RISK ASSESSMENT OF KOCHI WATER METRO USING ANALYTICAL HIERARCHY PROCESS

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ABSTRACT

Kochi City, the commercial capital of Kerala, faces severe traffic congestion due to inadequate road infrastructure. To address this, the Kochi Water Metro proposes an inland waterway transportation solution. However, the project faces challenges, including safety concerns such as fatal boat accidents. This research focuses on risk assessment and mitigation strategies for the Vyttila-Kakkanad and Vypin-High Court routes of Kochi Water Metro. Through Expert Survey and Analytic Hierarchy Process (AHP) analysis, risks related to terminal facilities, waterway conditions, and traffic management are evaluated. AHP helps in systematically ranking these risks and suggesting tailored mitigation measures to enhance project resilience. Proposed solutions include regulatory frameworks, community support for fishing communities, and technologies like rope cutters and traffic management systems. By improving adaptability and sustainability, the research aims to improve urban mobility and contribute to sustainable development. A comprehensive risk assessment and targeted mitigation strategies are essential for the success of the project and its broader impact on urban transportation challenges.

Keywords: Risk Assessment, Analytical Hierarchy Process, Risk Mitigation

1.0 INTRODUCTION

Kochi, the commercial capital of Kerala, is one of the most densely populated areas in Kerala. Kochi is growing exponentially, and the limited available road space is getting choked with the equally increasing private vehicles. In similar circumstances, the cities across the globe are forced to adopt the more sustainable mass public transport options such as metro rail systems, bus rapid transit systems, etc. Another option for cities is to return to their traditional modes of mobility such as the waterways in the state of Kerala, especially the city of Kochi. The State Water Transport Department was the main operator of the water transport system in Kochi besides the various private operators and the localized jangar services. Ferry services are operational between Ernakulam mainland, Fort Kochi, Vypeen, Mattancherry, Embarkation, Bolghatty, Mulavukadu, High Court, Vytilla, Eroor, and Kakkanad jetties. Other jetties such as Nettoor, Edakochi, Kumbhalam, Pizhala, Moolampilly, Thanthonithuruth, etc are served by private ferry services and jangars. However, the system has been deteriorating over the last few decades owing to depleting boat numbers, low quality of boats, lack of safety measures, lack of reliability, and poor access infrastructure to the jetties. The system has seen minimal investment and technology upgradation in recent years.

In this instance, Kochi Metro Rail Limited (KMRL) proposed an Integrated Water Transport System for Kochi city, with a vision to connect the mainland with all the islands in the Kochi area, reviving

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the sustainable traditional mode of public transportation. The system is proposed to be planned on the concept of the “One Island One Boat Hub” model thereby increasing the coverage of the water transport services. It is envisioned as a user-oriented and socially inclusive transport system than just a point-to-point service. It is also part of a bigger concept of seamless integration outlined for the city integrating the water transport system, metro system, city bus services, and feeder services along with improvised access by non-motorized transport infrastructure.

The Kochi Water Metro is proposed to have 16 routes connecting thirty-eight jetties across ten island communities across a 76 km route network. Of the 38 jetties, eighteen are proposed to be developed as major jetties or main boat hubs while the remaining twenty (20) jetties shall be developed as minor jetties for water transit services. Part of the identified 76 km and the areas around the jetty locations shall require dredging to maintain a minimum desirable clearance. The first route (Vyttila-Kakkanad) of Kochi Water Metro started operation on April 2023.

Risk is an inherent and unavoidable aspect of daily life, and this holds true for inland water transport as well. Inland water transport is subject to various risks that need to be carefully managed to ensure safety, sustainability, and operational efficiency. Each day we make judgments which balance desired goals or benefits against the chance that something undesirable (a risk) will happen on the way[1]. These judgments can range from the mundane through the routine and to the very specific. Risk is defined as the product of two factors – the probability (or likelihood) of an undesirable incident occurring and if it does occur, the severity of its potential long and short-term impact (or consequence)[2]. Safety in water transport is essential to prevent accidents, ensure the well-being of passengers and crew, and protect the environment(Wang and Yin 2020). Risk management is a structured process that involves identifying, assessing, and addressing risks. It encompasses all stages, from the initial identification of potential risks to implementing actions aimed at mitigating them and continuously monitoring their status[4].

