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The Unsung Hero: A Comprehensive Analysis of Tugmaster Operations

Tiong Kuong Chiing[1], Omar Faruqi Marzuki[1,2,*], Ellie Yi Lih Teo[1,2], Tze Jin Wong[1], Mohd Ibrani Shahrimin Adam Assim[3], Nor Mariah Adam[4]

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ABSTRACT

Tugboat Masters are essential in maritime logistics, ensuring the safe and efficient movement of large vessels in confined spaces. Despite their critical role, the operation of tugboats is fraught with challenges that demand a high level of skill and expertise. This paper analyzes common errors made by maritime pilots during tugboat navigation, such as communication failures, lapses in situational awareness, mechanical misunderstandings, and flawed decision-making. These errors can lead to significant risks, including collisions, environmental disasters, financial losses, and reputational damage. The paper proposes actionable recommendations to mitigate these risks, including enhanced training programs, the integration of advanced technologies, the development of standardized operating procedures (SOPs), and regular risk assessments. By implementing these strategies, the maritime industry can enhance the safety and efficiency of tugboat operations, safeguarding lives, property, and the environment.

1. Introduction.

Pilots always get the good name for the difficult maneurvere or completed berthing of a very large vessel. Tugboat Masters are the unsung heroes of maritime logistics, playing a vital role in ensuring the safe and efficient movement of larger vessels within the confined spaces of ports and harbors (Wei et al., 2020). These robust and maneuverable vessels provide the necessary power and precision to guide cargo ships, tankers, and other large marine craft through narrow channels, around tight bends, and into docking positions (Nitonye et al., 2017; Paulauskas et al., 2021). Their contribution is indispensable in maintaining the smooth operation of global maritime trade, facilitating the timely and secure transportation of goods across the world's oceans (Tiong et al., 2021).

Various designed harbor tugs such as convectional push-pull Tugs or Tractor Tugs, Azimuth Stern Drive, Voith Schneider Tugs and Rotor Tugs. Some of these tugs are fixed with fire fight and anti-pollution devices. Required combined tugboats' power force to maneuver larger vessels can be predetermined either by mathematic calculation or using advance simulator. However, the operation of tugboats is not without its challenges. Together with maritime pilots, who are entrusted with the critical task of navigating these vessels, often encounter complex situations that demand a high level of skill and expertise. These scenarios can include navigating through crowded waterways, contending with unpredictable weather conditions, and responding to sudden changes in the behavior of the vessels being assisted. Almost all the maritime accidents related to the pilotage could be avoided if there were tugs to assist or escort. Many major ports and canal have implemented compulsory to use escort tugs to reduce any potential accident. The margin for error in these operations is minimal, and even a slight miscalculation can lead to significant consequences (Tiong et al., 2021, 2022).

Errors in towage operation can result in collisions, ground-

[1]Department of Science and Technology, Faculty of Humanities, Management and Science, Universiti Putra Malaysia, 97008 Bintulu, Sarawak, Malaysia.
[2]Institut EkoSains Borneo, Universiti Putra Malaysia, Jalan Nyabau, 97008 Bintulu, Sarawak, Malaysia.
[3]Department of Social Science and Management, Faculty of Humanities, Management and Science, Universiti Putra Malaysia, 97008 Bintulu, Sarawak, Malaysia.
[4]Department of Chemical and Environmental Engineering, Faculty of Engineering, Universiti Putra Malaysia, 43400 UPM Serdang, Selangor, Malaysia.
*Corresponding author: Omar Faruqi Marzuki. E-mail Address: omar_faruqi@upm.edu.my .

ings, and other accidents that not only pose a threat to the safety of the crew, damages to vessel, detrimental impact on the environment and disrupt the flow of maritime logistics or commercial. Therefore, understanding the nature of these errors and the factors that contribute to them is of paramount importance. By identifying common pitfalls and analyzing the circumstances that lead to navigational mistakes, the maritime industry can develop targeted strategies to prevent such incidents (Aalberg et al., 2022; Fiskin et al., 2021; Pilatis et al., 2024).

Addressing these challenges requires a multifaceted approach that encompasses enhanced training for tug masters and pilots, conducting risk assessment, hazard identification, adaptation of advanced handling technologies, and the implementation of rigorous safety protocols. By investing in having good modern powerful tugs, and increase in the competency of tug crew, the industry can significantly reduce the risks associated with towage and pilotage operations, ensuring the continued safety and efficiency of maritime logistics.

