ISSN 2348-1218 (print)
International Journal of Interdisciplinary Research and Innovations ISSN 2348-1226 (online)
Vol. 11, Issue 2, pp: (72-80), Month: April 2023 - June 2023, Available at: www.researchpublish.com

Literature Review of Human Errors Caused OSVs-Offshore Structures Collisions

Capt. Khaled Mohamed Abo Bakr

Teaching Staff Member, College of Maritime Transport & Technology - Arab Academy for Science, Technology and Maritime Transport – AASTMT Alexandria – EGYPT

DOI: https://doi.org/10.5281/zenodo.7981381

Published Date: 29-May-2023

Abstract: **Offshore oil and gas operations are inherently risky, and human error is a major contributing factor to accidents. Risk assessment is a critical component of offshore safety management, and there is a growing body of literature on this topic, with a particular focus on collisions between offshore support vessels (OSVs) and offshore installations. This literature review provides an overview of the current state of offshore risk assessment, with a specific emphasis on human errors and their underlying factors. The review highlights the strengths and weaknesses of existing approaches to risk assessment, and identifies future directions in the field. The review provides a scope of the literature, and also defines the key terms and concepts. Overall, the paper emphasizes the importance of addressing human factors in offshore risk assessment, and the need to continuously improve risk assessment models to ensure the safety of personnel, environment and assets.**

Keywords: **Human error s, Underlying Factors, Collision, Offshore supply vessel OSVs, Risk assessment, Risk analysis, Offshore Installations/ Rigs.**

1. INTRODUCTION

Collision represents one of the top hazards in the offshore industry as statistics of many bodies reflect. For example, in 2021, the Transportation Safety Board of Canada published data covering marine accidents types in the period 2010 to 2020 as illustrated in Figure 1 which demonstrates that collision comes on top as the highest type.

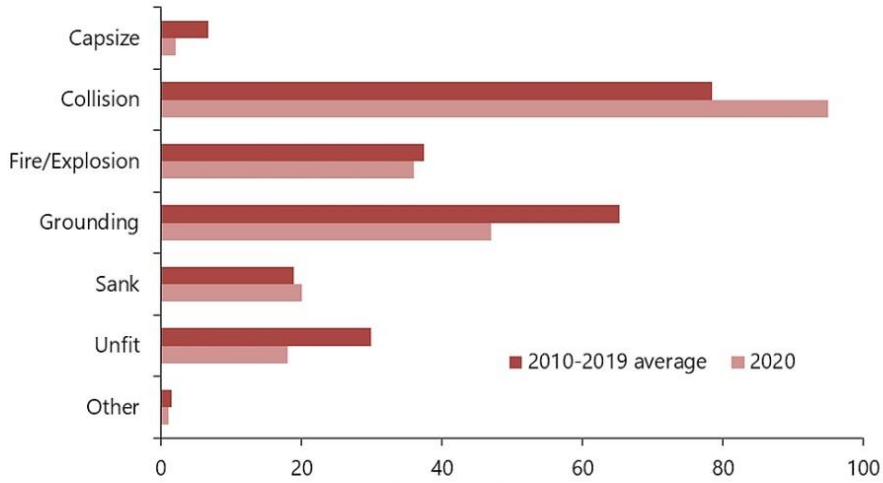

Figure 1: Average number of accidents by type (https://www.bst-tsb.gc.ca)

Hence, this literature review aims to provide a comprehensive overview of the role of human errors and their underlying factors in collisions between OSVs and offshore installations. Consequently, the review explores the current state of knowledge on, including the key methodologies and techniques used to identify and analyze human errors.

