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REVIEW

A Contemporary Review of the Operations Management in Handling Major Oil Spills from Ships and Tankers in the Straits of Malacca, Malaysia

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ABSTRACT

Operations Management (OM) plays a critical role in managing oil spills from tankers, specifically in the Straits of Malacca (SOM), Malaysia. Ineffective decision-making and outdated operational practices have historically led to significant environmental damage, endangering marine ecosystems and resources due to the activities of international shipping. Global experiences with tanker-related oil pollution disasters indicate that full recovery of spilled oil is rarely achieved, due to a combination of natural and physical constraints, a trend also observed in the SOM. Effective OM in this context requires a multidisciplinary approach involving experts in engineering, chemistry, biology, marine navigation, environmental economics, law, and the social sciences. These diverse inputs inform the development of comprehensive frameworks, including legal, institutional, and operational, which are integrated into the National Oil Spill Contingency Plan (NOSCP). The NOSCP outlines preparedness and response strategies, the strategic distribution of oil spill response equipment (OSRE), and the standard operating procedures (SOPs) to manage and sustain effective responses to future oil spill incidents in the SOM. It is a high time for the Malaysian authority to opt for a single agency to manage the major oil spill in the SOM for better operational efficiency and cost-effectiveness.

Keywords: Compensation; Contingency Plan; Frameworks; Marine Environment; Oil Spill Response Equipment (OSRE); Shipping; Pollution

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1. Introduction

Operations Management (OM) plays a critical role in designing, controlling, and optimizing processes, particularly in complex scenarios such as managing oil spills from tankers in the Straits of Malacca, Malaysia (SOM). In short, OM is the study of decision-making in the operations function. Specifically in its work, there are five main decision areas: quality, process, capacity, inventory, and workforce. OM was the most suitable tool to review the past mechanism for managing major oil spills from ships (tankers) in the Straits of Malacca (SOM), Malaysia. The mechanism was established in 1976, following approval by the Malaysian Cabinet. It marked the beginning of the first edition of the National Oil Spill Contingency Plan (NOSCP) [1]. Ever since, the plan had been enhanced five times, but it was found that no significant changes were made in terms of policies, and let alone the quality outputs, such as key performance indicators and the level of efficiency.

Since 45 years had passed since its inception, there were no successful stories to be picked up about the mechanism that advocates sustainable environmental policy. Based on the latest NOSCP, there has been little to no policy change [1]. These setbacks should not be prolonged, as they would jeopardise our living and non-living marine resources in the SOM. These resources are vast and estimated to have an economic value of RM5.70 billion based on 1995 prices [2,3]. Then, by conversion using a cost-benefit analysis (CBA), their present economic value is RM80.52 billion. Contingency must be maintained at all times through protection and conservation of our highly valued marine resources from damage caused by international shipping activities. With OM, we were able to measure its constraints and the level of efficiency. Therefore, inefficiency results in more marine resource damages, poor standards of claims and compensations due to obvious reasons of poor coordination to speed up preparedness and response. Poor compensation failed to support the oil spill operations costs and rehabilitation costs under the post-spill conservation of damaged resources.

1.1. The Objectives of this Review

The main objectives of this contemporary review are to look at the operations management in handling major oil spills from ships and tankers in the Straits of Malacca (SOM), Malaysia, across all operations functions, its systems and decision-making. There are five major operations functions based on the definition of operations management: quality, process design, capacity planning, and scheduling, inventory management and workforce management [4].

1.2. The Straits of Malacca

The Straits of Malacca (SOM) are geographically 520 miles in length and vary in width from 200 miles in the north to 11 miles in the south, where they meet the Strait of Singapore [5]. This connection of the SOM, the busiest international shipping lane, is shown as a map in **Appendix A**. Due to its geographical constrains with surges of shipping traffic, the straits are exposed to ship collisions and other maritime casualties, such as fires onboard, explosions and sinkings that all lead to oil pollution. The SOM, besides being important and a source of pride for global as well as local communities because of its richness in marine resources, they are also serves as one of the busiest straits in the world for international shipping. They provide a shortcut passage between Europe, the Indian Subcontinent and the Middle Eastern nations to Far Eastern countries [6]. The Straits shipping volume has shown a high growth over 31-year period from 1992 to 2023. The first decade, from 1991 to 2001, showed a growth of 95.9% or an average annual growth rate of 9.6% over a 10-year period, as shown in **Figure 1** [7]. For the second decade, from 2002 to 2012, its growth was slightly slower, at 25.7%, with an annual average of 2.6%, due to the 2008 global financial crisis and shipping overcapacity. Then, in the final decade, from 2013 to 2023, shipping growth was much slower, at 14.6% or an average of 1.5%. The sharp decline in growth in the third decade was due to the global economic conditions, mainly from the outbreak of the COVID-19 pandemic. However, the overall growth is still very high for this short and world's busiest strait.

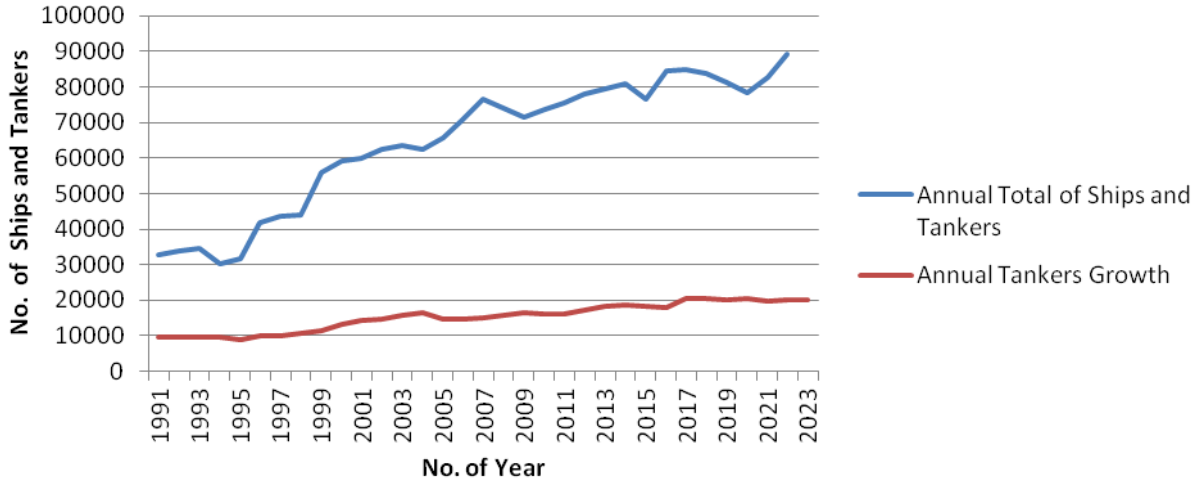

Figure 1. Ships transiting in the Straits of Malacca from 1991 to 2023.
Source: Marine Department Malaysia [7].

