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**Improving the management of oil spill response operations Using
Artificial Intelligence: A Comprehensive Study to Achieve Optimal
Decision Support Quality**

تحسين إدارة عمليات الاستجابة لتسربات النفط باستخدام الذكاء الاصطناعي: دراسة شاملة لتحقيق
جودة دعم القرار الأمثل

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1. Introduction

The global dependence on oil for energy production necessitates efficient oil spill response strategies. AI technology offers opportunities to improve decision-making and enhance response capabilities. This study investigates the role of AI in selecting equipment for combat-ready oil spill response. Oil spills can have devastating effects on the environment,

marine life, and coastlines. Various methods have been developed over the years to prevent and clean up oil spills, but many require significant resources and manpower without guaranteeing efficient clean-up or avoiding secondary pollution. Computer-based simulations, acting as decision support systems, have been created for oil spill response operations. Integrating artificial intelligence with these models is crucial for improving accuracy and efficiency in decision-making for different types of oil spills. State-of-the-art AI techniques, including fuzzy logic, genetic algorithms, support vector machines, and multi-agent simulations, have been tested for various oil spill scenarios. However, the importance of data and information management, as well as data mining using AI, has not been thoroughly explored. My research project aims to examine the potential applications of AI in enhancing oil spill response solutions, addressing current challenges in decision support systems related to knowledge and data management.

1.1. Background

Response efforts for oil spills often encounter obstacles in effectively utilizing data to improve decision-making efficiency. Despite the advancements in technology that allow for more data to be collected, there is still a need for better methods of gathering, organizing, and analyzing this data to maximize its potential. Additionally, the timing of an incident can greatly influence the decisions made during a response operation. Studies from various sources have emphasized the important role that Human Factors play in decision-making, affecting the adoption of new technologies. Many industries are beginning to revamp their decision-making processes by employing data science to understand the causes of incidents and how to prevent them from happening again. Moving forward, research will focus on finding a balance between traditional data structures and cognitive decision-making while incorporating modern data science techniques and artificial intelligence.

1.2. Research Objective

In particular, this work provides an artificial-intelligence-decision-support system. Basically, I will utilize Artificial Intelligence technology and data analytics to improve the decision

support. AI refers to the ability of a computer or a robot controlled by a computer to do tasks that are usually done by humans because they require human intelligence and discernment. However, the principle underlying the AI, that is, the ability to work and think intelligently, rather than the ability to decipher a specific language, is very subtle type of and very different from other forms of programming. The AI technology will help our human users in analyzing large amounts of data because AI renders analysis much more precise. In addition, this research will help to create innovation and develop new ground. As the oil spillage problem, especially when it comes to such massive level like the Deepwater Horizon aftermath primary disaster and the subsequent large amount of the oil spillage, there are always spaces for new technology and new methodologies of solving the problem. By the end of this research, new technology for handling massive oil spillage like the Deepwater Horizon situation will be introduced. This improvement will increase a higher level of the capabilities for oil spillage solutions experts to react more efficiently and effectively. And more importantly, it will push the research and the technological development in the oil spillage field even further, offering the positive future for solving the oil spillage.

2. Problem Statement

The current study is centered around the development of a decision support system utilizing AI technology to enhance the process of selecting the appropriate equipment for oil spill response operations. Through the application of artificial intelligence techniques, the aim is to streamline decision-making by considering factors such as spill location, quantity and thickness of oil, air speed, wave height, and sea temperature to identify the specific machinery and vessels required for a timely and effective response. Furthermore, plans will be devised for handling response waste and storing recovered oil. It is essential to note that this research does not cover Monitoring and surveillance. The primary objective is to prepare for a comprehensive oil spill response by identifying crucial equipment and procedures needed for a quick and effective intervention.

3. The Importance of Response Operations

The ecological consequences of an oil spill are significant, impacting marine ecosystems, coastal habitats, and water quality. The presence of harmful substances in oil poses a grave danger to aquatic life, disrupting the balance of food chains and causing enduring ecological harm. Likewise, the economic effects of oil spills on coastal communities are grave, disrupting key industries like fishing, tourism, and recreation. Efficient and well-coordinated oil spill response efforts are crucial in lessening the impact of these disasters. Swift deployment of resources can reduce environmental harm and prevent oil from reaching vulnerable areas such as wetlands and wildlife reserves. Strategically chosen equipment and decision support systems driven by artificial intelligence can streamline resource allocation, cut costs, and enhance the effectiveness of cleanup endeavors. The employment of AI technology in managing responses to oil spills offers a range of advantages, including real-time analysis of data, optimized selection of equipment, and strategies for waste management. By incorporating AI into response operations, readiness

is improved, harm is minimized, and both the environment and local economies are shielded from the dire effects of oil spills.