The Analytic Hierarchy Process (AHP) is a decision-making approach that helps in addressing complex issues by providing an objective framework, making it ideal for achieving consensus among experts when tackling a problem[5]. The Analytical Hierarchy Process (AHP), introduced by Professor Thomas L. Saaty in 1977[6], is a decision-making methodology used across various fields, including economics, politics, and engineering, to address complex decision-making situations[7]. It helps simplify multi-dimensional problems (with multiple criteria) by converting them into a one-dimensional scale of priorities[8]. A hierarchical structure is built to represent relevant aspects such as actors, scenarios, factors, and their interdependencies[9]. At the top of this hierarchy is the primary objective, with possible alternatives to evaluate placed at the bottom. These alternatives are assessed through criteria (second level) and sub-criteria (third level).

To evaluate alternatives, pairwise comparisons are made between criteria and sub-criteria using a numerical scale, helping to assign weights and establish priorities[10]. The AHP approach is characterized by the following features:

- It integrates both tangible and intangible factors into the decision-making model, addressing subjectivity and uncertainty inherent in the process.
- It provides a general theory of measurement to assess the impact of alternatives based on specific criteria or attributes.
- The information generated through this process can often be redundant or inconsistent, which is managed using comparison matrices that organize the judgments.
- Once the contributions of higher-level elements are assessed, the overall contributions of each alternative toward the primary objective are calculated using additive aggregation.

Risk assessment for water metro systems focuses on enhancing safety, reliability, and environmental sustainability by identifying hazards, evaluating their severity and likelihood, and prioritizing mitigation measures. This proactive approach ensures efficient resource allocation and the implementation of safety protocols and technologies to build a resilient urban transportation system, benefiting communities and supporting sustainable development.

The objective of the risk assessment for the Kochi Water Metro project is to determine risk ranking using the Analytical Hierarchy Process and propose safety measures to mitigate identified risks. The scope of risk assessment for the water metro extends beyond immediate safety concerns to include environmental impact and system reliability. It involves ensuring passenger and crew safety through measures like life-saving equipment and regular maintenance, enhancing system reliability by minimizing disruptions and optimizing schedules, and mitigating environmental impacts by preventing fuel spills and minimizing emissions. This comprehensive approach aims to create a safe, reliable, and sustainable urban transportation system.

2.0 METHODOLOGY

Risk assessment. Risk assessment is fundamental for decision-making in various fields, with methodologies like expert surveys and Analytic Hierarchy Process (AHP) analysis playing key roles. Expert surveys tap into specialized knowledge to provide qualitative insights, while AHP offers a structured approach to comparing criteria and alternatives. Together, these methods enhance decision-making by providing comprehensive assessments of potential hazards and mitigation strategies.

Identifying risks across infrastructures, environmental impacts, social factors, and regulatory compliance for the Water Metro project involves both quantitative assessment using data and qualitative evaluation with expert judgment. This dual approach analyzes risks to prioritize based on significance and potential consequences, ensuring focused strategies for mitigation during project planning and implementation. Methods like expert surveys and Analytic Hierarchy Process (AHP) are employed for thorough risk assessment, gathering insights and structuring comparisons to enhance hazard identification and mitigation strategies. The AHP analysis helped rank these risks, revealing their relative importance and guiding informed decision-making for effective risk management strategies in the Kochi Water Metro project.

Applying Analytic Hierarchy Process (AHP) analysis for risk assessment in High Court and Vyttila Water Metro projects involves a systematic evaluation of various risk factors and their potential impact on project success. Here’s how it could be done:

Define Risk Factors: Begin by identifying and defining the key risk factors relevant to both projects. These could include terminal condition risks, traffic condition risks, human condition risks, and so on. Each risk factor should be clearly defined to ensure a comprehensive assessment.

Build the Hierarchy: Construct a hierarchical structure that organizes the risk factors into categories and subcategories. For instance, traffic condition could include subcategories like fishing boats, passenger boats, large vessels and tourist boats.