In 2023 alone, the ships carried approximately RM7.4 trillion of goods and services, equivalent to about 30% of global trade. From that amount, approximately 80% of the oil was transported from the Middle East to China and Japan [6]. Ships and oil tankers transiting in the SOM were 32,949 in 1992 and rose to 89,390 in 2023, representing a significant increase of 65.4%. This significant growth resulted in shipping traffic increasing to an annual average of 2.1% from1992 to 2023 [7]. The growth of traffic in the SOM also reflects a global shipping growth of 4% over the 5 years, 2019 to 2023 [7].

Due to congested sea lanes, the SOM is always exposed to shipping casualties. Most major oil spills are accidental, not operational, and therefore unpredictable. Prevention is considered the best option to reduce the oil spill impacts, but once the accident happens, then the readiness of an efficient national oil spills contingency plan would make a difference. Since SOM is the busiest strait in the world for international shipping, it was reported that there were 888 casualties of various ship types over the past 31 years. Casualties may include ship collisions, grounding, beaching, onboard fire, explosion and sinking. Literature reviews indicate that these incidents were caused by a 75% human factor and the remaining 25% by a technical factor [3]. The intensity of oil spills will depend on the carrying capacity and severity of collisions involving oil tankers. Their carrying capacities range from 10,000 tonnes to 320,000 tonnes depending on the oil tanker class [8].

Mitigation of oil spills from ships is all about the consolidation of the legislative framework along with institutional and operational frameworks. With the demand for global shipping on the rise, it is important to plan for mitigation to protect the marine environment from possible damage from international shipping activities. As Malaysia is a maritime nation and a coastal state, it ratified and became a party to the United Nations Convention on the Law of the Sea, 1982 [9] on 14 November 1996. It became a significant mark for Malaysia to embark on its interest in the vast maritime areas, not limited to preservation and conservation of the marine environment, by ratifying all the relevant international maritime conventions with regard to marine pollution by all types of ships, including tankers.

1.3. Significance of the Review

The significance of this review paper is divided into two parts, whereas the legal aspect is excluded since it serves in both parts:

1.3.1. Theoretical Significance

The conclusion and recommendations of the study are not only intended to be applicable to Malaysia, but they can also serve as a base reference for any

coastal state that faces and experiences similar challenges as a result of oil pollution disasters from international shipping activities. Institutional framework plays an important role in adopting the legal instruments and transforming them into all frameworks that can work for the whole country and coastal states to mitigate the oil spills, especially on a large scale or in other words, an oil pollution disaster. Attributes of a good institutional framework may include revisiting the functions and responsibilities of the lead agency in national oil pollution management. In the case of Malaysia, the Department of Environment (DOE) needs to re-evaluate its functions in managing oil pollution in the SOM. Within these same activities, there are two other agencies, one of which deals with the implementation of the oil spill operations that come under the Marine Department Malaysia (MARDEP). Whilst the second agency, the Malaysia Maritime Enforcement Agency (MMEA) or Coast Guard in some developed and developing nations such as the United States of America, Japan and the Philippines is responsible mainly for maritime enforcement at sea on all marine matters.

1.3.2. Practical Significance

The conclusion of this study will also provide options for the Malaysian authorities to adopt for more comprehensive institutional and operational frameworks. These frameworks will address the previous mitigation mechanism weaknesses and move forward to improve the whole regime in the event of an oil spill disaster for both pre-spilt and post-spilt policies and implementation. Most operational actions can be referred to the National Oil Spill Contingency Plan (NOSCP) or the National Contingency Plan (NCP) in some coastal states. In Malaysia, NOSCP comprises 17 members or authorities known as the National Oil Spill Control Committee (NOSCC) for giving advisory and guidance on the control of oil spills under national jurisdiction, chaired by the DOE. All the chapters within NOSCP are based on the requirements of the International Convention on Oil Pollution Preparedness, Response and Cooperation, 1990 (OPRC 1990), and incorporate the respective national legislations of the coastal states. This is the official document for the operational framework.

2. Materials and Methods

2.1. Literature Review

2.1.1. Overview of the Operations Management

A subject in operations management can be traced back more than 200 years. Adam Smith, an economist, discussed the division of labour in his book, Wealth of Nations (1776). Then, came the standardisation of parts, which was advocated by the first car maker, Henry Ford (1913) and later enhanced by Chase and Aquilano. The next phase was the industrial revolution in the seventh century, which saw human power slowly replaced by machine power. In 1764, James Watt's steam engine successfully transported agricultural outputs to factories. After the industrial revolution, there came the interest in scientific study work, and later some of them were incorporated into physical and natural systems. These ideas were first mooted by Frederick Taylor in 1911 and later enhanced by Frank and Lillian Gilbreth throughout the early 1900s. Moving from the scientific study work, an area of human relations was emphasised on human motivation and the human element in work design. These works were developed by Elton Mayo and others at Western Electric, United States, in the 1930s, and the famous case was the Hawthorne studies. From there, decision models were introduced, and the most famous one is the "simplex method of linear programming," developed by George Dantzig in 1947. In the 1950s, computers were used to perform operations management in selected businesses.

The dynamics of operations management were very rich and therefore there was resurgence of its application in the nineteenth and twentieth centuries when global manufacturing and trades competed for competitiveness for exports [4]. Internally, in the same periods for developed nations, their economists suggested more investments for more competition with other nations, whilst the technologists keep on asking for more funds for research and development. Lastly, the human resources experts wanted to compete by

changing their approaches to managing people in order to better serve. However, the answers to competitiveness issues are simply laid out in the application of operations management to their businesses.

