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Analysis of Pier Contact Accident in Busan New Port of South Korea by System-Theoretic Accident Model and Processes (STAMP)

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ABSTRACT: Marine accidents are caused by complex and diverse causes. Therefore, it is necessary to analyse accidents from the perspective of the whole system rather than the existing analysis models that focus on cause-effect. The STAMP analysis is a constraint-based model that focuses on improper management or enforcement of safety-related constraints in system operation. Thus, as a case study of the application of the STAMP technique in marine accident analysis, the Milano Bridge pier contact accident that occurred on April 6, 2020 in Busan New Port of South Korea was analysed by the STAMP technique in this study. Through this study, it was proposed to break away from the domestic accident investigation, which focused only on the punishment of the ship operator, and to suggest improvements that enable organizations related to the marine accidents to take initiative to take efforts for safety.

1 INTRODUCTION

It is very important to prevent marine accidents because of huge impact on the whole society, such as physical damage, loss of life, economic loss, and environmental pollution. However, accidents caused by marine activities are very complex, and it is not possible to simply explain why accidents occur and how to prevent accidents[1]. Especially, accidents related to pilotage are directly or indirectly related to pilots who are placed at the forefront of safety, so it has a significant impact on related industries and can cause enormous port costs[2].

In South Korea, an accident occurred in which a pilot collided with a pier and an oil pipeline and spilled crude oil while berthing a crude oil carrier in 2014. This was the second-largest accident in the case of oil spill in marine accidents from 2000 to 2022, and environmental damage was serious[3]. In addition, in 2020, a 13,900 TEU large container ship, the Milano Bridge, which was approaching the pier for berthing with a pilot on board at Busan New Port, collided with a gantry crane and the other ship that was berthing. In this accident, it is estimated that a total of about 25 million euros of damage occurred only in the repair and restoration costs of gantry cranes[4].

Although the frequency of pilotage accidents is mostly low compared to other maritime accidents, it is very important to identify the cause of pilotage accidents and prepare safety measures because the scale of damage is significant[2]. However, according to the pilotage accident investigations from 1978 to 2017, it can be confirmed that the accident investigation was completed mostly by punishing the ship operators and pilots who mainly participated in the manoeuvring of the ships at the KMST[5].

Therefore, it was recognized that it was necessary to analyse the pilotage accident from the perspective of the social system rather than simply the existing cause-and-effect method of accident investigation analysis. This study intends to reveal more diverse causes of the accident and draw lessons by applying a systematic analysis model to the pier contact accident of the MILANO BRIDGE.

2 MILANO BRIDGE PIER CONTACT ACCIDENT

2.1 *Special report of Korea Maritime Safety Tribunal [4]*

On April 6, 2020, the Milano Bridge, a large container ship, collided with a gantry crane in the New port of Busan, South Korea. This huge incident caused significant damage to the crane, the ship, and the surrounding infrastructure resulting in a tremendous operating loss.

Figure 1. M/V Milano Bridge (MarineTraffic)

Table 1. Ship's particular of M/V MILANO BRIDGE

MMSI	371076000
Ship name	MILANO BRIDGE
Ship's type	Full container ship
Date of Launch	18th July 2017
Flag state	Panama
L X B X H X D (m)	365.94 X 51.20 X 71.33 X 29.9
Gross tonnage (t)	150,706
Design Speed (kn)	21.85

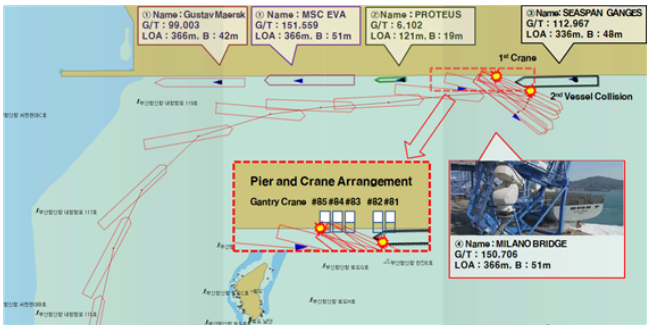

Figure 2. Berthing arrangement and collision when the accident occurred (KMST, 2021)

According to the official reports by KMST, the explicit cause of the accident was excessive speed during manoeuvring and the underestimated effects of the ship in ballast. The ship entered the port with about one-third of its propeller exposed above the water's surface because it was not carrying sufficient ballast water.