2. Common Errors in Towage Operation.

In the intricate world of towage operation, the margin for error is remarkably narrow (Sánchez-Beaskoetxea et al., 2021). As these powerful vessels measuring their power either by horse power or bollard pull that maneuver large ships through congested waterways and tight harbor spaces, the skills and decision-making abilities of maritime pilots are put to the test. Despite their expertise, pilots and Tug Masters are not immune to errors, which can stem from a variety of factors, including communication failures, lapses in situational awareness, mechanical misunderstandings, and hasty decision-making. This section delves into these common errors, shedding light on their causes and implications for tugboat operations, with the aim of enhancing safety and efficiency in this critical aspect of maritime logistics.

i. Communication Failures
Effective communication is the cornerstone of successful towage and pilotage operations. However, communication failures are a prevalent issue that can lead to significant errors in navigation. Miscommunication between the pilot, tug crew, and other vessels can stem from a variety of factors, including language barriers, technical glitches in communication equipment, and ambiguous instructions. These failures can result in misunderstandings that lead to incorrect maneuvers, such as misaligned positioning or improper towing techniques, ultimately compromising the safety of the operation (Galal & Hafez, 2023; Karahalios, 2018; Sánchez-Beaskoetxea et al., 2021; Tseng et al., 2021).

ii. Situational Awareness
Situational awareness is critical for the safe towage operations. Pilots and tug master must constantly monitor their vessel's position, the proximity of other vessels, and environmental conditions such as wind, currents, and visibility (Sharma et al., 2019). Losing situational awareness can lead to catastrophic outcomes, such as collisions with other vessels or infrastructure, or grounding in shallow waters. Factors that can contribute to a loss of situational awareness include distractions, fatigue, and over-reliance on electronic navigation systems without cross-checking with visual cues and other instruments (Chauvin et al., 2008; Dominguez-Péry, Vuddaraju, et al., 2021; Gommosani et al., 2021; Jaram et al., 2021; Kahraman et al., 2023).

iii. Mechanical Understanding
A thorough understanding of the tugboat's mechanical capabilities and limitations is essential for effective navigation. Inadequate knowledge of the vessel's propulsion system, steering mechanisms, and towing equipment can lead to the misuse of these critical components. For example, overestimating the tug's pulling power can result in the failure of towing lines or the inability to control the assisted vessel properly. Similarly, a lack of familiarity with the steering system can lead to delayed or incorrect responses to pilot's commands, increasing the risk of accidents (Asmara et al., 2022; Çakır et al., 2021; Oraith et al., 2021; Pérez-Canosa et al., 2022; Tiong et al., 2021; Tseng et al., 2021; Wang et al., 2020).

iv. Decision-Making
The high-pressure environment of tugboat operations often requires quick decision-making. However, under stress, pilots may make hasty decisions without fully considering the potential consequences. Rushed decisions can lead to errors such as choosing an inappropriate approach for docking, misjudging the distance to other vessels, or failing to anticipate changes in environmental conditions. Improving decision-making skills involves not only experience and training but also the ability to remain calm under pressure and to systematically evaluate the available options before taking action (Butler et al., 2022; Main et al., 2017; Main & Chambers, 2015; Tseng et al., 2021; Žagar et al., 2022).

3. Risk Analysis.

In the realm of tugboat operations, the analysis of risks is paramount to ensuring the safety and efficiency of maritime endeavors (Tseng et al., 2021). This section examines the multifaceted risks associated with tugboat navigation errors, including the potential for collisions, environmental disasters, financial repercussions, and reputational damage. By dissecting these risks, this paper aims to provide a comprehensive understanding of the challenges faced by tugboats or pilots and the broader implications for the maritime industry. This analysis serves as a foundation for developing targeted strategies to mitigate these risks and safeguard the well-being of crew members, the environment, and maritime assets.

i. Collision Risk
The risk of collision is a primary concern in tugboat operations, as these vessels often navigate in close proximity

to other ships and harbor infrastructure. Errors in navigation, such as misjudging distances or failing to properly coordinate movements, can result in collisions that cause significant damage to the tugboat, the assisted vessel, and potentially other nearby structures or ships (Çakır et al., 2021; Fazlee et al., 2023). The consequences of such incidents can include injuries to crew members, disruption of port operations, and substantial repair costs. Mitigating this risk requires stringent adherence to operation protocols, continuous situational awareness, and effective communication among all parties involved in the operation (Budianto et al., 2019; çakır et al., 2017; El Desouky, 2023; Kodak, 2022).