2.1.2. Global Major Oil Spills from Ships and Tankers

Nakhodka (1997)

The date of the incident was January 2, 1997, in the Sea of Japan, near Fukui Prefecture, Japan, where the Russian tanker Nakhodka broke apart in rough seas, spilling approximately 6,200 tonnes of heavy fuel oil. 1992. Compensation was paid by both the shipowner's insurer and the 1992 Fund. Claims for clean-up costs and economic losses were submitted by the Japanese government and local businesses. The compensation paid, exceeding ¥34 billion (approximately USD 300 million), was shared between the shipowner's insurer and the 1992 Fund [10].

Erika (1999)

The incident occurred on December 12, 1999, in the Bay of Biscay, off the coast of Brittany, France where the Maltese-flagged tanker Erika broke in two during a storm, spilling approximately 20,000 tonnes of heavy fuel oil and polluting over 400 km of coastline. The 1992 Fund handled a large volume of claims for clean-up costs, property damage, and economic losses (particularly in the tourism and fishing sectors). The compensation paid was approximately €129 million, with the Fund covering most of the amount [10].

Prestige (2002)

The date of the incident was November 13–19, 2002, off the coast of Galicia, Spain and the Prestige, carrying 77,000 tonnes of heavy fuel oil, broke apart after suffering structural failure, releasing a major portion of its cargo. The 1992 Fund assisted in processing claims and distributing compensation to affected parties in Spain and France. The compensation paid for the maximum amount available under the 1992 Fund Convention, and it reached approximately €171.5 million [10].

Solar 1 (2006)

The incident occurred on August 11, 2006, in the Guimaras Strait, Philippines, where the Solar 1 sank during a storm, spilling approximately 500 tonnes of oil initially, with additional oil leaking from the sunken vessel later. The 1992 Fund handled claims from fishermen, local businesses, and the Philippine government. The compensation paid was over PHP 1 billion (about USD 20 million), within the limits of the 1992 Fund [10].

Hebei Spirit (2007)

The date of the incident was December 7, 2007, near Taean, Yellow Sea, the Republic of Korea, where the anchored VLCC Hebei Spirit was struck by a crane barge, resulting in the release of approximately 10,500 tonnes of crude oil. The 1992 Fund received and assessed over 128,000 claims, including those for clean-up, tourism losses, and damages to the fishing industry. The compensation paid was over KRW 321 billion (USD 280 million), with a significant portion coming from the 1992 Fund [10].

2.1.3. Handling Major Oil Spills in Malaysia

Legislation Framework

Malaysia had ratified the UNCLOS 1982, and under Article 235, every state is obligated to have availability within the legal system for immediate and adequate compensations or other relief to undertake damages caused by oil pollution from ships into the marine environment. For this instance, Malaysia, as a coastal state and flag state, has to provide recourse to any oil pollution from ships in Malaysian waters, as well as beyond its territory, that involves Malaysian ships. Moreover, six national legislations and seven international conventions are used by different government agencies to enforce, control, and manage oil spills in Malaysia, as shown in **Table 1** [1]. These legislations serve those organisations for the functioning of administration, law and enforcement, but they are also sourced as the basis to establish the National Oil Spill Contingency Plan (NOSCP) and the ASEAN Regional Oil Spill Contingency Plan, especially from the International Convention on Oil Pollution Preparedness, Response and Cooperation, 1990 (OPRC 1990). This legislation will be enforced by its respective agencies, but most of the maritime enforcement now is being delegated to the Malaysia Maritime Enforcement Agency (MMEA) via a legal instrument, the Malaysia Maritime Enforcement Agency Act 2004 (Act 633).

In Malaysia, all international maritime conventions are officially administered by the Marine Department, Malaysia (MARDEP), also known as the lead agency, except for the OPRC 1990 and the United Nations Convention of the Seas (UNCLOS), 1982. OPRC 1990 was given to the Department of Environment (DOE) as its lead agency by the Malaysian government, whilst UNCLOS 1982 was given to the Ministry of Foreign Affairs (MOFA). Under the legislative framework, Malaysia has ratified all the international maritime conventions and enacted all the national legislation to control oil spills from ships and tankers. This framework serves as the foundation and provides the backbone for the other two frameworks, institutional and operational. However, the last two frameworks require enhancements over time due to new technologies, new benchmarks and new standard operating procedures (SOPs) created by the International Maritime Organisation (IMO) or by the industry itself.

Table 1. List of National Legislation and International Maritime Conventions in Malaysia.

No.	Name of National Legislation/Conventions	Lead Agencies in Malaysia
1.	Merchant Shipping Ordinance, 1952 (Ord. 70/1952)	Marine Department
2.	Environmental Quality Act, 1974 (Act 127)	Department of Environment
3.	Malaysia Maritime Enforcement Agency Act 2004 (Act 633)	Maritime Enforcement Agency
4.	Fisheries Act, 1985 (Act 137)	Fisheries Department
5.	Exclusive Economic Zone Act, 1984 (Act 311)	Ministry of Internal Trade, Consumer Affairs and Cooperatives
6.	Continental Shelf Act, 1974 (Act 83)	D. G, of Land Department
7.	United Nations Convention of the Seas (UNCLOS), 1982	Ministry of Foreign Affairs
8.	The International Convention for the Prevention of Pollution from Ships 1973/78 (MARPOL 73/78)	Marine Department Malaysia
9.	The International Convention on Oil Pollution Preparedness, Response and Cooperation, 1990 (OPRC 1990)	Marine Department Malaysia
10.	The International Convention on Civil Liability for Oil Pollution Damage, 1992 (CLC 92)	Marine Department Malaysia
11.	The International Convention on the Establishment of an International Fund for Compensation for Oil Pollution Damage, 1992 (the 1992 Fund)	Marine Department Malaysia
12.	The International Convention on Civil Liability for Bunker Oil Pollution Damage, 2001 (Bunkers Convention 2011)	Marine Department Malaysia
13.	The Convention n Limitation of Liability for Maritime Claims, 1976 (as amended by the Protocol of 1996)	Marine Department Malaysia

Source: Department of Environment [1].