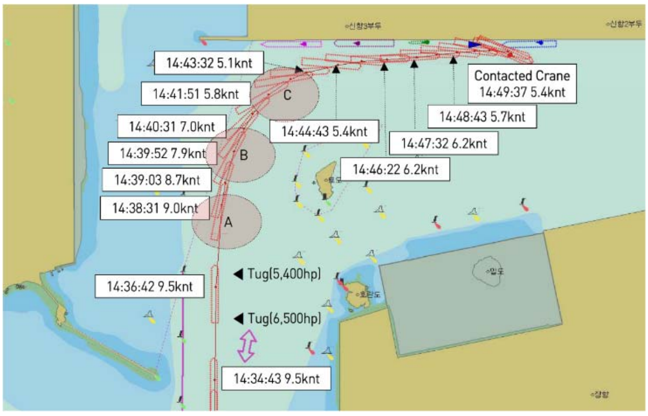

Figure 3. Track of MILANO BRIDGE at the time of the accident (KMST, 2021)

In order to search the cause of the accident, KMST conducted a various ship maneuvering simulations based on the operation records at the time of the accident stored in the VDR of the Milano Bridge.

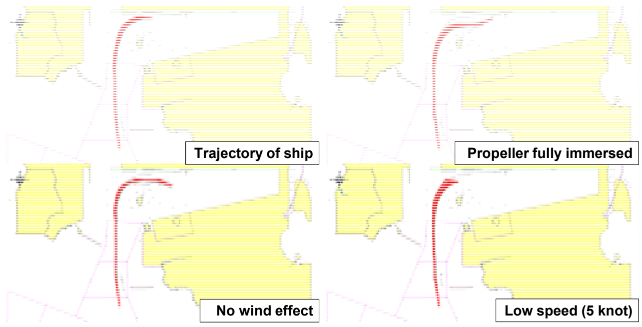

Figure 4. Ship manoeuvring simulation results (KMST, 2021)

The results of the simulation confirmed that the possibility of an accident was significantly reduced if the propellers were immersed 100% in the water to improve manoeuvring ability and ship entered the port at a lower speed. In addition, it was confirmed that the hull was pushed toward the pier due to the wind blowing from the south at the time of the accident. However, since the extent of wind and the change in wind speed during pilotage was insignificant, it is difficult to say that the influence of wind acted as a major factor in the occurrence of this accident.

Furthermore, KMST pointed out the lack of communication between the ship operator and the marine pilot as one of the causes of the accident.

2.2 *Literature Review*

A similar accident occurred worldwide formerly and afterward of Milano Bridge. In May of 2017, the container ship CMA CGM Centaurus collided with the quay and two shore cranes during its arrival at Jebel Ali, UAE, resulting in injuries and damage[6]. An investigation found that the ship was going too fast for the intended manoeuvre and there was no agreed plan between the bridge team and the pilot. Therefore, the investigation emphasizes the importance of effective communication and collaboration between pilots and bridge teams to ensure safety, especially as container ships continue to grow.