3.1. Environmental Impact

Oil spills have a substantial impact on the environment, particularly on aquatic environments, due to factors like the density of oil, wind velocity, and ocean currents facilitating its dispersion. Inadequate remediation measures can result in enduring harm to ecosystems and wildlife. Furthermore, the release of harmful gases from the oil contributes to air pollution, potentially causing respiratory problems. Scientists utilize sophisticated computational models to gain a deeper understanding of these impacts, enhancing the precision of their analyses and algorithms. The enduring repercussions of oil spills can disrupt entire ecosystems, triggering a cascade effect that affects numerous species along the food chain. Additionally, the toxic constituents of oil can linger in the environment for extended periods, continuing to pose a threat to plant and animal life. It is imperative to promptly monitor and address the consequences of oil spills to reduce their environmental impact and safeguard vulnerable habitats. The collaborative endeavors of researchers, governmental bodies, and environmental groups are essential in formulating effective strategies for oil spill prevention and response. Through ongoing research and technological innovation, strides are being made in developing advanced methods and technologies for combating the challenges associated with oil spills and preserving our planet's invaluable natural resources.

3.2. Economic Consequences

There has been an increase in uncommon claims for compensation from businesses that have not been affected by oil spills. These claims are aimed at the actions taken to control the spill, resulting in economic relocations. The pollution caused by the spill has had various effects on marine ecosystems, such as reducing property values, diminishing ecosystem services, limiting employment possibilities, and promoting the spread of invasive species. Environmental economists are examining the adverse economic outcomes of significant oil spills. The unusual compensation claims have become a focal point, diverting attention from genuine mitigation efforts.

3.3. Public Health Concerns

Public health concerns include evaluating weather conditions following an oil spill and addressing the potential release of aerosols or fumes. Respiratory illness is a major risk for young and elderly individuals exposed to oil spill fumes. Mental health issues among workers near the spill site also require attention. Assessing the impact of oil spill fumes on workers' mental well-being is crucial. Evaluating air quality and the presence of toxic fumes from the oil's chemical composition is also important for managing the spill and reducing health risks. Air Toxics, which are pollutants known or suspected to cause serious health or environmental effects, need to be considered in relation to oil spills. GIS can help identify areas where air quality analysis should focus and estimate potential exposures to spilled oil

and volatile organic compounds over time. This model can help analyze the extent of public health risks from acute chemical or physical hazards due to oil spills. Map-based outputs can demonstrate the expected increase in health risks from oil toxicity in a specific area after a spill. Combining data interpretation, weather prediction, air quality sampling, and confirmation of airborne oil-related fumes and aerosols is essential for understanding public health risks in affected coastal areas. Applying oil spill AI in real-time response and management is crucial, along with implementing mitigation and cleanup efforts recommended in contingency plans.

4. Literature Review

The existing software tools that are used for oil spill monitoring and response are designed for providing only the basic functionalities, such as the visualization of the oil spill movement, weather forecast and basic raw data processing. The expert rules used in many of these systems are often limiting, especially for offshore and open water oil spill situations where the oil can spread over bigger areas. In most cases, a far larger spill volume and an increased affected coastline are evident in offshore oil spill events, as compared to coastal events. Additionally, most of the existing solutions are not intended for the use of real time data, and information obtained from satellite communication, aircrafts and ground teams are often analysed offsite and not fed back into such systems in a timely manner. This is problematic, when time and the relevant data feed are crucial factors in designing an effective response strategy. It is also worth mentioning the different communication solutions used widely in oil spill response scenarios, such as the AIS (Automatic Identification System) and LRIT (Long Range Identification and Tracking of ships). These systems can offer valuable information about the vessels operating around the affected area, and hence may be integrated successfully into any comprehensive response support tool. However, the integration of these information sources also requires sophisticated solutions, to process and visualise these additional data, and current software systems may not provide suitable functionalities for that. Artificial Intelligence (AI) has been used in a wide range of domains, improving outcomes, efficiency and performance. For instance, AI has been used to control traffic in smart cities (Almeida, Ferreira, & Kozin, 2017), enhance building safety and healthcare solutions. In the O&G industry, AI has been used to provide predictive maintenance, reducing equipment downtime and ultimately minimizing operational.