Institutional Framework

Under the requirement under Article 6 of the International Convention on Oil Pollution Preparedness, Response and Cooperation, 1990 (OPRC 1990), the coastal states, through the lead agency, DOE, must establish a national and regional system for oil spill preparedness and response. As a comparison, the United Kingdom uses relevant parts of the OPRC 1990 to enact the National Contingency Plan (NCP) and hand it over to the Maritime and Coastguard Agency (MCA) as its lead agency and the owner of OPRC 1990. So here we can see different applications between Malaysia and the UK in terms of institutional framework. Not only in the UK, the same practices are used in the United States of America, European Countries, Japan, Korea, Singapore and the Philippines. For further comparison between Malaysia and other ASEAN countries, **Table 2** provides a view. In Malaysia, similar OPRC Articles were used to formulate the NCP, but the lead agency is given to DOE, with other core government agencies given implementation and supporting roles in managing oil spills. The Malaysian Cabinet had directed the DOE to be the lead agency for the NCP, or National Oil Spill Contingency Plan (NOSCP), as for Malaysia [1]. The lead agency has to play an important role in coordinating various strategies for managing oil spills, especially in congested sea lanes such as the SOM. However, management inefficiency had been observed due to poor coordination of operations and these should be avoided. If inefficiency persists, it will affect inventory and logistics management, leading to increased exposure to pollution damage.

Table 2. Lead and implementation agencies variation in managing oil pollution in ASEAN countries.

No.	Asean Coastal States	Lead Agency	Implementation Agency
1.	Brunei	Marine Department	Marine Department
2.	Cambodia	Marine Department	Marine Department
3.	Indonesia	Sea Transportation	Sea Transportation
4.	Malaysia	Department of Environment	Marine Department
5.	Myanmar	Marine Administration	Marine Administration
6.	Philippines	Coast Guard	Coast Guard
7.	Thailand	Marine Department	Marine Department
8.	Singapore	Maritime and Port Authority	Maritime and Port Authority
9.	Vietnam	Marine Administration	Marine Administration
10.	Laos	Land-locked Country	Land-locked Country

Source: ASEAN [11].

Multi-government agencies are given tasks to address oil spills at sea, which may result in inefficient management coordination in oil spills preparedness and response, affecting the high economic values of marine resources and the socio-economic of the impacted areas [12]. A former Malaysian Prime Minister stated in a forum that poor governance and overlapping jurisdictions of national maritime regimes would lead to the inefficient utilisation of resources [13]. This framework concludes that the existing institutional framework operated under multiple agencies, where the lead agency is DOE by virtue of being the custodian of OPRC 1990, should be given to another agency that can really focus on the maritime administration or maritime enforcement. Under the present arrangement, MARDEP is the implementation agency to combat oil spills at the site, whilst the MMEA is doing maritime enforcement at sea. Three different organisations, DOE, MARDEP, and MMEA, doing similar activities, will not produce better outputs because they have their own working cultures, priorities, and variations in competent human resources.

Operational Framework

As a coastal state, Malaysia has had a comprehensive National Oil Spill Contingency Plan (NOSCP) since 1976, and it has been subsequently revised in 1986, 1989, 1994, 2000 and most recently in 2014 [1]. Its main contents and main committee members are still the same, except for the inclusion of Malaysia Maritime Enforcement Agency (MMEA) and Department of Marine Parks Malaysia (MPM) [1], and later, in 2018, MPM was reorganised back to its former department, Fisheries Department Malaysia. The operational framework in Malaysia is guided by the NOSCP and has been drawn up according to national legislations and international maritime conventions, as stated earlier and also shown in **Table 1**.

Basically, OPRC 1990, via its various convention articles, played important roles in formulating and establishing the Malaysian NOSCP. These articles promote the establishment of each coastal state having its own national contingency plan under a single lead agency. Other promotions include the need for coastal states to cooperate regionally and internationally regarding assistance, training, and technology development. In Malaysia, NOSCP comprises 17 members who sit on the National Oil Spill Control Committee (NOSCC) to give advisory and guidance on the control of oil spills for Malaysian waters, as well as for regional cooperation between neighbouring states. This is the official document outlining the operational framework in Malaysia, which utilises a Tier System. Activation of Tier 1 is carried out by the terminal owner, but for Tier 2 and Tier 3, it must come from the DOE headquarters' directives based on the NOSCP, where each agency will be assigned to their responsibilities to undertake their roles in managing oil spills in Malaysia. The functions and responsibilities of these agencies are shown in **Table 3**.

Table 3. Malaysia National Oil Spill Control Committee (NOSCC) members.

Agencies	Functions and Responsibilities
1. Department of Environment (DOE)	Lead agency. Director General is the Chairman of the Committee
2. Marine Department Malaysia (MARDEP)	Implementation agency and On-scene Commander for Tier 2 and Tier 3 oil spills
3. Malaysia Maritime Enforcement Agency (MMEA)	Vessels provider, maritime enforcement and investigation
4. National Security Council (NSC)	Overall national security
5. Ministry of Foreign Affairs (MOFA)	Advisory on foreign aids
6. Department of Fisheries (DOF)	Fisheries resources provider and claim from fishermen
7. Department of Meteorology	Meteorology on weather and sea conditions
8. Royal Malaysian Navy (RMN)	Advisory on maritime boundaries and sovereignty
9. Royal Malaysian Air Force (RMAF)	Air surveillance on oil slick movement and dispersant spraying whenever required
10. Royal Malaysian Police (Air Force)	Air surveillance on oil slick movement
11. Royal Malaysian Police (Marine Force)	Oil spills site supervision and security controls
12. Royal Malaysian Customs	To facilitate oil spill response equipment (OSRE) imports
13. Immigration Department Malaysia	To facilitate foreign manpower and professionals into Malaysia to assist oil spills disaster
14. Fire and Rescue Department Malaysia	Dispersant spraying whenever required
15. Department of Marine Parks Malaysia	Provider for sensitive sea areas, biodiversity and ecotourism
16. Petroliam Nasional Berhad (PETRONAS)	Advisory on oil spills
17. Petroleum Industry of Malaysia Mutual Aid Group (PIMMAG)	Advisory on technical and operation of OSRE

Source: Department of Environment [1].