ii. Environmental Risk
Tugboats are frequently involved in the handling of tankers carrying oil, chemicals, or other hazardous materials. Any error in handling may leads to a collision or grounding of such vessels poses a serious risk of environmental pollution. The resulting oil spills or release of toxic substances can have devastating effects on marine ecosystems, endanger local wildlife, and impact coastal communities. Preventing environmental disasters necessitates rigorous training in emergency response procedures, the implementation of stringent safety measures, and regular inspections to ensure the tugboats and assisted vessels are in optimal condition (Assimizele et al., 2018; Byrnes & Dunn, 2020; Khan et al., 2023; J. Lee, 2017; Maruf, 2023; Rodriguez, 2023).

iii. Financial Risk
The financial implications of any mishap caused by tugboat errors can be substantial. Accidents can lead to costly damages to the tugboat itself, the vessels being assisted, and port infrastructure. Additionally, such incidents often result in insurance claims and increased premiums, legal liabilities, and potential fines for regulatory violations. The financial burden of these costs can strain the resources of the operating company and impact its profitability. To minimize financial risk, companies must invest in comprehensive insurance coverage, maintain high safety standards, and implement effective risk management strategies (Chou et al., 2021; Talley, 2001; Yao et al., 2024; Yuvita & Murtaqi, 2018).

iv. Reputational Risk
The reputation of a tugboat operating company is closely tied to its safety record. Incidents involving tugboats can quickly tarnish the company's reputation, leading to a loss of trust among clients, stakeholders, and regulatory authorities. This erosion of confidence can result in a loss of business opportunities, difficulty in securing contracts, and challenges in attracting and retaining skilled personnel. To safeguard their reputation, companies must prioritize safety, transparency in incident reporting, and a commitment to continuous improvement in operational practices (Budianto et al., 2019; Fukuoka & Furusho, 2016; Galal & Hafez, 2023; Oktafia et al., 2018; Oluseye & Ogunseye, 2016; Zhou et al., 2024).

4. Recommendations.

To address the challenges and risks identified in towage operations, this section presents a set of carefully considered recommendations. These proposals are designed to enhance the safety and efficiency of tugboat operations, focusing on key areas such as improved training programs, the integration of advanced technologies, the development of standardized operating procedures, and the implementation of regular risk assessments. By adopting these recommendations, stakeholders in the maritime industry can take proactive steps to mitigate risks, improve communication and decision-making, and ultimately contribute to safer and more reliable towage operations.

i. Enhanced Training
Comprehensive training programs are essential for ensuring that tugboat crew and pilots possess the necessary skills for safe and effective operation. These programs should include:

(a) Simulation Training: Simulation training is a cornerstone of modern maritime education, offering a risk-free environment for Tug Masters and pilots to refine their skills. State-of-the-art simulators can replicate a wide range of scenarios, from routine operations to complex emergency situations. This immersive experience enables pilots to practice maneuvering in various conditions, including adverse weather and high-traffic areas, without the real - world consequences. Regular sessions in simulators can help build confidence, enhance decision-making abilities, and reinforce the correct procedures for handling different types of vessels (de Oliveira et al., 2022; Kang et al., 2020; Kim et al., 2021; Sellberg et al., 2024).

(b) Continuing Education: The maritime industry is continually evolving, with new regulations, technologies, and best practices emerging regularly. To keep pace with these changes, tugboat pilots and crew must engage in ongoing education. Training curricula should be updated frequently to reflect the latest industry standards and technological innovations. This can include workshops, seminars, and online courses covering topics such as environmental regulations, cybersecurity, and advancements in navigation systems. By staying informed, maritime professionals can ensure their knowledge and skills remain relevant and effective (Konon, 2022; Paulauskas et al., 2021; Sari & Sari, 2020).

(c) Team Training: Effective teamwork and communication are critical for the successful operation of tugboats. Team training exercises should be an integral part of training programs, focusing on building a cohesive unit that can work seamlessly to-

gether. These exercises can simulate real-life scenarios that require coordination between the pilot, crew, and other vessels, such as docking operations and towing maneuvers. Emphasizing clear communication, mutual respect, and understanding of each team member's role can enhance overall efficiency and safety (Bouzón et al., 2023; Chowdhury et al., 2024; Griffioen et al., 2021; Lochner et al., 2018).

