enforcement of safety procedures. Bird's domino theory emphasised that weak management control enabled unsafe practices and conditions that increased the likelihood of ferry casualties (Bird, 1974). Technical knowledge was reflected in operational practices, where profit-oriented mindsets encouraged behaviours such as overloading, delayed maintenance, and the use of inadequate safety equipment, indicating deficiencies in the application of technical competence (Baig *et al*., 2024) These technical shortcomings increased operational vulnerability and elevated the risk of ferry casualties. Based on the reviewed literature, this study proposed the conceptual framework as shown in Figure 1 and formulated the following hypotheses:

H1: There is a significant positive impact of human factors on domestic ferry casualties.

H2: There is a significant positive impact of environmental conditions on domestic ferry casualties.

H3: There is a significant positive impact of mechanical failures on domestic ferry casualties.

H4: Organisational factors significantly influence domestic ferry casualties.

H5: Technical knowledge significantly influences domestic ferry casualties.

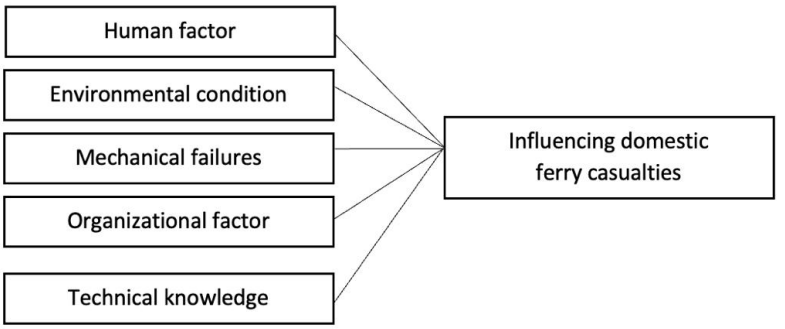

Figure 1: Research framework

Methodology

This study employed a cross-sectional quantitative research design utilising a survey strategy to examine the factors influencing domestic ferry casualties in Langkawi. The target population consisted of 360 ferry operators, including officers and crew members directly involved in maritime operations in the Langkawi region. According to the sample size determination table by Krejcie and Morgan (1970), a population of 360 requires a minimum sample size of 186. A sample of 186 respondents was targeted and achieved to ensure the study's statistical representativeness for this specific locale. Purposive sampling, a non-probability technique, was utilised to select participants based on their specific professional expertise (Makwana *et al*., 2023) and firsthand involvement in ferry safety management.

This approach was appropriate as it guaranteed that the data reflected the specialised perspectives of those most accountable for daily ferry operations, which is critical for understanding accident causation. While this targeted approach ensures depth of insight, it is acknowledged that the use of non-probability sampling may introduce sampling bias and limit the generalisability of the findings to the broader Malaysian maritime industry. A structured questionnaire was developed and adapted from previous maritime safety studies, covering human factors, environmental conditions, mechanical failures, organisational factors, and technical knowledge. Respondents were asked to indicate their level of agreement using a five-point Likert scale, ranging from 1 (strongly disagree) to 5 (strongly agree). Data analysis was conducted using the Statistical Package for the Social Sciences (SPSS) version 29, incorporating descriptive statistics and inferential analyses, including correlation and multiple linear regression, to examine the relationships between the independent variables and domestic ferry casualties. To ensure the reliability of the research instrument, a pilot test was conducted prior to the main survey, and the results demonstrated Cronbach's alpha values exceeding 0.70 for all constructs, confirming acceptable internal consistency and suitability for further analysis (George & Mallery, 2016).

Results and Discussion

The study involved 186 respondents, majority were male (79.0%) and primarily within the 31–50 age group (62.9%) reflecting the main workforce of domestic ferry services in Langkawi. Most respondents possessed undergraduate qualifications (50.5%) and 6–15 years of working experience (55.4%), indicating a workforce with substantial operational exposure. Table 1 showed that the mean values ranged from 2.574 to 3.886, while the standard deviations ranged from 0.649 to 0.853, indicating moderate variability in responses. The reliability of the measurement instrument was confirmed with Cronbach's alpha values ranging from 0.925 to 0.978, indicating excellent reliability. Data normality was established as all skewness and kurtosis values fell within the acceptable range of ±2 and supported the suitability of parametric analyses (Hair *et al*., 2010). Pearson correlation analysis in Table 2 revealed that environmental condition exhibited a strong positive correlation in influencing domestic ferry casualties ($r = 0.601$, $p < 0.001$), indicating that adverse environmental conditions were closely associated with increased casualty occurrence.