A famous modelling oil spill trajectory study in the Bosphorus Strait, Turkey, had shown that contingency planning is very important to prevent oil spills reaching the shorelines, and they will take less than four hours if no response is taken. The second conclusion is that emergency stations must be determined at a suitable arrangement to minimise the oil spill impact [14]. Under this framework, it can be concluded that the existing NOSCP is still relevant, but it is subject to being updated to complement the latest use of technology and new benchmarks in managing oil spills at sea. Whoever takes the responsibility of a single entity, preferably as both lead and implementation agency, will be the new custodian of NOSCP, including OPRC 1990.

2.2. Methodology

This study employs Grounded Theory (GT) as its primary research methodology to develop and review the handling of oil spills mitigation in the Straits of Malacca (SOM). Given the complex, dynamic, and multi-stakeholder nature of marine environmental management, GT offers a flexible yet rigorous approach for generating theories grounded in secondary data in the real-world shipping industry.

Rationale for Grounded Theory

Grounded Theory is particularly suitable for exploratory research areas where existing theories are insufficient to explain complex phenomena. GT is especially useful for undertaking complex questions about processes and how something changes over time [15]. GT has three categories: first, second and third categories. First category, the data come from interviews, observations and a wide variety of documentary materials. The second category involves analysing the data using the constant comparative method to identify similarities and differences. The third category is to form the similarities and differences into a core category. This theory used qualitative data to explain why a certain phenomenon happened by studying a variety of similar cases in different settings and using the data to derive causal explanations. It was first introduced by Glazer and Strauss in 1967 [15]. Data from the GT came from

documents, statistics, reports, and observations, which were analysed for findings and results.

The SOM, as one of the world's busiest maritime corridors, is susceptible to oil spills caused by vessel collisions, operational discharges, and illegal dumping. Traditional top-down regulatory approaches have yielded mixed results, and a deeper, grounded understanding of stakeholder experiences, institutional challenges, and situational responses is essential for creating effective mitigation strategies. The analysis of the existing oil spill mechanism frameworks that comprise the legislation, institutional and operational arrangements in handling major oil spills from ships and tankers in the Straits of Malacca (SOM) is the main focus. The fundamentals of oil spill mitigation in Malaysia did not change much, but minor amendments did materialise in the national oil spills contingency plan [1]. Therefore, some of this analysis will explore and identify the efficiency of the current practices and processes of these frameworks.

3. Results

There were five major oil spills from ships and tankers in the SOM from 1990 to 2010 (20 years), as shown in **Table 4**. They are very important to analyse for outcomes in order to prevent old practices and past weaknesses from recurring in the SOM in the long run. These oil spills occurred at intervals of one to ten years and ranged in their severity, with oil pollution volumes between 2,000 and 29,000 tonnes per incident.

Table 4. Oil spill disasters in the Straits of Malacca from 1990 to 2010.

Incident	Year	Location	Estimated Oil Spilled (Tonnes)	Length of Affected Areas	Environmental Effect
MT Nagasaki Spirit	1992	Langkawi	13,000	14 miles	Fisheries, beaches, small islands and tourism
MT Evoikos	1997	West Coast of Johor, Malacca, N.Sembilan, Selangor and Perak	29,000	391 miles	Fisheries, beaches,small islands, sea-grass and tourism
SS Sun Vista	1999	Coast of Perak	2226	23 miles	Fisheries, beaches,small islands, sea-grass and tourism
MT Natuna Sea	2000	Eastern coast of Johor	7791	23 miles	Fisheries, beaches,small islands, sea-grass and tourism
MT Bunga Kelana 3	2010	Eastern coast of Johor	2067	23 miles	Fisheries, beaches,small islands, sea-grass and tourism

Source: IOPC funds [10].

3.1. MT Evoikos Case

On October 15, 1997, the Very Large Crude Carrier (VLCC) *Evoikos*, registered in Cyprus, collided with the Thai-registered vessel *Orapin Global* in the Singapore Strait and part of the Straits of Malacca (SOM), one of the world's busiest shipping lanes. The *Evoikos,* although not loaded with crude oil at the time, was carrying approximately 29,000 tons of heavy fuel oil in its slop tanks. The collision breached these tanks, resulting in the release of approximately 28,500 tons of heavy fuel oil into the sea. The *Orapin Global*, which was in ballast at the time, did not contribute to the spill [10]. The incident marked as the largest oil spill in history took place in the SOM until today. By October 19, the oil had drifted into Malaysian and Indonesian waters, and by December 23, it had reached approximately 40 kilometres of the Selangor coastline in Malaysia, affecting sandy beaches, rocky shores, concrete breakwaters, and mangrove areas. The socio-economic impacts on Malaysia were profound. The contamination of coastal areas disrupted local fisheries, particularly affecting fish and prawn farms that rely on the health of mangrove ecosystems as breeding and nursery grounds. Tourism, particularly in regions like Port Dickson, a popular beach destination, suffered due to oil-contaminated waters and beaches, resulting in a decline in tourist arrivals and associated economic activities. It took nearly three months for the oil slick to fully dissipate from the SOM's waters, eventually reaching as far as Pangkor, Perak. This demonstrated that the current OSRE

stockpile is insufficient and requires more than 19,000 tonnes under the existing setup.

The adequacy of OSRE stockpiles is a critical factor for effective handling of major oil spills. Following a comprehensive assessment of the impacts of *Evoikos* on the current Oil Spill Response Equipment (OSRE) stockpiles stationed in the Straits of Malacca (SOM), it was determined that the existing capacity is only 62.5 kilobarrels (KB), equivalent to 9,938 tonnes [1]. This capacity indicates that the OSRE can remove oil slicks from an incident site at a rate of 9,938 tonnes per hour.

This incident underscored the vulnerabilities associated with heavy maritime traffic in the Straits of Malacca and Singapore. It highlighted the need for stringent navigational protocols, robust environmental protection measures, and comprehensive international agreements to ensure adequate compensation and prevent future ecological and socio-economic impairment.