First, the scope of this research is introduced, and then the paper is structured as follows: The first section provides background information on OSVS-offshore installations collision and how they are associated with human errors and their impact on offshore collisions. The second section reviews human error in offshore risk assessment. The third section covers literature and is divided into three sub-sections: The first of which reviews the current state of knowledge on human factors in offshore risk assessment, highlighting key studies and their findings. The second discusses the methodologies and techniques used to identify and analyze human errors, such as the Human Factors Analysis and Classification System (HFACS) and cognitive task analysis (CTA). The third sub-section identifies the gaps and limitations of current literature. The fourth and last section introduces emerging trends and future directions, such as the use of virtual reality and simulation-based training to improve human performance in offshore environments. Finally, the conclusion summarizes the key findings and their implications for risk assessment in this specific context.

2. SCOPE OF THE RESEARCH

This literature review focused on the role of human factors in collisions between OSVs and offshore installations. The review examined the current research on the causes of collisions, including the impact of human factors such as communication, situational awareness, and decision-making. Additionally, the review examined the effectiveness of current risk assessment practices in addressing human factors in collisions between OSVs and offshore installations.

The review drew on a range of sources, including academic journals, industry reports, and accident investigation reports. Relevant databases such as the Association of Oil and Gas Producers collision incidents database (GOP, 2006: 2021) provided by the Bureau of Safety and Environmental Enforcement (BSEE). In the GOP reports data was collected from a number of collision incidents for the Gulf of Mexico (GoM) in the period from 2006 to 2021. More than 247 of 4128 collision incidents between attendant vessels and offshore installations have been reported in this period.

Section 1: Overview of OSVs-Installations operations and Collisions caused by Human Error

Supply OSVs carry goods, supplies, offshore workers, and equipment, including below-deck cargo such as dry bulk, liquid mud, freshwater, and excess fuel in support of exploration, exploitation, or production of offshore mineral or energy resources. They also support different operations including ROV and diving operations. Many Supply OSVs have Dynamic Positioning (DP) capability, allowing the vessel to hold station close to an offshore facility while conducting these operations. Supply OSVs may carry packaged hazardous material per Department of Transportation (DOT) regulations and may transfer excess fuel to offshore facilities (American Bureau of Shipping, 2019).

To understand and assess the human error induced collision risks between OSVs and offshore installations, we had to identify OSVs operations. This study focused on the most hazardous operable phases within the 500m safety zone illustrated in Figure (2)

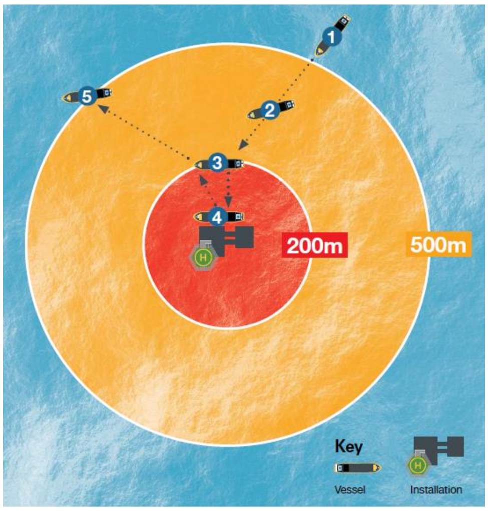

Figure (2): OSV approach in 500m Zone (www.Stepchangeinsafety.net).

There many hazard scenarios resulting from human error and involved in OSVs operations within the 500m zone including:

- Communication breakdowns between vessel crews and offshore installation personnel
- Inadequate training and experience of vessel crews and offshore installation personnel
- Lack of situational awareness due to fatigue or distractions
- Poor decision-making by vessel crews or offshore installation personnel (Berg, 2018).

The sample scenarios above highlight that there are several factors that can contribute to human error in offshore collisions. Table 1 illustrates the top underlying factors contributing to human errors according to:

Table (1): Top underlying factors contributing to human errors (Ishak et al., 2019)