In contrast, human factor ($r = 0.262$), mechanical failures ($r = 0.261$), organisational factor ($r = 0.192$), and technical knowledge ($r = 0.159$) demonstrated weak but statistically significant positive correlations. This statistical hierarchy suggested that while all factors contribute to maritime risk, environmental conditions dominate because they represent external, volatile forces that lie outside the direct control of ferry operators. Human factor, mechanical, and organisational risks are effectively mitigated through strict SOLAS compliance and standardised training.

Following confirmation of linearity, multiple linear regression analysis indicated that the independent variables collectively explained 41.0% of the variance in influencing domestic ferry casualties (R^2 = 0.41). Among all predictors, environmental condition emerged as the only significant factor (β = 0.571, p < 0.001), followed by technical knowledge (β = 0.111, p = 0.079), mechanical failures (β = 0.097, p = 0.137), and organisational factor (β = 0.092, p = 0.126). Human factor (β = 0.026, p = 0.703) did not exhibit significant predictive effects. The variance inflation factor values remained below 5, indicating no multicollinearity issues were detected. These findings supported only H2, while H1, H3, H4, and H5 were not supported.

Table 1: Description statistics of variables and correlation matrix

Var.	I	M	SD	α	Var.	Correlation Matrix					
						IDFC	H	EC	MF	O	TK
IDFC	4	3.597	0.649	0.956	IDFC	1					
HF	5	2.616	0.853	0.978	H	0.262**	1				
EC	4	3.886	0.822	0.925	EC	0.601**	0.233*	1			
MF	4	3.036	0.750	0.969	MF	0.261**	0.444*	0.177*	1		
OF	3	2.574	0.783	0.930	O	0.192**	0.227**	0.088	0.221**	1	
TK	5	2.677	0.732	0.937	TK	0.159*	0.355**	-0.012	0.273**	0.204**	1

Note: Var.-Variables; I-Items; M-Mean; SD-Standard deviation; α-Cronbach's Alpha; IDFC-Influencing domestic ferry casualties; HF-Human factor; EC-Environmental condition; MF-Mechanical failures; OF-Organisational factor; TK-Technical knowledge. **Correlation is significant at the 0.001 level (2-tailed)

Table 2: Multiple linear regression results

F	β	SE	Beta	t	P	VIF	Results
(Constant)	1.079	0.252	-	4.288	<0.001	-	
HF	0.020	0.052	0.026	0.382	0.703	1.414	Not supported (H1)
EC	0.451	0.047	0.571	9.585	<0.001	1.082	Supported (H2)
MF	0.084	0.057	0.097	1.493	0.137	1.301	Not supported (H3)
OF	0.076	0.050	0.092	1.536	0.126	1.092	Not supported (H4)
TK	0.098	0.056	0.111	1.769	0.079	1.201	Not supported (H5)

Note: F-Factors; β-Unstandardised coefficients; SE-Standard error; Beta-Standardised coefficient; t-t-value; p-p-value; VIF-Variance inflation factor; IDFC-Dependent variable; *R = 0.641*; *R^2 = 41.0%*; *adjusted R^2 = 39.4%*; *F = 25.048*; *significant = 0.005*

The dominance of environmental condition as a predictor indicates that maritime safety in Langkawi is highly contingent on external and volatile forces. This is specifically linked to Langkawi's unique hydrographic constraints where extreme tidal ranges and monsoon effects compound shallow waters and heavy siltation in narrow navigational corridors. These conditions directly impede vessel manoeuvrability and under-keel clearance, which increases the physical risk of grounding or operational disruption regardless of the crew's intentions or expertise (Ian McIntyre, 2022). This finding aligns with Gao *et al*. (2024), who identified environmental forces as primary drivers of accidents in restricted waterways where the margin for error is geographically constrained.