3.2. MT Nagasaki Spirit Case

On September 19, 1992, the oil tanker *Nagasaki Spirit*, carrying approximately 40,000 tonnes of crude oil, collided with the container ship *Ocean Blessing* in the northern part of the Malacca Strait. The collision resulted in a massive fire, leading to the death of all crew members aboard the *Ocean Blessing* and only two survivors from the *Nagasaki Spirit*. An estimated 12,000 tonnes of crude oil spilt into the sea, igniting and causing extensive environmental damage. The incident highlighted challenges in marine salvage operations and influenced the development of the Special Compensation P&I Club (SCOPIC) clause to address such situations in the future. The oil spill intensity was about 50% less than in the case of *Evoikos*, which was 13,000 tonnes and affected the coastlines approximately 14 miles. Marine environmental effects were observed in fisheries, beaches, small islands, and tourism. These environmental damages were not covered by the oil pollution compensation regime, as Malaysia is not a party to the CLC 1992 yet, but is still bound by the CLC 1969.

3.3. SS Sun Vista Case

The *SS Sun Vista*, a cruise ship, sank on May 20, 1999, approximately 104 kilometres south of Penang, Malaysia. The vessel suffered an engine room fire that led to a complete power failure. All 1,090 passengers and crew were safely evacuated before the ship sank. While the incident did not result in a significant oil spill, it raised concerns about potential environmental impacts due to fuel and other hazardous materials on board. The spilt fuel is calculated to be 2,300 tonnes. However, reports indicate that environmental damage was minimal, and the incident primarily emphasised the importance of safety protocols and emergency preparedness on passenger vessels (ITOPF, 2010).

3.4. MT Natuna Sea Case

On October 3, 2000, the *MT Natuna Sea*, a tanker carrying 70,000 tonnes of Nile Blend crude oil, grounded in Indonesian waters within the Singapore Strait and part of the Straits of Malacca (SOM). The grounding damaged several cargo tanks, resulting in an estimated spill of about 7,800 tonnes of oil. Due to calm wind conditions, the oil was carried by tidal currents, contaminating shorelines in Singapore, Indonesia, and Malaysia [10]. Since coastal areas in Johor were impacted, Malaysian authorities have had cleanup operations and environmental monitoring. The response included aerial dispersant applications and extensive shoreline cleanup activities. The oil spills were spreading into three neighbouring countries, so regional coordination was activated using the existing regional oil spills contingency plan, the Standard Operating Procedure for Joint Oil Spill in the Straits of Malacca and the Straits of Singapore among the affected countries (DOE, 2014).

3.5. MT Bunga Kelana 3 Case

On May 25, 2010, the Malaysian-registered tanker *MT Bunga Kelana 3* collided with the bulk carrier *MV Waily* in the Singapore Strait, approximately 13 kilometres southeast of Changi East. The collision caused a rupture in one of the tanker's cargo tanks, leading to a spill of approximately 2,300 tonnes of Bintulu light crude oil. The incident prompted reviews of national oil spill contingency plans and highlighted the importance

of regional cooperation in managing maritime environmental disasters (ITOPF, 2010).

4. Discussion

4.1. Efficient Operations Management

Oil spill operations management is a critical component of an effective oil spill contingency plan, aimed at minimising environmental damage, safeguarding public health, and ensuring business continuity. The core of this process lies in the strategic planning, coordination, and execution of response activities that enable organisations to act swiftly and effectively in the event of an oil spill. Other critical components are human resources and Oil Spill Response Equipment (OSRE).

The adequacy of Oil Spill Response Equipment (OSRE) stockpiles is a key parameter for effective disaster mitigation during major oil spill events [16]. Spills occurring near shorelines and populated areas result in significantly higher economic impacts and are more expensive to remediate [16]. Therefore, having sufficient OSRE capacity is a paramount justification. However, equipment alone is not enough, but the success of a response also hinges on the skills and training of response teams. Above all, the appointment of a competent on-scene commander (OSC) is a critical issue to address for quality command on-site. A poorly chosen OSC can compromise the entire mission and undermine efforts to achieve a pollution-free environment.

Developed maritime nations like the United States, have adopted robust stakeholder communication strategies during the oil spill preparedness and response phases. These practices have helped improve coordination in post-spill planning and disaster mitigation. According to Walker et al. [16], five key approaches include: structured dialogue with stakeholders to understand scientific and risk complexities, scenario adaptation planning, collaboration with local knowledge, social media and online surveys, and engaging digital volunteers.

These practices were largely inspired by the Deepwater Horizon (DWH) disaster in the Gulf of Mexico on April 20, 2010, considered the worst oil spill in global history. The incident resulted in the release of 134 million gallons (approximately 4,219,847 tonnes) of oil, causing 11 fatalities and extensive environmental damage, including to marine wildlife, fisheries, marshes, and recreational beaches. British Petroleum (BP), the polluter, paid USD8.8 billion (approximately RM35.2 billion at current value) for ecosystem restoration [17]. This remains the highest compensation for an oil spill worldwide.

4.2. Efficient Claims Submission

Managing oil spills at sea is neither simple nor inexpensive. The associated costs can be extremely high unless clean-up expenses are recovered through compensation mechanisms established by oil spill liability regimes. According to the data in **Table 5**, Asia recorded the highest average clean-up cost per tonne of oil spilt globally [18]. Higher costs may lead to a reduction in oil spill compensations if the authorities cannot substantiate the true costs of the cleanup operations. The high costs could also largely be attributed to inefficiencies in inventory management and logistics within operational response systems. These shortcomings highlight the need for cohesive reforms and updated practices through the development of new Standard Operating Procedures (SOPs) in the National Oil Spill Contingency Plan (NOSCP) or any other necessary changes.

Limitations on liability caps and the principle of channelling liability solely to the shipowner can restrict fair compensation for affected parties. This issue, along with the stringent admissibility criteria for claims, must be addressed for fairness. Professional intervention and negotiation expertise are often required to overcome these legal and procedural barriers for oil spills claims and compensation [19,20]. There are specific types of damage that are covered as defined by the CLC 1992 and IOPC 1992. The damages covered are clean-up and preventive measures, property damage, consequential loss, pure economic loss, environmental damage and use of advisers. In many major oil spills, compensation may vary from very satisfactory to unsatisfactory.

Table 5. Average clean-up cost per tonne of oil spillled.