Factor	Description
Fatigue	Long working hours, irregular shifts, and demanding workloads can lead to fatigue among offshore workers, impairing cognitive function, attention, and decision-making abilities.
Communication Failures	Miscommunication, misunderstandings, or lack of communication among crew members, between vessels, or between vessels and onshore facilities can lead to incorrect or inadequate information sharing, increasing collision risks.
Navigation and Situational Awareness	Inadequate navigation practices, poor situational awareness, or failure to properly monitor the vessel's position and surroundings can result in navigational errors and collisions with other vessels or structures.
Human Factors and Decision-Making	Cognitive biases, such as overconfidence, complacency, or a lack of risk perception, can influence decision-making processes and lead to poor judgment or inappropriate actions, increasing the likelihood of collisions.
Training and Experience	Insufficient training, lack of experience, or inadequate familiarity with specific vessel operations or equipment can contribute to human error in offshore collisions.
Compliance with Procedures and Regulations	Failure to adhere to standard operating procedures, safety protocols, and industry regulations can increase the risk of collisions.

Section 2: Human Error in Offshore Risk Assessment

Offshore operations have always been associated with high risks due to the hostile and challenging environments in which they occur. As a result, risk assessment has become an essential aspect of offshore operations, aimed at identifying potential hazards and assessing their likelihood and consequences. Over the years, offshore risk assessment has evolved, with advancements in technology and knowledge, leading to improved risk management strategies.

However, the offshore industry has experienced several significant collisions between OSVs and offshore structures in the past, leading to the loss of lives, damage to the environment, and financial losses. For example, the collision between the Farstad Shipping-owned PSV and the Seadrill-owned drilling rig, which occurred in the North Sea in 2016, and was attributed to errors in the bridge team's decision-making process (AAIB, 2017).

These incidents have been instrumental in driving the need for more effective risk assessment and management strategies. As a result, regulatory bodies and industry associations have developed guidelines and standards aimed at improving offshore risk assessment and management practices. Nonetheless, the impact of human factors on safety has remained a significant challenge.

Such a challenge stems from the fact that human error is rather complex and difficult to classify. Figure (1) Illustrates Koester's Septigon Model of how human factors can be categorized and defined as a socio-technical system. "The system approach means that not only the human as an individual is affecting the possibility for a failure that is categorized as a human error in for example an accident report. Human errors are also influenced by the surroundings through legislation, organizational culture, environment, design etc and the relations between these elements" (Grech et al. 2008).

ISSN 2348-1218 (print)
International Journal of Interdisciplinary Research and Innovations ISSN 2348-1226 (online)
Vol. 11, Issue 2, pp: (72-80), Month: April 2023 - June 2023, Available at: www.researchpublish.com

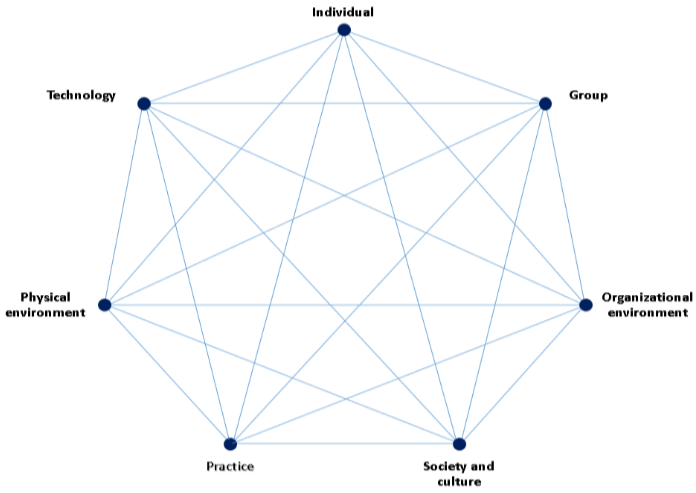

Figure (3): "The Septagon Model" by Thomas Koester (Grech et al. 2008).

Given the critical role of human factors in offshore risk assessment, there is a need to gain a deeper understanding of the underlying factors that contribute to human errors. By doing so, effective risk management strategies can be developed to address the root causes of these errors, leading to improved safety outcomes.

Several previous incidents involving human errors in collisions between OSVs and offshore installations have been reported in previous literature.