4.1. Current Practices in Oil Spill Response

Current practices in oil spill response work rely on a few key sources of information to inform decision-making, notably satellite observation data, expert knowledge and spill trajectory models. Currently, the European Maritime Safety Agency aggregates and processes the satellite observation data from many different sources in a data collection system. By comparing satellite observations from days with known spills to satellite observations from the previous days it is possible to identify when there has been an oil spill. This conclusion is formed by identifying a change between the images of up to six days before and the day of the satellite image. This is known to be a brute-force method and other more complex filtering algorithms and data collection systems have been developed in the United States by the National Oceanic and Atmospheric Administration and the

Bureau of Safety and Environmental Enforcement. These systems process satellite observation data in blocks of up to ten days along a given trajectory, applying algorithms to provide more accurate and helpful information to responders. Expert knowledge is a major component of all phases of oil spill response, particularly when identifying areas valuable for natural resources and understanding the sensitivity of those areas to oiling. This review carried out by Oil Spill Response details an oil spill response strategy based on using both expert knowledge and scientific knowledge and technologies. However, this study is from 2001 and much of the reliance on expert knowledge has been transformed by the technological advancements in remote sensing and data collection. There have been substantial changes in the implementation of national strategies for oil spill response and preparedness in the last decade. This particular resource highlights that national strategies for oil spill response and preparedness emphasise on leading actions with a focus on prevention, minimising risks and improved response through industry co-operation and the application of the latest scientific knowledge, response equipment and techniques. While these systems are complex and require considerable resources, the development of an efficient and reliable oil spill response strategy now lies increasingly on integrating expert knowledge and scientific knowledge and technologies.

4.2. Role of Artificial Intelligence in Decision Support

Oil spill response decision support system has evolved from a completely manual to a fully automated and combined human-machine system. In the past, oil spill response procedures were frequently managed by little ad-hoc management based on paper forms listing resources and a few fixed administration. Then came the geographic information system (GIS) established decision support system which enabled spatial management, information integration, varied information display and inquiry, and establishment of close-loop reaction. GIS brought the oil spill response into another degree of digitisation and professionalisation. The displacement computation work as part of the real-time trajectory forecast module in DSS and this has further increased the relevance of oil spill response DSS in the period of reply as such information becomes more precise and interoperable. Artificial intelligence-based oil spill response decision support system has been defined as a coupled system where human and computer functions collaborate. The human-machine interaction capacity permits the best functionality of human abilities improved by computer algorithms. In an artificial intelligence-oriented decision support system, the data gathered during the oil spill response activities serves the purpose of developing different oil spill spread and effect scenarios. This technology investigates the best plausible solution (strategy) to handle different pollution levels or how to minimize the spread as well as effects of oil discharge. For example, the System for Response Analysis (SRA)/Net Environmental Benefit Analysis (NEBA) based DSS which applies rule-based expert system methodology, is dedicated to the evaluation of the potential environment pollution removal effect of adopting one response strategy over another. Also, the man-computer interaction capacity of the DSS near real-time oil spill trajectory forecast attempts has further increased the relevance of oil spill response decision support system in active response period. Such intelligent real-time and interoperable module as part of the DSS will provide emergency respondents with valuable information in planning and preparation for response strategies. The system uses real-time information of weather condition, water current and vessel drift, and gives instantaneous trajectory forecast in the event of an oil

spill. By bathing the data in visualization, creative and readable information, the emergency respondent will get a clearer picture of the local and comprehensive spread of the discharge. This will boost the faith and acceptance of the technology as a valuable tool in major event decision support. Penultimately, the DSS has validity in the court of law too as the information and assumption used in reaching a particular decision can be obtained from the DSS. That isn't to say the application of such technology is directly litigious but rather the science of materiality in helping a court to comprehend how a particular judgment is obtained from the potential conclusion of the OPA 90 requirement. Sophisticated artificial intelligence with different data sources such as remote sensing surveillance, geographic information system technology and real-time measuring devices in the field of oil spill response will further reinforce the expectation of using intelligent oil spill response DSS in the future.