Pairwise Comparisons: Experts or stakeholders were approached to compare risk factors to determine their impact on project success and assign numerical weights accordingly.

Calculation of Average of Normalized Column (ANC)**:** Normalize each column by dividing each element by the sum of the column. Then, sum the elements in each row and divide by the number of elements in the row to obtain the priority vector (pv).

Calculation of Priority Vector (wi): The priority vector (wi) is calculated as wi = 1/n * sum (aij), where (n) is the number of elements and aij represents the pairwise comparison values.

New Vector (nv): The new vector (nv) is obtained by multiplying the judgment matrix by the priority vector. The judgment matrix contains the pairwise comparisons, and the priority vector represents the weights assigned to the criteria or alternatives.

Normalized Eigenvector (λ): The normalized eigenvector (λ) is calculated by dividing the elements of the new vector by their corresponding elements in the priority vector.

Consistency Check: To ensure the reliability of the assessments, verify the consistency of the pairwise comparison judgments. If inconsistencies are detected, adjustments may be necessary. The consistency index (CI) is calculated as CI = (λmax- n) / (n - 1) , where λmax is the maximum eigen value of the pairwise comparison matrix and n is the number of elements in the matrix.

Calculation of Consistency Ratio (CR): The consistency ratio (CR) is calculated as CR = CI / RI , where CI is the consistency index and RI is the random index. These equations are essential for synthesizing pairwise comparisons, checking for consistency, and determining the overall priority ranking in AHP analysis. The CR value is used to assess the consistency of pairwise comparisons in the AHP analysis. A CR value less than 0.1 indicate acceptable consistency, A CR value exceeding 0.1 indicates inconsistency, necessitating a review of judgments for potential improvement.

Calculation of Risk Scores: After determining the weights of the risk factors, evaluate the probability and severity of each risk factor and its potential impact on the project. Assign scores to quantify the magnitude of each risk, taking into account both its likelihood and consequences.

Risk Mitigation Strategies: Based on AHP analysis conducted, various risk factors for the Kochi Water Metro project will be systematically assessed and categorized. Strategies for mitigating identified risks, such as risk avoidance, transfer, reduction, or acceptance, are crucial. This structured approach enables informed decision- making throughout the High Court and Vyttila Water Metro projects, ensuring their safety and success.

3.0 STUDY AREA AND DATA COLLECTION

The Water Metro project aims to revolutionize urban mobility by utilizing waterways for public transportation in Kochi. This study focuses on two operational routes of water metro - High Court–Vypin (3.34 km) and Vyttila–Kakkanad (5 km). The High Court–Vypin route connects the Kochi mainland with Vypin area, and this region have heavy traffic including tourist boats. Vyttila–Kakkanad route connects Vyttila mobility hub with Kakkanad area, which the major IT hub of Kochi. Understanding the context and regulatory framework involves analyzing official project documents, stakeholder data analysis, and detailed literature review to gain insights into successes, challenges, and best practices. Environmental impact assessments and compliance with other regulations are crucial to assessing the project's scope and environmental implications. On-site assessments of canal bank conditions, infrastructure, and navigational challenges are conducted through an inventory survey, documenting findings with photos, notes, and GPS coordinates for feasibility evaluations and environmental planning. Data collection for risk assessment includes reviewing past incidents, assessing site-specific risks such as currents and infrastructure issues, and consulting stakeholders. This comprehensive approach ensures that mitigation strategies are prioritized effectively, addressing hazards like electric lines and fishing nets while incorporating user perspectives to enhance safety protocols and stakeholder engagement for successful project implementation.