For instance, Jamina et al. (2019) examined the role of human error in collisions between offshore supply vessels (OSVs) and offshore platforms in the Gulf of Mexico. The study analyzed 22 collisions using the Human Factors Analysis and Classification System (HFACS) and found that inadequate communication, lack of situational awareness, and inadequate training were significant factors that contributed to human error and increased the risk of collisions. The study recommended several strategies for reducing the risk of OSV-platform collisions caused by human error, including improving communication and situational awareness through training and standard operating procedures, implementing technology such as collision warning systems, and enhancing safety culture and management practices.

Such work highlights the importance of understanding the human factors that contribute to offshore collisions and the need for effective risk assessment and management strategies. In the next section of this research, the current state of knowledge on human factors in offshore risk assessment was presented.

Section 3: Literature Review

This literature review was conducted through a systematic search of academic databases. It analyzed offshore risk assessment and management related to collisions between OSVs and offshore installations, focusing on human errors and the methodologies/tools developed to manage associated risks

3.1 Human Factors in Collisions

Literature cites some of the most contributing human factors resulting in the defined collisions. For example, according to Gyenes (2019) ommunication breakdowns between vessel crews and offshore installation personnel have been identified as a major contributing factor to collisions between OSVs and offshore installations (Duyar & Vatne, 2016; Gyenes et al., 2019). In addition, with reference to Tavares and Saores (2016) work, inadequate training and experience of vessel crews and offshore installation personnel have also been found to play a significant role. This can result in poor decision-making and a lack of situational awareness, particularly when crew members are fatigued or distracted (Tavares & Soares, 2016). By inspecting the studies of the latest, the researchers attempted to employ a semi-quantitative approach; however, they only identified the human error related task type and location onboard vessels in general collision and grounding incidents, and did not present risk assessment that is specified to OSVs.

Risk Assessment and Management of collisions is a process that includes multiple steps. Figure (3) illustrates these steps via the IMO's FSA Process Flowchart that summarizes them in five steps that begin with defining the systems and ends with the cost benefit assessment.

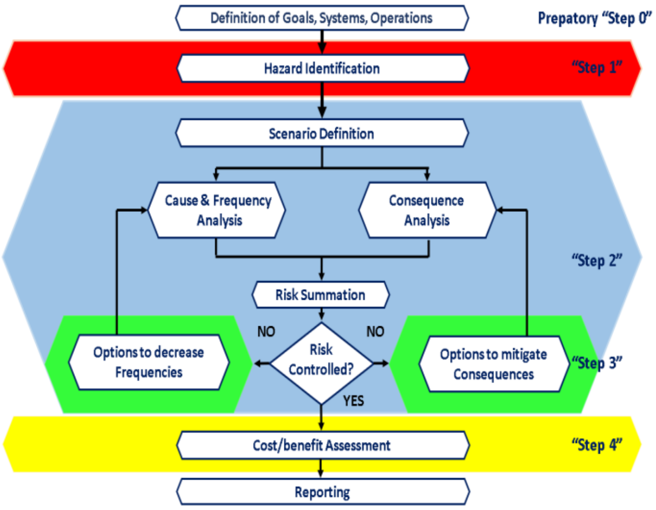

Figure (4): Flow chart of the Formal Safety Assessment process based on MSC/Circ. 1023 (IMO, 2019).

Another example that tackled the case in point is Ishak et al. (2019) who aimed to analyze three factors of human error, namely fatigue, communication, and lack of technical knowledge as the major contributors to the occurrence of accidents. The researchers' methodology relied on expert judgement and obtained their results from corresponding with a number of 60 respondents from an oil and gas company, and a government agency located in Lumut, Perak, Malaysia. They concluded that a strong positive relationship between the human factors which include fatigue, communication, and lack of knowledge towards the maritime accident rates, and that the latter is the highest contributing factor which could result in major accidents in the maritime industry.