Figure 5. CMA CGM Centaurus making contact with the quay (MAIB, 2018)

On 28 January 2019, the container vessel Ever Summit was berthing under the conduct of a pilot at Vanterm in the Port of Vancouver, British Columbia (BC), with 2 tugs assisting when the vessel struck the berth and a nearby shore gantry crane[7]. The vessel, berth, and crane were damaged and there was no injuries or pollution. The investigation determined that the Ever Summit struck the berth after the vessel made a close approach and that the pilot inadvertently gave the assisting tugs the opposite instructions from what was intended during the berthing manoeuvre. The investigation looked at communications with tugs during berthing, the suitability of the berth infrastructure for large container vessels at Vanterm, and overall risk management of the terminal. (MARINE TRANSPORTATION SAFETY INVESTIGATION REPORT M19P0020, Transportation Safety Board of Canada, 2019)

Figure 6. Striking of berth and shore gantry crane with Ever Summit (TSB, 2020)

Previous studies using STAMP in marine accident analysis include study of Kim et al. [8] that analyzed the Korean Sewol ferry accident as STAMP-Model. The author recognized of the vulnerability of the safety control system in the accident of the Sewol ferry and tried to approach it from an institutional perspective. The analysis points out the institutional problems of Sewol ferry accident, highlights the need for a system approach to detection and prevention of safety constraint violations, and asks for corrective action at national and international levels.

In addition, a study that analyzed the explosion accident at an oil company that handles crude oil production work found out that the main cause of the accident was a spark, but the organizations of oil company also had a great influence on the accident [9]. In particular, ineffective safety policies, inadequate communication between and within departments, poor oversight, and inadequate resource allocation were cited as contributing factors to this tragic accident. It was then suggested that policies and regulations should be implemented at oil company to ensure safety for humans, equipment and the environment. Additionally, the authors suggest that all efforts at various levels of the hierarchical structure must work together to design safer systems in the company to prevent accidents.

3 ACCIDENT ANALYSIS

3.1 *STAMP(System-Theoretic Accident Model and Processes) Model*

In the modern world, newer and more complex socio-technical systems are in existence and the sequential and epidemiological models cannot be used effectively as before [10]. The systematic theory safety approach does not blame one single contributory factor and is a more suitable approach for analyzing accidents originating from such complex systems [11]. There are numerous systemic methods, for accident analysis of complex socio-technical systems, such as the Functional Resonance Accident Model (FRAM) [12], the AcciMap model [13], and the System-Theoretic Accident Model and Processes (STAMP) model [14]

Among the various systematic models, the STAMP casualty model is used to impose behavioural safety constraints in a system. The STAMP model projects a comprehensive view of the system and investigates the links between events. Notably, STAMP is useful in analyzing feedback and control actions and considers the dynamic characteristic of a system. Furthermore, when STAMP is adopted as the basis of safety, safety, and risk are considered as a function of the efficacy of the controls to instill safe system behavior [15]. STAMP is a more comprehensive model in terms of the identified causal factors as well as coverage of the entire socio-technical system [16].

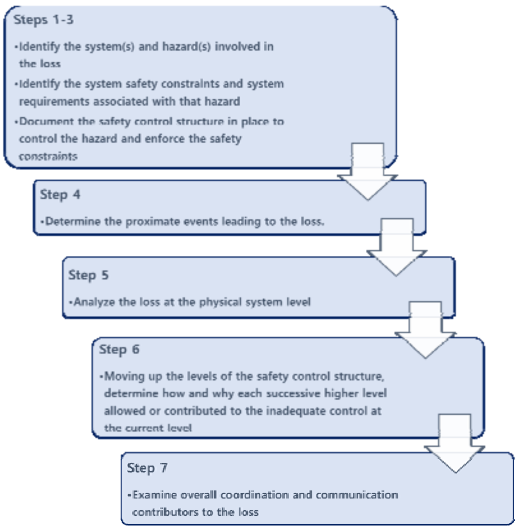

Figure 7. STAMP process (Leveson,2016)

3.2 *Application of STAMP to the MILANO BRIDGE pier contact accident*

The generic socio-technical hierarchical safety control structure for the STAMP model comprises two major structures-one for system development and the other for system operation. Each system within the hierarchical safety control structure can be modelled to include its specific features for both structures. In addition, both these structures have interrelationships between them. However, in this accident analysis, only the system operational structure will be considered because all the main components that were identified as having immediate control are under this structure [14].