Conversely, the predictive insignificance of human factors, mechanical failures, organisational factors, and technical knowledge likely stems from a standardisation effect within the Malaysian maritime industry. Since the Malaysian ferry sector is strictly governed by Marine Department protocols and mandatory SOLAS requirements, there is minimal variability in baseline competency across operators. This high level of regulatory compliance effectively masks these variables in the statistical model. When most operators adhere to a uniform high standard, those factors no longer serve as statistical differentiators for casualty outcomes.

A critical policy gap remains. While SOLAS provides a framework for international vessels, domestic ferry safety in Malaysia relies heavily on localised enforcement. These findings suggest that current policies may be over-reliant on standardised crew training while under-addressing the volatile environmental frontier. To mitigate these risks, the Malaysian Marine Department should move beyond traditional safety briefings toward technology-driven interventions. Integrating ferry routes into a Vessel Traffic Management System (VTMS) and utilising Automatic Identification System (AIS) data would allow shore-based authorities to monitor traffic density and provide real-time warnings during tidal surges. Implementing specialised weather routing and real-time monitoring at terminals would provide captains with the objective data needed to navigate Langkawi's silt-prone channels safely. Thus, while internal risks are mitigated through standardised policies, the primary determinant of safety remains the external environment, necessitating a strategic shift toward digital navigational support.

Conclusion and Future Research

This study examined factors including human factors, environmental conditions, mechanical failures, organisational factors, and technical knowledge in influencing domestic ferry casualties in Langkawi. The findings addressing the first research objective revealed that individuals involved in domestic ferry operations in Langkawi were predominantly male, mainly within the prime working age group of 31–50 years, possessed formal educational qualifications and had substantial operational experience, providing a comprehensive demographic profile that supported the interpretation of the study's findings. The findings for the second research objective showed that human factors, environmental conditions, mechanical failures, organisational factors, and technical knowledge were all positively and significantly correlated with domestic ferry casualties in Langkawi. Building on this, the findings for the third research objective indicated that when analysed collectively through regression, environmental condition emerged as the only significant predictor influencing domestic ferry casualties in Langkawi.

The findings further indicate that regulatory bodies and operators should prioritise specific technology-driven interventions to mitigate environmental risks. The implementation of real-time weather monitoring systems at both Kuah and Kuala Perlis terminals is essential. These systems would allow for the continuous tracking of localised wind speeds, visibility and tidal surges, providing masters with live data to decide whether a passage is safe during monsoon surges or sudden squalls. Besides that, ferry routes should also be more strictly integrated into the VTMS. A VTMS equipped with radar, Very High Frequency (VHF) radio, AIS, and CCTV allows for real-time monitoring of vessels to ensure safe traffic management within port limits (PKA, 2026). By integrating radar data from multiple stations for wider coverage, VTMS provides pilots and masters with accurate information on vessel positions and traffic density, thereby enhancing passage planning.

While this study provides critical insights, it is subject to several limitations. First, the reliance on self-reported questionnaire data

may introduce response bias as participants might provide socially desirable answers regarding safety compliance. Second, the cross-sectional design of the study captures data at a single point in time, which restricts the ability to establish definitive causality between the variables. Third, the model may have omitted several relevant variables that influence maritime risk. For example, traffic density within narrow channels was not measured, which can significantly increase the risk of collisions or groundings during peak tourism seasons. In addition, the intensity of regulatory enforcement, such as the frequency of surprise inspections, vessel age, and technology levels, was not accounted for, all of which could amplify the influence of human and mechanical factors. Lastly, the study was geographically limited to domestic ferry operations in Langkawi.

To build upon these findings, future research should expand the geographical scope through comparative studies across other major Malaysian ferry corridors, such as Tioman Island and Sabah, to determine whether regional risk profiles differ from the Langkawi context. To address the limitations of perception-based data, a mixed-method approach is recommended. This would involve supplementing quantitative surveys with qualitative interviews with ferry captains and maritime regulators to capture deeper operational insights. Future studies should integrate AIS data, which utilises VHF radio signals to broadcast real-time vessel positions, speeds and headings every few seconds (AMT, 2024). This high-frequency data would allow researchers to move beyond perception-based surveys to empirically analyse collision prevention and traffic management during adverse weather in Langkawi's narrow corridors. Finally, employing advanced modelling techniques like structural equation modelling would also allow researchers to map the complex interdependencies between human factors and the environment more accurately.