An expert survey was conducted for risk assessment in the Water Metro system involved gathering insights from 19 experts related to boat operation and working in the Water Metro boats as staff, focusing on two distinct routes: the Vyttila-Kakkanad Water Metro route and the Vypin-High Court Water Metro route. A hierarchical structure was constructed that organizes the risk factors into categories and subcategories as shown in figure 1. The methodology employed for this survey utilized a pairwise comparison questionnaire form, allowing experts to systematically evaluate and rank various risk factors associated with the operation of the Water Metro. Among the surveyed experts, 8 were from the Vyttila-Kakkanad route, while 11 were from the Vypin-High Court route. Each expert provided their perspectives on the risks inherent in the operation of the Water Metro, which includes main risks such as terminal conditions, boat conditions, waterway conditions, traffic conditions, human conditions, immediate consequences, and subsequent consequences and each main risk encompasses several sub-categories of risks, further delineating the potential challenges and vulnerabilities within the operation. These sub-categories provide a more nuanced understanding of the factors contributing to each main risk, allowing for more targeted risk assessment and mitigation strategies.

Terminal condition consist of 6 sub risk categories. They are risks associated with surface condition, lighting condition, security concerns, docking condition and safety. Boat condition consists of 5 sub risk categories. They are risks associated with safety measures, navigational charts and maps, communication facility, charging and boat equipment issue. Waterway condition consist of 10 sub risk categories. They are risk associated with waterway width, water depth, cross structures, fishing nets, electric lines, aquatic weeds, weather condition, visibility, water current and wind. Traffic condition consist of 4 sub risk categoies. They are risk associated with passenger boats, fishing boats, large vessels and tourist boats. Human condition consists of 3 sub risk categories. They are risk associated with working hours, awareness on safety procedures and medical emergencies.

Immediate consequences consist of 4 sub risk categories. They are the risk associated with mobility issues, oil transport, sewage disposal and accidents. Subsequent consequences consist of 4 sub risk categories. They are risk associated with health and safety, environmental condition, aquatic resources and economic condition.

4.0 RESULTS & DISCUSSION

AHP analysis was conducted to evaluate, rank risks within the Kochi Water Metro project. This methodology allowed for a systematic identification, ranking, and mitigation strategy development for diverse risks associated with the Water Metro as shown in figure 1. The analysis focused on two routes: Vyttila-Kakkanad and Vypin-High Court.

Utilizing the Analytic Hierarchy Process (AHP) analysis, the survey findings revealed the relative importance and ranking of these main risk factors and sub risk factors of Kochi Water Metro. The AHP analysis provided a structured approach to discerning the significance of each risk factor based on expert opinions, facilitating informed decision-making and risk management strategies. In this study a questionnaire survey was conducted, and the data were analysed using the AHP method. Experts related to boat operations in this region were approached to participate in the survey. They took part in a pairwise comparison to evaluate the relative importance of each risk factor and assign weights accordingly. As shown in Table 1, each column was normalized by dividing each element by the sum of the values in that column. Then, the elements in each row were summed and divided by the number of elements in the row to obtain the priority vector (pv), as illustrated in Table 2. The priority vector (wi) is calculated. The new vector obtained by multiplying the judgment matrix by the priority vector is shown in Table 3. The normalized eigenvector calculated by dividing the elements of the new vector by their corresponding elements in the priority vector is shown in Table 5.

Consistency check was conducted to ensure the reliability of the assessments and verify the consistency of the pairwise comparison judgments. The random index is calculated as shown in Table 4. The consistency index calculated from Table 5 is 0.00, and the consistency ratio calculated is 0.09. The CR value is used to assess the consistency of pairwise comparisons in the AHP analysis. A CR value less than 0.1 indicate acceptable consistency, A CR value exceeding 0.1 indicates inconsistency, necessitating a review of judgments for potential improvement. Therefore, the AHP analysis is consistent.