In this accident analysis, factual data was sourced from the special accident investigation reports from the Korea Maritime Safety Tribunal (KMST) as published on 12 January 2021 as well as from interviews with persons of interest from other system components identified.

The initial phase of STAMP model analysis is the identification of the hazards as well as the construction of the hierarchical control structure. To achieve this, the author will begin the analysis of the Milano Bridge contact accident by establishing the berthing process of a vessel and identifying the key system components involved in the ship berthing process in Busan New Port. Furthermore, the relationships between all the identified system components will be outlined to gain a bigger overview of the entire ship berthing process. In figure 8, the process of berthing a ship is embodied through interviews with industry praticians participating in ship arrivals and departures at Busan Port.

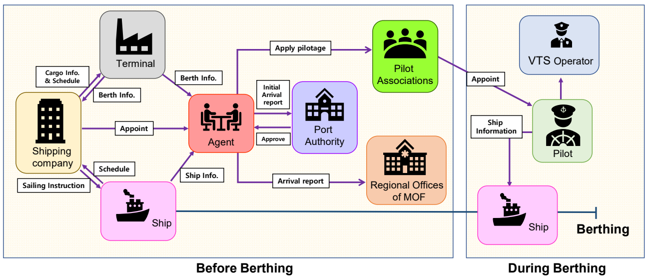

Figure 8. Ship berthing process of Busan port

As shown in figure 8, the organization that mainly participates in the ship's berthing process is shipping company, ship's crew, agent, terminal, port authority, regional office of Ministry of Oceans and fisheries, VTS and pilot. Accordingly, if the role of each organization and the constraints in this accident are arranged, the following system operation control structure can be created as figure 9-11.

Figure 9 shows the highest hierarchical control structure that ensures safe arrival of cargo ships in Busan. The safety control structure is initiated by the Ministry of Oceans and Fisheries (MOF), which has guidelines and legislations to ensure that ships can navigate the domestic waters safely while complying with the International Maritime Organization (IMO) Convention. MOF is the headquarters responsible for the safety of ship navigation in Korea, so regional administrations are delegated to local administrative agencies assigned to each port. Accordingly, the regional office of MOF will carry out regional port administration and the port authority will carry out port operations. In addition, the Korea Coast Guard, which is in charge of vessel traffic service, belongs to the MOF and performs tasks such as marine security and pollution control.

However, the Ministry of Oceans and Fisheries only received reports of major issues from local administrative offices and believed that local offices will doing well. The regional office of MOF entrusted the operation of Busan Port to the Busan Port Authority (BPA), and no consultations were held during the COVID-19 epidemic. BPA did not closely check the ship entry reports that are too common, and it was believed that the ship operator would safely manoeuvre ship for berthing even the ship which is exposed one-third of the propeller. Those of local institutions have also failed to prevent the accident because they have not been able to come up with sufficient countermeasures against the same accidents that occurred before. They had their own rules, but they were mainly revised by civil complaints, and there was no change after the accident. VTS has not been reported on the condition of the vessel, but the system has shown that it is operating at an excessive speed unlike other ships. However, proper control was not carried out, and finally the vessel was contacted with the pier at high speed by the pilot, without being advised anywhere.