3.2 Methodologies and Tools for Risk Assessment

Various methodologies and tools have been developed to assess and manage the risks associated with collisions between OSVs and offshore installations. Qualitative and quantitative risk assessments are commonly used to evaluate the likelihood and consequences of such incidents (Tavares & Saores, 2016). Collision risk models, such as those developed by Lloyd's Register (2016), use vessel and installation characteristics to estimate the probability of a collision. Dynamic Positioning (DP) Failure Mode and Effects Analysis (FMEA) is another commonly used method that evaluates the failure modes and consequences of DP systems, which are critical in preventing collisions (Ling et al., 2018). Collision avoidance systems, including Automatic Identification System (AIS) and Radar, have also been developed to alert vessel crews and offshore installation personnel to potential collision risks (Mallam et al., 2014).

Rashwan (2019) conducted a risk assessment process in his Master's thesis focused on collision accidents between infield vessels and offshore installations. Using both descriptive and analytical approaches, he aimed to identify hazards, evaluate them, and propose a systematic risk assessment procedure. The researcher utilized a Quantitative Risk Assessment (QRA) approach, based on industry experts' questionnaire results and data analysis. Using the Analytic Hierarchy Process, he divided twelve hazard scenarios from SAFEDOR into five groups and ranked human safety as the top criterion, followed by the environment's effect. Rashwan concluded that special programs should be designed and applied to reduce the risk and enhance the safety of deck and engine officers, and regulations enforced by IMO and other maritime safety bodies should be followed to minimize human errors. However, the researcher did not present any new specific scenarios based on offshore supply vessels, nor did he provide a risk index or risk control options.

In 2014, Azad conducted a master's thesis where he aimed to study and review the available methods of criticality analysis (CA) of PSV in Troms Offshore (Arctic). To achieve this, the researcher employed the methods of meeting with experts and using the experience of other industries to find weaknesses of these methods as well as modify and improve them. The study presented a case study for Dynamic Positioning (DP) system of PSV to demonstrate how the FMECA method could be applied. Eventually, the researcher attempted to prove that FMECA was a useful tool for criticality analysis of mechanical and electrical equipment.

Additionally, in 2017, John and Osue utilized the Fuzzy Fault Tree Analysis (FFTA) method to examine the intricate structure of Offshore Supply Vessel (OSV) collisions with platforms. The researchers chose this approach due to its ability to accommodate imprecise information during the analysis process. Their methodology involved combining and synthesizing various sets of data to analyze the system comprehensively. According to the researchers, their proposed method could offer analysts a framework to assess collision risks and make informed decisions on resource allocation to enhance the system. Nevertheless, the study did not present any quantitative results or risk control measures.

Yasa and Akylidiz (2018) also proposed a framework for enhancing safety on OSVs through the application of FSA. The researchers noted that their approach relied on expert judgments and historical data, without the need for mathematical or statistical methods. They also suggested the use of FTA, ETA, and FMEA as assessment tools. While the study provided general guidance for future research, it did not include any risk modeling.

3.3 Gaps and Limitations in the Literature

Despite the various methodologies and tools available for offshore risk assessment and management, there are still gaps and limitations in the current literature. One area of concern is the lack of standardization in risk assessment methodologies, and the absence of clear guidelines for assessing and managing risks associated with collisions between OSVs and offshore installations (Gyenes et al., 2019). Additionally, most risk assessment tools focus on the technical aspects of collisions, such as vessel and installation characteristics, and do not adequately consider human factors (Duyar & Vatne, 2016). Finally, there is a need for further research into the effectiveness of collision avoidance systems and the development of new technologies that can improve situational awareness and prevent collisions (Ling et al., 2018).

In 2014, Hassel and colleagues outlined the drawbacks of the COLLIDE-methodology, which has been the industry's standard risk model for assessing the likelihood of ship collisions with offshore installations for the past two decades. Using a descriptive approach, the researchers identified areas that require enhancements and alternative approaches to the existing model, and explored key issues that require further investigation in this field. Their study demonstrated the importance of collecting precise data pertaining to the underlying factors, which can enhance the accuracy of risk modeling.