Region	Cost per Tonne Spilled (USD per Tonne)	Share of Global Oil Tanker Traffic in Region (%)
Middle East	300	8
South America	3800	18
Africa	3900	18
Oceania	6900	2
Europe	13,100	11
North America	24,000	19
Asia	33,000	24
Weighted global average	**15,900**	**100**

Source: Vanem et al. [18].

Shortfalls in compensation are frequently linked to inadequate claims preparation and submission by coastal states to the oil pollution compensation regime [21–24]. This trend undermines the *Polluter Pays Principle* (PPP), which is meant to ensure that polluters bear the costs of pollution, allowing public goods to be protected while maintaining economic efficiency [25]. Given the increasing ecological and economic value of the Straits of Malacca, it is crucial not to neglect the pursuit of oil pollution claims. Proper claim management, supported by sound legislation and inter-agency coordination, will ensure the region's marine resources are protected for future generations, though a single agency is much preferred for prompt action flow.

A review of the past compensation claims reveals inefficiencies in Malaysia's claims submission process. For instance, in the 1997 *Evoikos* incident, Malaysia received only USD 0.792 million in compensation, it was 26% less than the amount originally claimed. By contrast, Singapore was compensated in full, receiving USD 8.038 million [10]. The reduction of compensation for Malaysia was primarily due to substandard and incomplete submissions, as well as a failure to meet the criteria for admissibility under the relevant compensation regimes. Additionally, Malaysia may have faced challenges in gathering the necessary documentation and substantiation required under the same regimes, which often limit payouts without rigorous proof of damages. Malaysia's lower compensation reflects systemic limitations in international maritime environmental law, highlighting the need for regional preparedness and legal harmonisation in handling transboundary marine pollution. In contrast, the oil slick only reached Malaysian shores several days later, and although the environmental and socio-economic impacts were real, they were less intense and more dispersed.

The other four ship and tanker incidents are not discussed since the oil spill compensations are not publicly disclosed. However, in the case of *Nagasaki Spirit*, Malaysia had missed the compensation from the oil spill compensation regime since it is not a party yet toto the CLC 1992 and IOPC 1992, but was still under the CLC 1969 and IOPC 1971 coverage terms at the material time [10]. Costs for other services, such as salvage, combating oil spills, firefighting, and lifesaving operations of the *Nagasaki Spirit*, were paid to authorised parties involved by the shipping insurance of both vessels.

4.3. Marine Environment Protection

One of the most direct impacts of oil spills is the physical contamination of marine organisms and habitats. When oil is discharged into the sea, it spreads rapidly, forming a slick that affects the water surface and eventually sinks or disperses into the water column. Marine life, such as fish, seabirds, sea turtles, and

marine mammals, can be coated in oil, impairing their ability to move, breathe, or regulate body temperature. Coral reefs, seagrass beds, and mangroves, ecosystems abundant along the Malaysian and Indonesian coasts, are especially vulnerable. Oil clogs the roots of mangroves, smothers coral polyps, and reduces light penetration essential for photosynthesis in seagrass habitats.

To sustain and protect our marine environment from damage as a result of international shipping activities in the SOM, the priority should be given to establish an efficient inventory and logistics management to undertake operations in combating oil spills at sea promptly. The marine environment impacts will be a huge burden to the stakeholders if prompt preparedness, response and combating are neglected. Advocating for effective environmental policies and strategic marine planning has shown a positive influence on long-term ecosystem sustainability and the socio-economic recovery of affected areas [26]. A strong, two-way relationship between post-spill planning coordination and marine ecosystem management is essential to preserve the natural and pristine condition of marine environments.

4.4. Socio-Economic Impacts

The spill contaminated approximately 40 kilometres of shoreline in Selangor, affecting beaches, rocky shores, mangrove areas, and aquaculture operations. One of the most significant sectors impacted was fisheries. The presence of heavy fuel oil in coastal waters disrupted fishing activities, especially inshore operations, which form a vital part of the livelihood for many local communities. Fish and prawn farms, which rely on clean water and healthy mangrove ecosystems as breeding grounds, experienced losses due to contamination and subsequent declines in water quality. As of 2017, Malaysia had an estimated 132,305 fishermen, with 44,251 (approximately 55%) operating along the west coast of Peninsular Malaysia. This region, encompassing states such as Perlis, Kedah, Penang, Perak, Selangor, Negeri Sembilan, Melaka, and western Johor, is a significant hub for the nation's fishing industry [27]. The West Coast's prominence in fisheries is attributed to its rich marine biodiversity and the presence of major fishing ports. The area supports a mix of traditional and commercial fishing activities, with fishermen employing various methods, including trawling and purse seining. Notably, the West Coast contributes substantially to Malaysia's total fishery production, underscoring its importance to the country's food security and economy. However, the fishing communities along the west coast face challenges such as environmental degradation, overfishing and competition from larger commercial operations.

Some of the examples of recorded marine resources found on the SOM, in the Malaysian waters [3]: mangrove areas having 93,505 hectares; coral reefs are naturally found in Port Dickson, Pulau Payar and Pulau Perak; seagrass is found in Langkawi, Port Dickson, Seberang Perai and Teluk Nipah; and total fishery landings were 700,000 metric tonnes. Besides marine resources, the economic loss to fishermen, aquaculture and tourism industries, especially seaside beaches of Melaka, Port Dickson, Pangkor, Penang and Langkawi, must be addressed as well. Without efficient mitigation of oil spills in the SOM, these marine resources may be exposed to damage as a result of the impacts of oil pollution from ships and tankers [27].

Impacts for economic loss in the tourism sector due to oil spills along the SOM, especially in Langkawi, Penang, Pangkor, coastal towns of Selangor, Port Dickson, Malacca and Johor, were not publicly published, but the lessons should be learnt for future improvement. Tourism was another sector affected, particularly in coastal towns like Port Dickson. As a popular domestic beach destination, Port Dickson experienced a decline in tourist visits due to polluted beaches and health concerns, resulting in revenue losses for local businesses, including hotels, restaurants, and recreational operators. If businesses derive

a large percentage of their income from tourists located close to the incident site, they may pollute the stretches of beaches and other amenities, which could affect guest arrivals.

Cleanup operations also diverted local government resources and temporarily limited public access to coastal amenities. The broader economic costs extended to reduced marine biodiversity, which can have long-term implications for sustainable fisheries and eco-tourism. Overall, the *Evoikos* oil spill underscored the vulnerability of Malaysia's coastal economy to maritime pollution and highlighted the need for stronger environmental safeguards and regional cooperation.

