

Design and implement a Fuzzy Logic Model that enhances automated emergency alert and rescue coordination: A Case Study of MV New Victoria

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Abstract- Maritime transport plays a crucial role in global economies, but emergency preparedness on passenger vessels remains a significant safety concern, especially in developing nations. Traditional emergency alert systems often struggle with delayed transmissions, lack of coordination, inadequate use of real-time data, and poor onboard communication. To tackle these issues, this research developed the Automated Emergency Alert and Rescue Coordination Operation (AEARCO) model, which uses fuzzy logic for intelligent decision-making. The model assesses emergency severity and initiates appropriate responses based on real-time onboard conditions. The AEARCO model features a Mamdani-type Fuzzy Inference System (FIS) that incorporates six essential parameters: Weather Condition, Engine Performance, Communication System Status, Vessel Stability, Passenger Load, and Availability of Safety Equipment. These inputs are modelled linguistically and transformed into fuzzy rules to handle uncertainties in maritime operations. Data from 47 stakeholders, including crew members, passengers, and regulatory bodies in the Lake Victoria region, were analyzed using SPSS and MATLAB to identify key factors affecting alert efficiency. Findings showed that weather conditions (96.7%), passenger load (91.7%), and engine performance (88.3%) were the most critical factors influencing maritime emergency outcomes. Conclusion: The fuzzy logic model, evaluated using MATLAB Simulink, demonstrated improved accuracy and responsiveness compared to traditional systems. Overall, the AEARCO model enhances decision-making under uncertainty, offering a scalable approach to improving passenger vessel safety and emergency coordination.

Index Terms-Fuzzy logic, maritime emergency, automated rescue, decision support system, MV New Victoria, real-time alert, marine safety, Simulink, emergency response.

I.INTRODUCTION

Maritime transportation serves as an essential link for coastal and lakeside communities (Pooley & Roy, 2023), particularly in extensive inland bodies of water such as Lake Victoria (Masoud, 2021), which is recognized as the largest freshwater lake in Africa

and accommodates over 40million individuals along its shores (Sterner et al., 2020). Passenger ferries, such as the Mv New Victoria, play a crucial role in fostering regional connectivity (Yonazi, 2024). However, they continue to confront significant challenges related to vessel maintenance, regulatory compliance, and effective emergency management (Sterner et al., 2020). Safety issues on Lake Victoria are frequently reported (Guy et al., 2024). A salient example is the tragic sinking of the MV Nyerere in September 2018, which resulted in 228 fatalities, underscoring the dire consequences of inadequate safety measures (Tugume, 2024). Likewise, the MV Victoria has suffered from mechanical breakdowns and has undergone extended phases without substantial overhauls, sometimes exceeding two decades (Masoud, 2021), thereby highlighting the pressing necessity for enhanced safety protocols and decision-support systems (Waked, 2025). Existing maritime safety frameworks, including the Global Maritime Distress and Safety System (GMDSS), excel in automated alert generation and communication (Ilcev, 2024).

Nonetheless, these frameworks predominantly rely on human initiation and provide limited intelligent processing of ambiguous or dynamic data (Zeng et al., 2024). To address this deficiency, fuzzy logic emerges as a robust methodology for managing uncertain and imprecise inputs, such as sensor anomalies, fluctuating wave heights, and inconsistent passenger reports, thereby converting these variables into actionable insights (Sarihi et al., 2023).

Research has already illustrated the efficacy of fuzzy logic within maritime contexts (Gharib & Kovács, 2024), including collision avoidance systems that incorporate variables such as Time to Closest Point of Approach (TCPA) and relative bearing (Zhou et al., 2024), as well as fuzzy-based decision-making systems that optimize search-and-rescue (SAR) asset deployment amid uncertainty (Badry & Noureldin, n.d.). Additionally, a study has successfully applied fuzzy logic to assess the risk of system flooding on naval vessels (Karunanayaka et al., 2024). However, the integration of a comprehensive fuzzy logic engine within a real-time Automated Emergency Alert and Rescue Coordination Operation (AEARCO) system, capable of generating alerts and orchestrating coordinated response measures, remains a largely uncharted territory.

This paper delineates the design and implementation of a fuzzy logic-enabled AEARCO system specifically tailored for passenger ferries, using the Mv New Victoria as a case study. Challenges such as ageing infrastructure, variable weather conditions on the water, and limited human oversight necessitate the development of an automated, intelligent alert mechanism designed to enhance passenger safety and improve the efficacy of rescue coordination efforts.

II. ANALYSIS & SOLUTION

Passenger ferries on Lake Victoria, including the MV New Victoria, play a vital role in regional transportation (Karunanayaka et al., 2024). However, the ferry is operate in an environment characterized by frequent mechanical failures, insufficient maintenance, and inadequate emergency preparedness (Kaale et al., 2023). Although safety frameworks like the Global Maritime Distress and Safety System (GMDSS) are in place to ensure communication (Ilcev, 2024), significant limitations still exist (Ilcev, 2024), including delayed or unclear alerts (Ombe & Igwe, 2025), human errors in judgment (Sameera Sulakshana, 2024), and uncoordinated rescue efforts (Liu et al., 2024).

Ferry operations in Lake Victoria often suffer from poor maintenance (Kafeero, 2024). Many vessels operate without valid seaworthiness certificates (Kayanda, 2021), qualified crew members (Kayanda, 2021), or essential safety equipment such as rescue boats and life jackets (Kayanda, 2021). According to (Karunanayaka et al., 2024) The MV Victoria has experienced serious incidents, including an engine failure in October 2014 and a dockside fire in early 2013. Additionally, critical ferries like the MV Victoria h...(truncated 20779 characters) ...diverse range of vessels and locations, rather than solely on the MV New Victoria. A comprehensive assessment is essential for instilling confidence in the AEARCO model's resilience and scalability across various operational and environmental conditions.

Moreover, the incorporation of additional data sources, such as meteorological APIs, GPS, and marine traffic, has the potential to facilitate predictive warning systems that could revolutionize maritime safety. Since human interaction is equal

y important, it is vital to conduct research on crew engagement with the fuzzy system and to evaluate user experiences to enhance the design and promote wider adoption of the system.

III. REFERENCES

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