Strengths and weaknesses of existing approaches to offshore risk assessment

The offshore oil and gas industry is inherently hazardous, and risk assessment is a critical component of safety management. There are various approaches to offshore risk assessment, each with its strengths and weaknesses.

Commonly risk assessment approaches can be classified into qualitative or quantitative. To begin with, qualitative risk assessment, which is a common approach, relies on expert judgment to identify hazards and assess their likelihood and consequences. This approach is relatively simple and inexpensive, and it can be useful for identifying potential hazards and risks. However, it has limitations in terms of its subjectivity and lack of precision in quantifying risks. In comparison, quantitative risk assessment uses mathematical models to estimate the likelihood and consequences of hazards. This approach is more objective and precise than qualitative risk assessment, and it can provide valuable insights into the risks associated with specific scenarios. However, it can be complex and time-consuming, and it requires specialized expertise and data (Soares & Zayed, 2020).

Inspecting a more specific example that can be used to assess collision risk between OSVs and offshore installations caused by human errors and their underlying factors, Dynamic Positioning Failure Modes and Effects Analysis (DP FMEA) is a risk assessment method used in the offshore industry that focuses on identifying and mitigating the failure modes of a vessel's dynamic positioning system. This approach is useful for identifying potential failures and their consequences, and for developing appropriate mitigating measures. However, traditionally it is not employed to address other sources of risk such as human error in the marine field. (Sharifi et al., 2019)

Collision risk models such as the Collision Risk Assessment for Ship Systems (CRASH) the International Regulations for Preventing Collisions at Sea (COLREGs), or the Simultaneous Operations (SIMOPS) models are also commonly used in offshore risk assessment to estimate the likelihood and consequences of collisions between vessels and offshore installations. These models take into account factors such as vessel size and speed, environmental conditions, and vessel traffic. They can be useful for identifying high-risk areas and developing appropriate mitigation measures. However, none of them is specific to human error caused collisions of OSVs with offshore installation.

Overall, the strengths of existing approaches to offshore risk assessment lie in their ability to identify potential hazards and assess their likelihood and consequences. However, their weaknesses lie in their limited ability to address human factors and their potential lack of precision in quantifying risks related to collisions between OSVs and offshore installations.

Although there are several studies that focus on risk control options/measures for preventing collisions between offshore support vessels (OSVs) and offshore installations such as the work of Liu et al., 2019 and the work of Zhang and Wang, 2019, these studies remain inadequate. To elaborate, the studies propose various measures such as improving communication between vessels and offshore installations, using advanced collision warning systems, implementing strict traffic management and routing measures, and developing emergency response plans. The studies also employ different methodologies such as fault tree analysis and statistical analysis to evaluate the effectiveness of the proposed measures. Overall, the studies aim to provide practical solutions for reducing the risks associated with collisions between OSVs and offshore installations; however, these studies do not specialize in human errors and their underlying factors as the main cause of accidents.

Section 4: Emerging Trends and Future Directions

The offshore oil and gas industry is constantly evolving, and new technologies and approaches to risk assessment are emerging. Some of the emerging trends and future directions in offshore risk assessment include:

- **Use of artificial intelligence and machine learning:**

With the increasing availability of data and computing power, artificial intelligence and machine learning are being used to improve the accuracy and efficiency of risk assessment models. These technologies can be used to identify patterns and trends in data, and to develop predictive models that can help to identify potential risks and hazards.

- **Integration of human factors:**

Human error is a major source of risk in the offshore industry, and there is a growing recognition of the need to integrate human factors into risk assessment models. This involves considering factors such as crew fatigue, workload, and training when assessing risk, and developing appropriate mitigation measures to address these factors.

- **Development of risk-based inspection and maintenance strategies:**

Traditionally, offshore inspections and maintenance have been conducted on a fixed schedule, regardless of the actual level of risk. However, there is a growing trend towards risk-based inspection and maintenance strategies, which prioritize inspections and maintenance based on the actual level of risk.