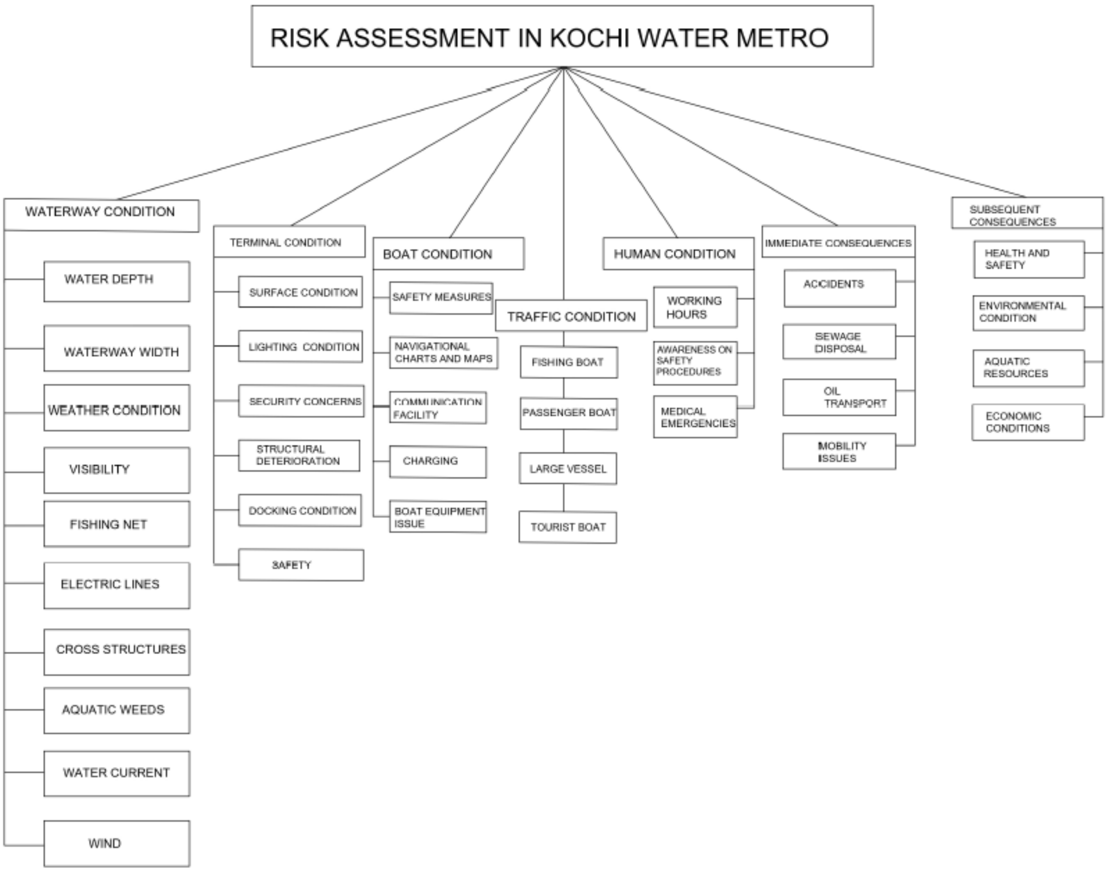

Figure 1. Hierarchical model for risk assessment in Kochi water metro

Table 1. Comparing criteria pairwise in relation to the overall goal.

CRITERIA	**TC**	**BC**	**WC**	**TRC**	**HC**	**IC**	**SC**
Terminal Condition [TC]	1	1	1/8	1/6	3	1	1
Boat Condition [BC]	1	1	1/6	1/7	1	1	½
Waterway Condition [WC]	8	6	1	1/7	6	5	5
Traffic Condition [TRC]	6	7	7	1	6	5	6
Human Condition [HC]	1/3	1	1/6	1/6	1	1	1/3
Immediate Consequences [IC]	1	1	1/5	1/5	1	1	1/3
Subsequent Consequences [SC]	1	2	1/5	1/6	3	3	1
Total Coloumn	18.33	19	8.86	2	21	17	14.17

Table 2. Synthesized matrix for criteria

Criteria	TC	BC	WC	TRC	HC	IC	SC	Total Row	Priority Vector
TC	0.05	0.05	0.01	0.08	0.14	0.06	0.07	0.48	0.07
BC	0.05	0.05	0.02	0.07	0.05	0.06	0.04	0.34	0.05
WC	0.44	0.32	0.11	0.07	0.29	0.29	0.35	1.87	0.27
TRC	0.33	0.37	0.79	0.50	0.29	0.29	0.42	2.99	0.43
HC	0.02	0.05	0.02	0.08	0.05	0.06	0.02	0.30	0.04
IC	0.05	0.05	0.02	0.10	0.05	0.06	0.02	0.36	0.05
SC	0.05	0.11	0.02	0.08	0.14	0.18	0.07	0.66	0.09