4.5. Single Agency the Way Forward

Multi-agencies with different legislation, institutional, and operational frameworks will distort the command and planning structures of the national oil spill contingency plan (NOSCP), including funding and regular maintenance of OSRE. New frameworks should be explored to create new norms in handling major oil spills in the SOM. Currently, there are three main agencies looking for oil pollution from ships and tankers, excluding others sitting on the National Oil Spill Contingency Committee (NOSCC). The three main agencies are DOE, MARDEP and MMEA. Their functions and responsibilities are also shown in **Table 3**. To have effective and strong management in handling major oil spills at sea, particularly in the SOM, Malaysia needs to have just one entity or single agency. Other agencies can still be maintained as per the existing arrangement, as per the National Oil Spill Contingency Plan (NOSCP), which provides inputs for the regime to adopt new technologies, benchmarks, and standard operating procedures (SOPs) that are found to be useful. To change to new norms is not an easy task for the authorities, but it will need strong political will to revolutionise since it has been operating the existing framework for more than four decades.

Issues related to the OPRC 1990 are likely to be a cross-cutting issue among DOE, MARDEP, and MMEA because of their shared nature and similarities in functions, responsibilities, assets, and funding. There is an urgent need to address these problems to inform future policy direction and prevent redundancies. The convention looks simple, but operationally, it differs from one authority to another because the scope of activities, operations, and responsibilities is based on their own legislations. It is recommended that the government consider transferring the OPRC 1990 either to the Marine Department Malaysia (MARDEP) or the Malaysia Maritime Enforcement Agency (MMEA) for effective enforcement. The change of lead agency from DOE to a new single entity will definitely improve the efficiency of the logistics management in handling major oil spills in the SOM since the duplication of functions and responsibilities is eliminated, and funding is streamlined and focused.

The presence of multiple agencies with overlapping jurisdictions had often led to poor governance and inefficient resource allocation [12]. Effective disaster mitigation requires a fully integrated preparedness and response system, coupled with a comprehensive, well-coordinated post-spill damage assessment [28–30]. The old practices gave Malaysia some indication of some negative results in handling major oil spills, especially in the SOM, compared to some developed coastal states, such as the United States of America, European countries, Japan or even to our neighbouring country, Singapore.

To clarify, a comparison table identifying the duplication of functions and responsibilities among authorities is provided in matrix form, as shown in **Table 6**. A careful selection will be made to transfer some of the functions and responsibilities to a single agency, as shown in its right column of the matrix. Legislation and regulatory instruments play a critical role in shaping oil spill response plans and on-scene command structures, which are essential for minimising environmental and socio-economic impacts.

Table 6. Matrix functions from multi-agencies to a single agency/entity to enhance inventory and logistics management in managing oil spills in the SOM.

No.	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19
Government Agency's Functions and Responsibilities	The Convention of OPRC, 1990	National Oil Spill Contingency Plan	Tier System Declaration	Oil Spill Committee Chairman	Oil Spill Compensation Regime	OSRE Stockpiles	OSRE Funding	OSRE Maintenance	OSRE Response Team	OSRE Response Vessels	On-Scene Commander	Maritime Competent Authority & IMO	Maritime Administration & IMO	Maritime Enforcement	Vessel Movement Monitoring	Search and Rescue (SAR)	Vessel Assets and Fleets Availability	Maritime Operations Communication	Post-Oil Spilled and Restoration
Department of Environment, Malaysia (DOE)	✓	✓	✓	✓	✓														✓
Marine Department Malaysia (MARDEP)					✓	✓	✓	✓	✓	✓	✓	✓	✓						
Malaysia Maritime Enforcement Agency (MMEA)														✓	✓	✓	✓	✓	
Single Agency/ Entity	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓			✓	✓	✓	✓	✓	

Source: Author.

5. Conclusion

The persistent inefficiencies in oil spill management within the Straits of Malacca (SOM) highlight the urgent need for structural reform. The current multi-agency framework, shared among the Department of Environment (DOE), Marine Department Malaysia (MARDEP), and Malaysia Maritime Enforcement Agency (MMEA), has resulted in overlapping duties, poor coordination, resource duplication, and delayed responses during spill incidents. These inefficiencies have not only hampered operational readiness but also placed Malaysia's high-value marine environment and coastal communities at unnecessary risk.

The fragmented responsibilities have hindered the execution of the National Oil Spill Contingency Plan (NOSCP) and diluted accountability across agencies. The experiences from major oil spill cases, such as the *Evoikos* and *Nagasaki Spirit*, *SS Sun Vista, Natuna Sea* and *Bunga Kelana 3*, underscore the critical need for a centralised, authoritative, and agile response body. A single-agency model would resolve jurisdictional confusion, improve inventory and logistics management of oil spill response equipment (OSRE), and enable faster and more effective mobilisation of personnel and assets.

The proposed transition to a single agency, ideally either MMEA or MARDEP, would consolidate leadership and operational functions under one entity. This alignment would ensure that Malaysia meets international standards outlined in OPRC 1990 and maximises institutional efficiency. MARDEP brings two decades of operational experience, while MMEA has the enforcement capacity and maritime infrastructure necessary for a national response mandate. Either agency, if empowered through legislative amendments and institutional restructuring, can serve as the dedicated national authority for oil spills.

This reform is not merely an administrative adjustment; it is a strategic imperative. A single, well-equipped and well-led agency would significantly

enhance Malaysia's maritime governance, improve disaster response, and safeguard marine ecosystems vital to national marine environmental protection and socio-economic stability.

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Conceptualization, M.B.I.; methodology, C.A.T. and M.B.I.; formal analysis, M.B.I.; Resources, M.B.I.; writing-original draft preparation, M.B.I.; writing-review and editing, C.A.T. and M.B.I.; supervision, C.A.T.; project administration, M.B.I.; funding acquisition, M.B.I. All authors have read and agreed to the published version of the manuscript.

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Appendix A

Figure A1. A map showing the Straits of Malacca used for international shipping lane.

Legend: International shipping lane.

Source: World Ocean Review [31].

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