- **Use of advanced simulation tools:**

Advanced simulation tools, such as virtual reality and 3D modeling, are being used to simulate offshore operations and assess potential risks. These tools can be used to identify potential hazards and assess the effectiveness of mitigation measures in a safe and controlled environment.

A case in point is Liu and Chen’s work. Liu, Zhao, and Chen (2020) proposed a collision risk assessment method for offshore oil and gas platforms using artificial intelligence. The authors developed an algorithm based on a back-propagation neural network, and used it to analyze data on collision risks from different scenarios. The algorithm was trained and tested using data from actual collisions and near-miss incidents, and achieved good results in terms of accuracy and efficiency. The authors conclude that their method can help improve safety in offshore operations by providing early warning and risk assessment for potential collisions between offshore platforms and support vessels.

Overall, the emerging trends and future directions in offshore risk assessment are focused on improving the accuracy and efficiency of risk assessment models, integrating human factors into risk assessment, developing risk-based inspection and maintenance strategies, and using advanced simulation tools to assess risks in a safe and controlled environment.

3. DISCUSSION

This study is concerned with OSVs-platform collision risk identification and classification, assessment of human error in the maritime field, and risk assessment of OSV-offshore installation collisions caused by human errors and their underlying factors. The study reviewed previous research in these areas, emphasizing the need for deep specialization and specific case-study applications to make the results reliable and effective for decision-makers and industry experts. The study also highlights the importance of providing risk control options/measures based on qualitative and quantitative research to prevent and mitigate risks. The gap in risk control options is pinpointed as an area of focus for this study. Therefore, this study pinpoints this gap as illustrated in Figure 4.

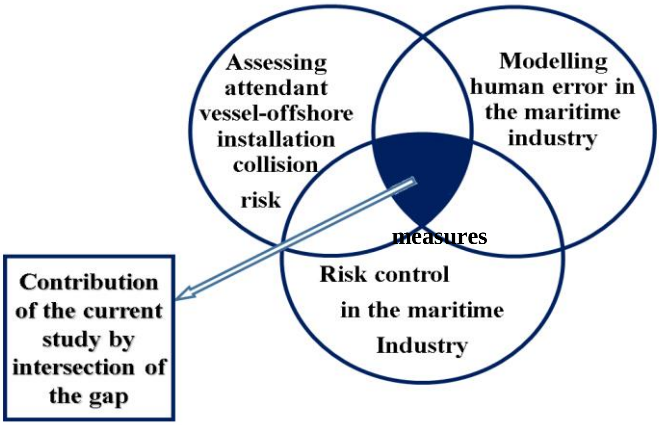

Figure (5): Gap Analysis in Literature Review

4. CONCLUSION

Collisions between OSVs and offshore installations are a significant risk in the offshore oil and gas industry, and human factors play a major role in contributing to these incidents. Various methodologies and tools have been developed to assess and manage these risks, but there are still gaps and limitations in the current literature. Addressing the human factors that contribute to these incidents, developing clear guidelines for risk assessment and management, and continuing research into new technologies are all important steps in reducing the risk of collisions between OSVs and offshore installations.

REFERENCES

[1] AAIB. (2017). *Report on the investigation of the collision between the platform supply vessel "FS Kristiansand" and the drilling rig "West Phoenix" in the North Sea on 5* November 2016. Air Accidents Investigation Branch. Retrieved from https://assets.publishing.service.gov.uk/media/5a2ff5a340f0b649f70003c3/FS_Kristiansand_and_West_Phoenix.pdf

[2] American Bureau of Shipping. ABS (2019). *Offshore Support Vessel Dynamic Positioning Failure Mode and Effects Analysis*. Retrieved from https://ww2.eagle.org/content/dam/eagle/rules-and-guides/current/offshore/1916_OSV_DP_FMEA.pdf

[3] Berg, H. P. (2018). *Avoiding collisions between offshore support vessels and fixed offshore installations.* In Proceedings of the 3rd International Conference on Maritime Technology and Engineering (pp. 147-152). Springer.