Table 3. Calculation to obtain new vector

	1		1		1/8		1/6
	1		1		1/6		1/7
	8		6		1		1/7
0.07	6	**+ 0.05**	7	**+ 0.27**	7	**+ 0.43**	1
	1/3		1		1/6		1/6
	1		1		1/5		1/5
	1		2		1/5		1/6

							New vector
	3		1		1		0.50
	1		1		½		0.36
	6		5		5		2.15
+ 0.04	6	**+0.05**	5	**+0.09**	6	=	4.13
	1		1		1/3		0.31
	1		1		1/3		0.38
	3		3		1		0.67

Table 4. Random Index in the Analytic Hierarchy Process

Size of matrix (n)	1	2	3	4	5	6	7	8	9
Random index (RI)	0	0	0.58	0.9	1.12	1.24	1.32	1.41	1.45

Table 5. Eigenvalue calculation

	NEW VECTOR	λ= nv/pv
TC	0.50	7.28
BC	0.36	7.50
WC	2.15	8.05
TRC	4.13	9.65
HC	0.31	7.22
IC	0.38	7.41
SC	0.67	7.13

After determining the weights of the risk factors, the next step is to evaluate the probability and severity of each risk and its potential impact on the project. Scores are assigned to quantify the magnitude of each risk, considering both its likelihood and consequences. Based on the AHP analysis conducted by 19 experts, various risk factors for the Kochi Water Metro project were systematically assessed and categorized (Figure 2). Strategies for mitigating the identified risks, such as risk avoidance, transfer, reduction, or acceptance, are essential. This structured approach facilitates informed decision-making throughout the High Court and Vyttila Water Metro projects, ensuring their safety and success.

For the Vyttila-Kakkanad route, traffic conditions were identified as the highest risk, followed by waterway conditions, subsequent consequences, terminal conditions, immediate consequences, human conditions, and boat conditions. Sub-risks included safety in terminal conditions, boat equipment issues, visibility in waterways, and fishing boat traffic.

In the Vypin-High Court route, waterway conditions posed the highest risk, with subsequent consequences, immediate consequences, human conditions, terminal conditions, boat conditions, and traffic conditions following in rank. Sub-risks included water depth, visibility, safety measures on boats, and medical emergencies.

The AHP analysis revealed that traffic conditions are the primary concern for the Vyttila- Kakkanad route, while waterway conditions are the most significant risk for the Vypin-High Court route. These findings provide a basis for informed decision-making and effective risk mitigation strategies, enhancing the safety, operational efficiency, and sustainability of the Kochi Water Metro project.