(d) Emergency Response: Preparedness for emergency situations is vital for tugboat operations. Training programs should include comprehensive drills and exercises that cover a range of emergency scenarios, such as fire outbreaks, man-overboard incidents, and environmental spill containment. These drills should be conducted regularly to ensure that all crew members are familiar with emergency procedures and can respond effectively under pressure. By fostering a culture of safety and preparedness, tugboat operators can minimize the impact of unforeseen events and protect both personnel and the environment (Assimizele et al., 2018; Aydogdu, 2022; Baliyan & Dhankher, 2022; Griffioen et al., 2021).

ii. Technology Integration

The integration of advanced technologies can significantly enhance the safety and efficiency of towage operations:

(a) Navigation Systems: The integration of advanced navigation systems is crucial for the precise and safe maneuvering of tugboats. State-of-the-art GPS systems, radar, and Automatic Identification Systems (AIS) provide real-time data on vessel position, movements, and the surrounding maritime environment (Chen et al., 2020). These systems enable pilots to navigate with greater accuracy, even in poor visibility or congested waterways. By incorporating electronic chart display and information systems (ECDIS), pilots can access digital nautical charts and plan routes more effectively, further enhancing navigational safety (Car et al., 2019, 2020; Chou et al., 2022; Weintrit, 2020).

(b) Communication Tools: Clear and reliable communication is essential for coordinating tugboat operations, especially during complex maneuvers or in emergency situations. Modern communication tools, such as VHF radios, satellite phones, and digital communication platforms, ensure that the pilot, crew, and other vessels can exchange information seamlessly. Implementing standardized communication protocols and ensuring that all crew members are trained in their use can prevent misunderstandings and improve the overall efficiency of operations (Costa et al., 2018; Jürgens & Singer, n.d.; Nikghadam et al., 2023; Tseng et al., 2021; Yao et al., 2024).

(c) Collision Avoidance Systems: Collision avoidance systems are critical for preventing accidents and ensuring the safety of tugboats and the vessels they assist. These systems use radar, sonar, and other sensors to detect potential obstacles and alert pilots to collision risks. Advanced algorithms can analyze the data and suggest corrective actions, such as course adjustments or speed reductions. By integrating these systems into tugboats, operators can significantly reduce the risk of collisions and enhance navigational safety (Ma et al., 2022; Tran et al., 2023; Zhang et al., 2022, 2023).

(d) Data Analytics: The use of data analytics in tugboat operations can provide valuable insights into performance, operational trends, and potential risks. By collecting and analyzing data from various sources, such as navigation systems, sensors, and logbooks, operators can identify patterns and areas for improvement. Predictive analytics can be used to anticipate potential issues before they occur, allowing for proactive measures to be taken. This data-driven approach can lead to more informed decision-making, optimized operations, and reduced risks (Borzyszkowski, 2022; Dominguez-Péry, Tassabehji, et al., 2021; Ernstsen & Nazir, 2020; Hadi et al., 2023; Pipchenko et al., 2023; Tay et al., 2021).

iii. Standard Operating Procedures (SOPs)

Clear and comprehensive SOPs are critical for ensuring consistency and preparedness in tugboat operations:

(a) Scenario-Based SOPs: Developing detailed Standard Operating Procedures (SOPs) for a variety of scenarios is crucial for maintaining consistency and safety in tugboat operations. These SOPs should cover all aspects of tugboat operations, from routine tasks like docking and undocking to more complex maneuvers such as towing and assisting vessels in distress. Additionally, SOPs should address emergency situations, including fire outbreaks, man - overboard incidents, and environmental spills. By having clear, step-by-step guidelines for each scenario, crew members can respond confidently and effectively to any situation that may arise (Anjani & Hati, 2021; Asmara et al., 2022; Baldauf et al., 2020; Huang et al., 2020).

(b) Regular Updates: The maritime industry is constantly evolving, with new regulations, technologies, and best practices emerging regularly. To ensure that SOPs remain relevant and effective, they should be reviewed and updated periodically. This process should involve input from experienced crew members, feedback from drills and actual operations, and the latest industry standards and guidelines. By keeping SOPs up to date, tugboat operators can ensure that their crews are always following the most current and effective procedures (Bošnjak et al., 2021; Brooks et al., 2016; S.-M. Lee et al., 2021; Yao et al., 2024).