[4] *Che Ishak, I., Azlan, M.F., Ismail, S.B., and Mohd Zainee, N. (2019). A study of human error factors on maritime accident rates in maritime industry. Asian Academy of Management Journal, 24(Supp. 2), 17–32. https://doi.org/10.21315/ aamj2019.24.s2.2*

[5] Duyar, O., & Vatne, E. (2016). Human error and safety management in the offshore oil and gas industry. *Safety Science*, 89, 1-9.

[6] Grech, M., Horberry, T. and Koester, T. (2008). *Human factors in the maritime domain*. New York: CRC Press.

[7] Gyenes, A. N., Hegedűs, P., & Bánhidi, L. (2019). Overview of marine accident statistics and investigation of human factor related accidents in Hungary. Periodica Polytechnica Transportation Engineering, 47(3), 134-139.

[8] International Maritime Organization [IMO]. (2019). *Formal Safety Assessment (FSA): MSC-MEPC.2/Circ.12/Rev.2.* London: IMO. Available from: https://www.imo.org/en/OurWork/Safety/Pages/FormalSafetyAssessment.aspx

[9] Ishak, I. C., Azlan, M. F., Ismail, S. B., and Zainee, N. M. (2019). A study of human error factors on maritime accident rates in maritime industry. *Asian Academy of Management Journal*, 24, 17-32.

[10] Jamina, M. J., Huang, Y., & Zeng, S. (2019). Examining the role of human error in collisions between offshore supply vessels and offshore platforms in the Gulf of Mexico. *Safety Science*, 117, 55-64.

[11] John, A., and Osue, U. J. (2017). Collision risk modelling of supply vessels and offshore platforms under uncertainty. *The Journal of Navigation*, 70(4), 870-886.

[12] Ling, K. C., Ong, Z., & Ng, K. M. (2018). A review of maritime supply chain research: Trends and future directions. *Transportation Research Part E: Logistics and Transportation Review*, 118, 598-611.

[13] Liu, C., Zhao, J., & Chen, Y. (2020). A collision risk assessment method for offshore oil and gas platforms based on artificial intelligence. *Journal of Loss Prevention in the Process Industries*, 68, 104222.

[14] Liu, P., Li, Y., Lu, X., & Li, Z. (2019). Risk control measures of OSV offshore installation collision based on fault tree analysis. *Journal of Marine Science and Technology*, 24(1), 30-40.

[15] Lloyd's Register. (2016). *Global Marine Technology Trends 2030*. Retrieved from https://www.lr.org/en/insights/articles/global-marine-technology-trends-2030/

[16] Mallam, S., Wang, X., & Bell, M. G. H. (2014). Identifying common factors influencing marine accidents. *Accident Analysis & Prevention*, 62, 241-250.

[17] Rashwan, M. H. (2019). *Risk assessment of collision between Supply vessels and offshore installations* (Master Thesis), Arab Academy for Science, Technology and Maritime Transport, Egypt.

[18] Sharifi, M. S., Barabadi, A., & Razmjoo, A. (2019). Risk assessment of dynamic positioning system in offshore vessels using the fuzzy failure modes and effects analysis. *Ocean Engineering*, 191, 106582.

[19] Soares, C., & Zayed, A. (2020). Modelling of marine accidents and incidents involving ships and offshore structures: review and future directions. *Safety Science*, 131, 104883.

[20] Tavares, G., & Saores, T. (2016). A review of collision risk models for vessels navigating in close proximity. *Ocean Engineering*, 117, 132-143.

[21] www.Stepchangeinsafety.net

[22] https://www.bst-tsb.gc.ca/eng/stats/marine/2020/ssem-ssmo-2020.html

[23] Yasa, A. and Akylidiz, H. (2018). Formal safety assessment of offshore. *Research Gate*, 3, 23254424.

[24] Zhang, X., & Wang, G. (2019). Study on risk control measures for offshore platform and OSV collision accidents. *Ship Engineering*, 41(1), 43-46.