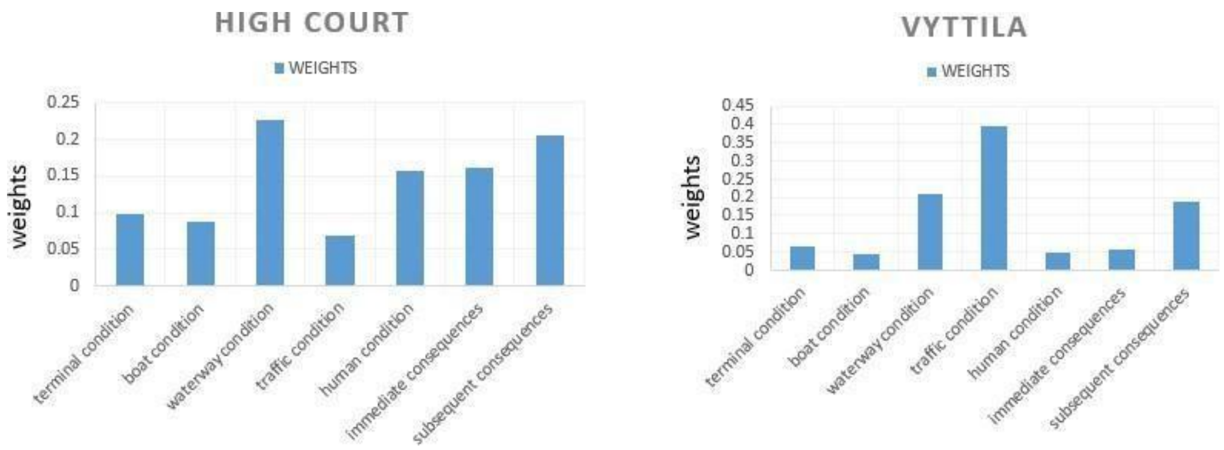

Figure 2. Risks ranking based on AHP analysis

4.1 Risk mitigation and management. Reviewing current risk mitigation measures in the Water Metro project aims to assess effectiveness. Proposed new strategies include engineering solutions, community engagement, and environmental conservation efforts to enhance safety, minimize environmental impact, and gain community support, ensuring comprehensive risk management for project success and sustainability.

4.2 Existing Mitigation Measures

- Terminal Conditions. Key measures include hand railings for support, emergency lights for evacuation, and automated fare gates. Passenger screening, surveillance cameras, fire exits, and alarms enhance security. Floating fenders help prevent collisions, while life buoys and first aid kits ensure passenger safety.
- Boat Conditions. Safety measures include readily available life jackets, strategically placed fire extinguishers, marked fire exits, and surveillance cameras. An alarm system alerts authorities to navigational issues, while a hybrid engine design promotes efficiency and minimal environmental impact.
- Waterway Conditions. Dredging maintains navigable depths, and weather forecasts help adjust routes proactively. Navigational buoys guide vessels, and designated anchorage areas provide safety during emergencies.
- Traffic Conditions. Communication tools like microphones and the Automatic Identification System (AIS) improve traffic management. Adhering to specified schedules helps minimize congestion and enhances passenger experience.
- Human Conditions. Continuous training for staff ensures readiness in emergencies. Digital screens display safety protocols, reinforcing adherence to safety measures among passengers and crew.
- Immediate Consequences. Fenders absorb impact during collisions, and rescue boats facilitate swift evacuations. These measures emphasize preparedness and quick responses to incidents.
- Subsequent Consequences. First aid facilities and trained personnel provide immediate medical assistance, while weather forecasting enables proactive adjustments to operations.

4.3 Gaps in Existing Mitigation Measures. Despite existing strategies, several gaps remain:

- Fishing Nets: Current reactive measures to remove nets from propellers are often ineffective, leading to operational delays.
- Aquatic Weed Management: Challenges in controlling aquatic weeds in the waterwt routes hinder operational efficiency.
- Traffic Congestion: Insufficient protocols for managing fishing and tourist boat traffic increase the risk of collision.

Addressing these gaps requires proactive measures, innovative solutions for aquatic vegetation management, and tailored traffic strategies to enhance overall safety and efficiency in water metro systems. Continuous evaluation and improvement of mitigation measures are essential for adapting to evolving risks.

4.4 Proposed New Mitigation Measures in Water Metro Systems

To enhance safety, operational efficiency, and environmental sustainability in water metro systems, several innovative strategies are proposed in response to identified gaps.

- Navigation Regulations: Implement strict rules for water metro operations, including speed limits and designated routes to avoid fishing areas. Establish restricted zones to minimize conflicts with fishing activities.
- Fishing Gear Regulations: Enforce standards for fishing gear, such as gear markings and mesh sizes, to reduce entanglement risks. Regulate high-risk gear types to mitigate impacts on water metro operations and promote sustainable fishing practices.
- Rehabilitation Programs: Create programs to support fishing communities affected by gear entanglements, offering financial assistance, repair resources, and training in gear maintenance to help them recover.
- Compensation Mechanisms: Establish compensation funds to fairly reimburse fishermen for losses due to water metro interactions, fostering trust and accountability between stakeholders.
- Community Engagement: Encourage collaboration between government agencies, water metro operators, and fishing communities to develop tailored, inclusive solutions that address local concerns.
- Rope Cutter Technology: Install automatic rope cutter devices on vessels to detect and sever fishing nets and debris before they jam propellers, reducing operational disruptions.
- Adoption of Gillnets: Promote the use of gillnets, which are less likely to entangle with propellers, thereby minimizing disruptions and promoting sustainable fishing by reducing bycatch.
- Signaling Buoys for Traffic Management: Implement controlled signaling buoys that provide real-time information to vessels about traffic conditions and navigational hazards, optimizing movement and enhancing safety.