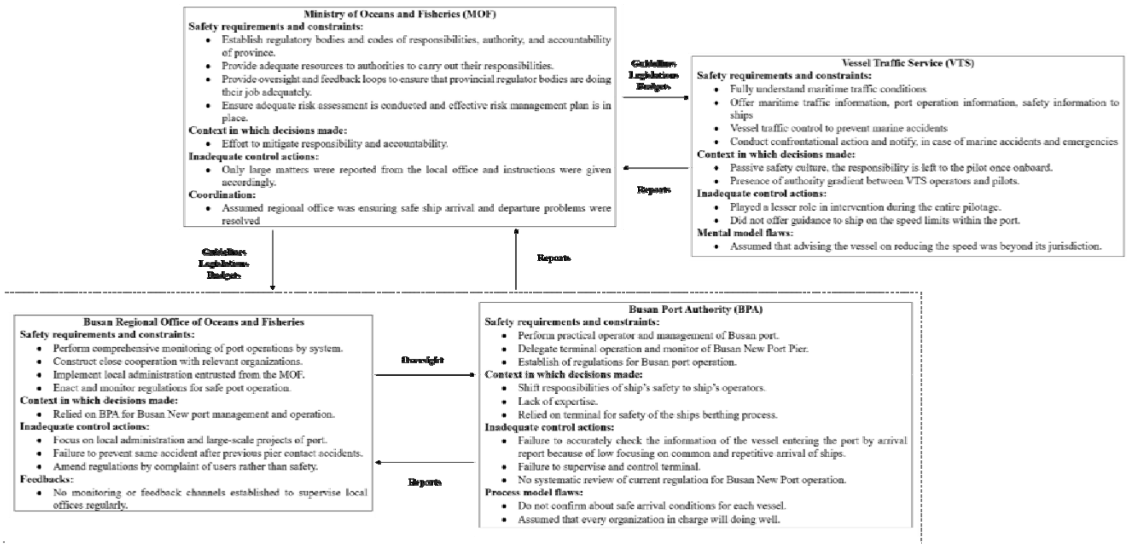

Figure 9. Analysis of government regulatory authorities

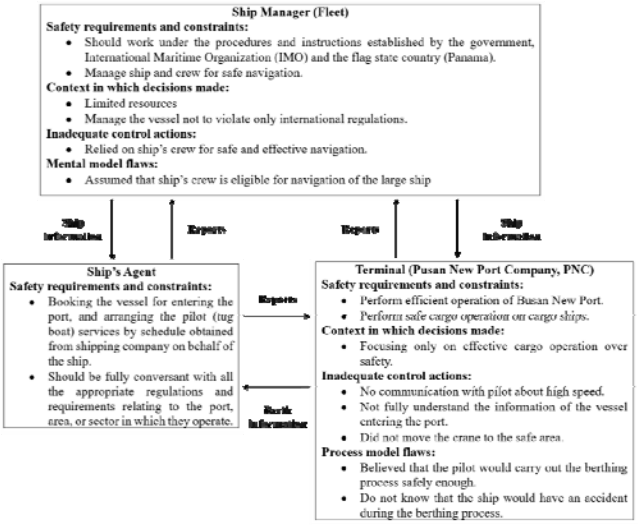

Figure 10. Analysis of industry association and ship manager

As shown in figure 10, for ship berthing and cargo operations, major industry-related agencies consult closely before ship berthing. The ship manager has the duty to manage the ship and crew so that the ship can safely carry the cargo under the charter contract. The charterer or ship manager contact the terminal for cargo loading and unloading and appoint an agent for administrative processing for entry into the port to delegate their tasks. Terminal prepares the berths according to the vessel's schedule and prepares for safe cargo operations. The Agent conducts a ship entry report to institutions such as port authority through the information received from the terminal and the ship manager.

However, the ship manager did not advise the crew to inject more ballast water, despite receiving reports of the ship's condition when the Milano Bridge left the shipyard in China and when it arrived in Busan. Additionally, although ship managers were responsible for ensuring that adequately qualified crew members were assigned to operational duties, crew members failed to act in accordance with Bridge Resource Team Management training and consequently failed to prevent accidents. According to the terminal's own regulations, the vessel foreman must listen to the transceiver to communicate with the pilot and check the speed and direction of the ship one hour before berthing. But the pilot was not given any advice from the vessel foreman, and no action was taken to adjust the ship's speed by him, resulting in an accident. Agents who are delegated with administrative tasks for the arrival and departure of ships play a role in sharing ship information. However, the agent's inappropriate control actions could not be found through the special investigation report and interview.