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Conflict of Interest Statement

The authors declare no conflict of interest.

Author Contributions Statement

TSC, CVT, and SYO contributed to the original draft preparation, data collection, and data analysis. NAI, KMC, MHS, KBL, and LC were responsible for the review and editing of the manuscript.

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Appendices

Part A: Demographic information	
Gender	1. Male 2. Female
Age	1. 18 – 30 years 2. 31 – 40 years 3. 41 – 50 years 4. 51 – 60 years 5. Above 61 years
Degree of education	1. Secondary level 2. Diploma/Sub degree level 3. Undergraduates 4. Postgraduates
Marital status	1. Single 2. Married
Working experience	1. 1–5 years 2. 6–10 years 3. 11–15 years 4. 16–20 years 5. Above 20 years
Position in ferry operations	1. Crew including captain 2. Officer

Part B: Domestic ferry casualties in Langkawi									
No.	**Dependent variable**		**Questions**	**Linkert scale:** **1. Strongly disagree** **2.Disagree** **3.Neutral** **4.Agree** **5.Strongly agree**				
	Influencing domestic ferry casualties	IDFC1	Casualty (eg: grounding/collision) occurs frequently in ferry transport.	1	2	3	4	5
		IDFC2	Near-miss incidents are often ignored.	1	2	3	4	5
		IDFC3	Lessons learned from maritime casualties are lacking.	1	2	3	4	5
		IDFC4	Weather or visibility frequently result in casualty events despite operational precautions.	1	2	3	4	5

Part C: Factors influencing domestic ferry casualties in Langkawi									
No.	**Independent Variables**		**Questions**	**Linkert scale: 1. Strongly disagree 2.Disagree 3.Neutral 4.Agree 5.Strongly agree**				
1.	**Human factor**	HF1	Crew members often work long hours that leads to tiredness and reduced alertness.	1	2	3	4	5
		HF2	Crew members sometimes lose concentration during routine tasks.	1	2	3	4	5
		HF3	Lack of sufficient training causes confusion during critical operations.	1	2	3	4	5
		HF4	Personal issues or stress can make it difficult for crew to concentrate fully while on duty.	1	2	3	4	5
		HF5	Language differences among crew sometimes cause miscommunication.	1	2	3	4	5
2	**Environmental condition**	EC1	Adverse weather conditions such as rain and strong winds will increase the risk of ferry casualty.	1	2	3	4	5
		EC2	Floating or submerged objects pose a risk to ferry navigation.	1	2	3	4	5
		EC3	Restricted visibility increases the risk of navigation errors and collision.	1	2	3	4	5
		EC4	Night operations will increase the risk of casualty.	1	2	3	4	5
3	**Mechanical failures**	MF1	Mechanical components such as engines, pumps and steering systems often experience faults due to poor maintenance.	1	2	3	4	5
		MF2	Lack of engine monitoring systems increases the risk of undetected failures.	1	2	3	4	5
		MF3	Maintenance checks are performed only after a breakdown occurs.	1	2	3	4	5
		MF4	Minor mechanical issues are ignored until they become serious.	1	2	3	4	5
4	**Organizational factor**	OF1	Management prioritizes operation schedules and profit over safety compliance.	1	2	3	4	5
		OF2	Insufficient company profit causes delays in upgrading critical vessel equipment.	1	2	3	4	5
		OF3	Insufficient emergency and safety training from the organization increases the risk of ferry casualties.	1	2	3	4	5
5	**Technical knowledge**	TK1	Lack of knowledge in interpreting navigation systems increases the risk of route deviation.	1	2	3	4	5
		TK2	Crew members seldom receive refresher courses or training on newly introduced navigation and safety technologies.	1	2	3	4	5
		TK3	Inadequate knowledge of machinery and engine systems leads to delayed responses during equipment breakdowns.	1	2	3	4	5
		TK4	Lack of technical understanding of vessel load limits leads to overloading to meet passenger or scheduling demands.	1	2	3	4	5
		TK5	Lack of knowledge of safety procedures among crew members can lead to ferry casualties.	1	2	3	4	5