These proactive measures leverage technology and promote sustainable practices to address challenges faced by water metro operators, contributing to the overall resilience and sustainability of water transport systems.

5.0 CONCLUSION

The project highlights the importance of robust risk assessment and mitigation in the Kochi Water Metro Project, focusing on key routes like Vyttila-Kakkanad and Vypin-High Court. Through an Expert Survey and Analytic Hierarchy Process (AHP), various risks were identified including traffic challenges and fishing nets. Proposed solutions involve implementing government regulations, providing compensation for fishermen, and deploying tools like rope cutters and signaling buoys. By integrating expert insights with structured analysis, the goal is to enhance the project's resilience and efficiency, offering guidance for similar global initiatives. Ultimately, the aim is to promote proactive risk management for the sustainable success of the project.

Conflict-of-interest statement

The authors have no competing interests to declare that are relevant to the content of this article. The authors have no relevant financial or non-financial interests to disclose

REFERENCES

[1] N. M. Sabitha, A. S. Athulya, B. G. Sreedevi, and V. S. S. Kumar, 'Development of Risk Assessment Model for Waterway Safety', in *Lecture Notes in Civil Engineering*, Springer, Singapore, 2022, pp. 163–179. doi: 10.1007/978-981-16-9925-2_11.

[2] T. Bačkalić and M. Maslarić, 'NAVIGATION CONDITIONS AND THE RISK MANAGEMENT IN INLAND WATERWAY TRANSPORT ON THE MIDDLE DANUBE', *Transport problems*, vol. 7, no. 4, pp. 13–24, 2012.

[3] Z. Wang and J. Yin, 'Risk assessment of inland waterborne transportation using data mining', *Maritime Policy and Management*, vol. 47, no. 5, pp. 633–648, Jul. 2020, doi: 10.1080/03088839.2020.1738582.

[4] V. Bolbot *et al.*, 'A novel risk assessment process: Application to an autonomous inland waterways ship', *Proc Inst Mech Eng O J Risk Reliab*, vol. 237, no. 2, pp. 436–458, Apr. 2023, doi: 10.1177/1748006X211051829.

[5] V. Guillén-Mena, F. Quesada-Molina, S. Astudillo-Cordero, M. Lema, and J. Ortiz-Fernández, 'Lessons learned from a study based on the AHP method for the assessment of sustainability in neighborhoods', *MethodsX*, vol. 11, p. 102440, Dec. 2023, doi: 10.1016/j.mex.2023.102440.

[6] T. L. Saaty, 'A scaling method for priorities in hierarchical structures', *J Math Psychol*, vol. 15, no. 3, pp. 234–281, Jun. 1977, doi: 10.1016/0022-2496(77)90033-5.

[7] J. E. Leal, 'AHP-express: A simplified version of the analytical hierarchy process method', *MethodsX*, vol. 7, p. 100748, Jan. 2020, doi: 10.1016/J.MEX.2019.11.021.

[8] A. H. Afolayan, B. A. Ojokoh, and A. O. Adetunmbi, 'Performance analysis of fuzzy analytic hierarchy process multi-criteria decision support models for contractor selection', *Sci Afr*, vol. 9, Sep. 2020, doi: 10.1016/j.sciaf.2020.e00471.

[9] S. Mihic, M. Golusin, and M. Mihajlovic, 'Policy and promotion of sustainable inland waterway transport in Europe - Danube River', 2011, *Elsevier Ltd*. doi: 10.1016/j.rser.2010.11.033.

[10] Leccese F, Salvadori G, Rocca M, Buratti C, and Belloni E, 'A METHOD TO ASSESS LIGHTING QUALITY IN EDUCATIONAL ROOMS USING ANALYTIC HIERARCHY PROCESS', 2019. [Online]. Available: https://www.elsevier.com/open-access/userlicense/1.0/