Figure 11 shows human controller and vessel operation flow. As a main human controller, crew members, including captain, are hired by ship owners and ship managers to ensure safe cargo transportation. Since ships must live independently once they leave port, bonding and communication between crew members are essential and must be trained. As a port expert, marine pilots act as guides through skilful manoeuvring so that ships can safely berth and load and unload cargo. Since captains are usually not familiar with the geography of a particular port, they must work closely with pilots to safely complete the berthing operation.

Despite this heavy responsibility, the captain failed to exchange sufficient information with the pilot. The specific information that could be helpful in steering the ship was ignored, and he just believed that a foreign pilot would do it well. Although he delegated manoeuvring to a pilot for berthing, but when there was a risk of an accident, he had to manoeuvre by himself, but it was not carried out, and appropriate emergency response procedures also were not implemented. The pilot worked as a pilot in Busan Port for more than 10 years and manoeuvred many ships of the same size as the Milan Bridge. Therefore, he judged that he would be able to ship for berthing sufficiently by increasing the horsepower of the tugboat and drove the ship in a hurry as before. However, he belatedly judged that the turning of the ship was late and panicked, failing to take additional actions that could have prevented the accident.

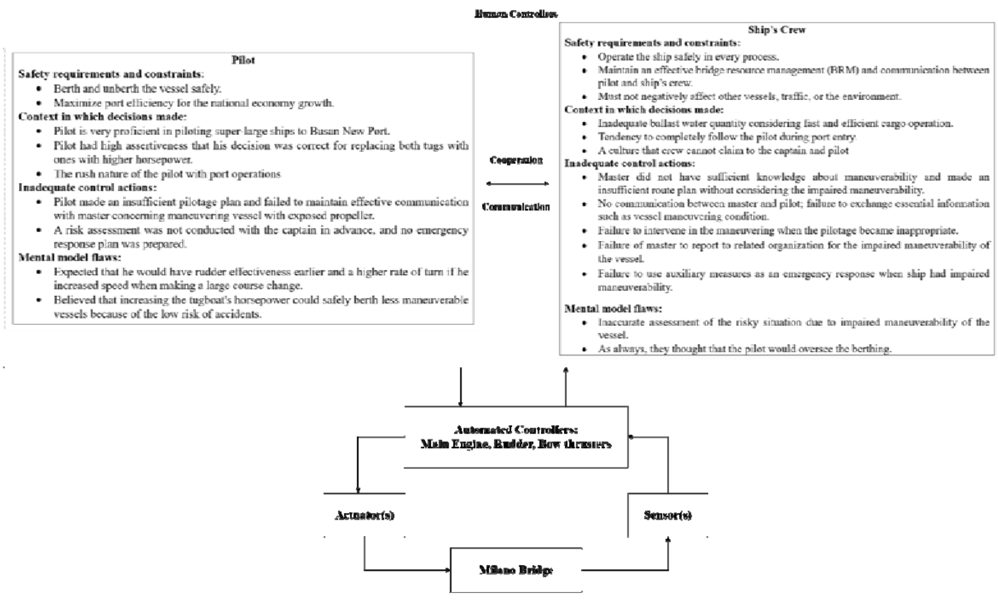

Figure 11. Analysis of human controller and vessel operating process

4 CONCLUSION

In April 2020, there was a pier contact accident that caused huge economic losses at Busan New Port of South Korea. The KMST concluded the investigation by punishing the pilot who participated in the operation of the ship at the time. However, in order to prevent future marine accidents, the cause should be found in a more diverse and complex social system rather than a punishment-oriented investigation. Therefore, this study attempted to draw lessons by analyzing the Milano bridge pier contact accident with STAMP, and the recommendations for preventing similar accidents in future were as follows.:

1. Each system of the safety control structure, identified through the special investigation report and operators' interview, should not postpone its responsibility, but should take an active attitude to prevent accidents and improve proper communication between each system.
2. Vessels wishing to enter the port should be compared with the previous database and reviewed to see if there are any unusual items when applying for port entry. Institutions that can check the information of the ship must carefully observe the condition and operation status of the ship, and communicate with the ship to give advice so that the ship can operate more safely.
3. Seafarers must receive appropriate on-the-job training in order to have sufficient knowledge about ship handling and ship conditions, and must be continuously checked for knowledge. Even in the case of delegation of manoeuvring authority, proper training must be given to take responsibility for the safety of the ship by communicating closely with foreign pilots.
4. Even if the pilot is a port expert, a detailed pilotage manual or plan customized for each port must be supported, and the effectiveness of pilot training conducted on a regular basis must be checked and improved according to practice. In addition, institutions around pilots should have a procedure for checking safety once more.
5. Lastly, the way to prevent accidents cannot be solved only by punishing operators. Therefore, the maritime accident investigation and tribunal must clearly identify the cause of the accident and make a judgment, but officially demand safety measures from organizations related to the accident through techniques such as STAMP.

This study is meaningful in applying the systematic theoty to the recent pier contact accident in South Korea, and it can suggest countermeasures in the analysis of the current maritime accident analysis. However, the limitation is that comparisons may be insufficient because accident analysis models other than system analysis techniques are not used for accident analysis, which should be supplemented and studied in the future.

REFERENCES

[1] Svein Kristiansen, 2005, "Safety Management and Risk Analysis" in Maritime Transportation, Elsevier, Oxford, UK.

[2] E. K. Lee, and Y. S. Park., 2020, A Study on Cause Analysis of Accidents related to Pilotage in Korean Waterways, Journal of Korean Maritime Police Science, Vol. 10, No. 2, pp. 109-129.

[3] e-NaraStatistics, 2023, Marine Pollution Accidents (https://www.index.go.kr/), Accessed in 2023.03.30.

[4] Korean Maritime Safety Tribunal, 2021, Marine Safety Investigation Report on M/V MILANO BRIDGE - Contact with gantry cranes-.

[5] Korea Maritime Pilot's Association, 2018, Pilot Safety Judgment Casebook (1978-2017).

[6] Marine Accident Investigation Branch, 2018, Accident report on the investigation of heavy contact with the quay and two shore cranes by the UK registered container ship CMA CGM Centaurus at Jebel Ali, United Arab Emirates.

[7] Transportation Safety Board of Canada, 2020, Maritime Transportation Safety Investigation Report M19P0020.

[8] T. E. Kim, S. Nazir, and K. I Øvergård., 2016, A STAMP-based causal analysis of the Korean Sewol ferry accident, Safety Science, Vol. 83, pp. 93-101.

[9] H. Altabbakh, M. A. Alkazimi, S. Murray, and K. Grantham, 2014, STAMP e Holistic system safety approach or just another risk model?, Journal of Loss Prevention in the Process Industries, Vol. 32, pp. 104-119.

[10] Z.H. Qureshi, and A. Campbell., 2009, Systemic Safety and Accident Modelling of Complex Socio - technical Systems, INCOSE International Symposium, Vol. 1, pp. 21-35.

[11] P. Underwood, and P. Waterson., 2013, Systemic accident analysis: Examining the gap between research and practice, Accident Analysis and Prevention, Vol. 55, pp. 154-164.

[12] E. Hollnagel, and O. Goteman, 2004., The functional resonance accident model, Proceedings of cognitive system engineering in process plant, pp. 155-161.

[13] J. Rasmussen., 1997, Risk management in a dynamic society: a modelling problem. Safety Science, Vol. 27, pp. 183-213.

[14] N. G. Leveson., 2016, Engineering a safer world: Systems thinking applied to safety, The MIT Press, Cambridge, Massachusetts, USA

[15] N. Leveson., 2004, A new accident model for engineering safer systems, Safety Science, Vol. 42, pp. 237-270.

[16] P. M. Salmon, M. Cornelissen, and M. J. Trotter, 2012, Systems-based accident analysis methods: A comparison of Accimap, HFACS, and STAMP, Safety Science, Vol. 50, pp. 1158-1170.