(c) Training and Drills: Incorporating SOPs into training programs and conducting regular drills is essential for ensuring that all personnel are familiar

with the procedures and can execute them effectively. Training should include both theoretical instruction and practical exercises, allowing crew members to apply what they have learned in simulated scenarios. Regular drills should be conducted to reinforce the SOPs and ensure that crew members can perform their duties automatically and efficiently, even under pressure. By integrating SOPs into training and drills, tugboat operators can build a culture of safety and preparedness, ensuring that their crews are ready to handle any situation that may arise (Baliyan & Dhankher, 2022; Dragomir & Simona, 2016; Lech Kobyliński, 2016; Palbar Misas et al., 2024).

iv. Regular Risk Assessments
Proactive risk management is key to identifying and mitigating potential hazards:

(a) Risk Identification: Regular risk assessments are essential for proactive risk management in tugboat operations. These assessments should be conducted periodically to identify new risks that may have emerged due to changes in operations, regulations, or the external environment. Additionally, existing risk mitigation strategies should be reviewed to ensure they remain effective and relevant. By continuously identifying and evaluating risks, tugboat operators can stay ahead of potential hazards and implement timely measures to address them (Budianto et al., 2019; Daryanto et al., 2020; de Larrucea, 2017; Tseng et al., 2021; Weerakoon Karunatilleke, 2024; Zaman et al., 2020).

(b) Hazard Analysis: Once risks have been identified, a thorough hazard analysis should be conducted to assess the likelihood and potential impact of each risk on tugboat operations. This analysis should consider factors such as the probability of occurrence, the severity of consequences, and the vulnerability of the operation to the hazard. By understanding the nature and magnitude of potential hazards, operators can prioritize risks and allocate resources more effectively to address the most significant threats (El Desouky, 2023; Singh & Raju, 2016; Stukonog, 2021).

(c) Mitigation Strategies: Based on the results of the hazard analysis, mitigation strategies should be developed and implemented to reduce the identified risks to an acceptable level. These strategies may include implementing new safety procedures, enhancing training programs, upgrading equipment, or making operational changes. It is important that these strategies are tailored to the specific risks and operational context of the tugboat operation to ensure their effectiveness (Budianto et al., 2019; Kodak, 2022; Nikghadam et al., 2023; Tseng et al., 2021).

(d) Continuous Monitoring: Establishing a system for continuous monitoring and evaluation is crucial for ensuring the ongoing effectiveness of risk management efforts. This system should include regular reviews of risk assessments, mitigation strategies, and incident reports to identify trends and areas for improvement. Key performance indicators (KPIs) can be used to measure the success of risk management initiatives and guide adjustments to strategies as needed. By maintaining a vigilant and adaptive approach to risk management, tugboat operators can enhance the safety and resilience of their operations (Cope et al., 2020; Hjellvik & Sætrevik, 2020; Mthembu & Chasomeris, 2023; Tseng et al., 2021).

Conclusions.

Experienced tug masters understand the dynamics of different vessels and can execute complex maneuvers safely. Tug Master or pilot errors represent a critical challenge to the safety and efficiency of maritime operations. These errors can have far-reaching consequences, including the potential for collisions, environmental disasters, financial losses, and damage to reputation. It is imperative for stakeholders in the maritime industry to recognize the gravity of these risks and to take proactive measures to address them.

A thorough understanding of the common errors made by maritime pilots and the risks associated with these errors is the foundation for effective risk management. By identifying the root causes of these errors, stakeholders can develop targeted strategies to prevent their occurrence. Key to this endeavor is the implementation of comprehensive training programs that focus on enhancing communication, situational awareness, and decision-making skills among tugboat pilots and crew. Equally important is the integration of advanced navigation and communication technologies, which can provide critical support to pilots in making informed decisions and maintaining situational awareness.

The development and enforcement of standardized operating procedures (SOPs) for various scenarios is another vital component of a robust risk management framework. These SOPs should be regularly reviewed and updated to reflect changes in regulations, technologies, and best practices. Additionally, regular risk assessments are essential for identifying potential hazards and implementing proactive mitigation strategies. By continuously monitoring and evaluating the effectiveness of these risk management measures, the maritime industry can adapt and respond to emerging challenges.

In conclusion, the safety and efficiency of tugboat operations are of paramount importance to the maritime industry. By implementing targeted strategies to mitigate the risks associated with tugboat maritime pilot errors, stakeholders can contribute to safer and more reliable operations. Enhanced training, technology integration, standardized procedures, and regular risk assessments are crucial components of a comprehensive risk management approach. Tugboats equipped with the proper towing gear, winches, and correct type of towlines can reduce

the risk of accidents. Through these efforts, the maritime industry can safeguard lives, property, and the environment, ensuring the continued vitality and sustainability of global maritime operations.

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