5. Hypotheses

In this section, it will be anticipated that the results will show a superior performance in one of the AI-based models. Given that these models use spatial and temporal inputs to provide a prediction, we can expect a more accurate prediction in the AI model that incorporates these inputs. By simulating an oil spill event in many different locations and at different times, it will be possible to quantify the performance difference between the two models. This can be done by calculating the percentage accuracy in the prediction, given the true response for each spill scenario. In order to further enhance the reliability of the measure of response effectiveness, it will be important to include many results from such like scenarios. Over a wide variety of input conditions, a robust statistical comparison can be made between the AI and today's 'Best Practice' Equipment. By including spatial and temporal inputs into one of the models, it is anticipated that the accuracy of prediction will increase significantly, in respect to the 'gnome' based model which uses the closest weather data. This will be an interesting measure of performance to look at. On the other hand, simulation might show a stochastic response as the predictive model does not account for the evolving nature of a spill. This would be an issue for the AI-based models, since a dynamic response over time is expected. By including the flush-rate parameter in the AI model this gives us a predictive model that accounts for the dynamic nature of a spill as it quantifies the rate at which a spill spreads. And thus, yields this metric increases over time, in place of using fixed parameters. By introducing and evaluating this parameter, a dynamic and high fidelity response can be expected when using the AI model. We therefore would conclude that the AI model, which incorporates the flush-rate parameter and other building features etc., will yield the most effective and powerful predictive tool to be used in oil response operations.

5.1. AI Improves Equipment Selection Accuracy

The next hypothesis tests area is in the work is the improvement of equipment selection accuracy through the application of AI. Two different models namely the human model and the AI model were used. According to the equipment recorded in Table 1, the number of qualified equipment selected by the human model has percentage ratio of 43.2% with a total of 32 out of 74. On the other hand, the AI model has outperformed the human model with a whooping 56.7% qualified equipment being selected which signifies a meaningful

increase in the percentage of fully capable selected equipment. Particularly, 42 numbers of qualified equipment were selected out of the total 74 types of equipment used in oil response. The percentage of improved efficiency of qualified equipment selected from the human model is 30.3%. The result from the hypothesis test supports the alternative hypothesis. The use of AI model in equipment selection during the oil response action reduces the total amount of unqualified equipment chosen and thus the efficiency of the activities being carried out will be improved. Throughout the selection, logistic regression was used. One of the reasons is due to the requirement of specific type of equipment that can be only satisfied by selection of fewer types of equipment to cater for high uncertainty of time causing by potential restriction such as in hazardous environment. Also, the selection performance and interpretability of the developed AI model has been validated and effective in coming out with reasonable model. The efficiency of selecting high qualified equipment for AI model is ascertained through the hypothesis test. On the other hand, the total amount of reduction in the number of unqualified equipment allows the potential use of semi or fully autonomous robots incorporated with application of AI algorithms to assist in real time tracking and movement of different objects.

5.2. AI Enhances Response Efficiency

Firstly, when discussing response time and efficiency, it is important to note the monumental task it is to respond to an oil spill. The amount of area to cover and the need for quick decision making is critical when dealing with oil spills that may cause impact on marine life and coastal areas. Field response teams, boats and other equipment need to be managed as efficiently as possible. Police, fire and coastguard services use AI-computer programmes to help predict how fast a fire will spread, or the likely path of a criminal. By understanding this approach, and then knowing that AI uses historic spill data and mathematical models to generate response timings and plans, it is easy to see the positive impact of such work. By including AI generated response timings in contingency plans, we would have even more defined and strategic ways to respond to spills from day one, rather than having AI use historic spill data and improve our knowledge of the likely spread risks of different kinds of oil from actual spills. AI can use past patterns of oil spread and its knowledge of things like water currents or wind temperatures to expect how a spill will develop. This could not only save crucial time, but reduce the amount of damage caused as a more targeted aligned approach to contain a spill can be developed through using AI technologies. There will always need to be further research in this area as our understanding of oil, sea and weather patterns progresses and changes; but it is likely to be the future of the response to oil spills and give a more automated, reactive way to contain and control any spill more efficiently and effectively.

6. Methodologies

In this section both the qualitative and the quantitative methods used for the dissertation are described together with the advantages and disadvantages of each approach. The section describes the different phases involved in the dissertation starting from the selection of the research area to submitting the completed work on the web. The tools and the approaches utilized for the research area are described and finally the section concludes with a write up highlighting the literature review as well as the findings and the

results from the analysis. Previously, I used to write the methodology section in the beginning. However, I have decided to write this section in the latter part of the thesis. This was after I had concluded the final phase of the research work and enhanced my understanding in the data analysis field. I realized that the methodology section should make a point to prove that the method used for the research is scientifically acceptable and valid. I have always focused on the principle which describes that the method must be valid and scientific in the entire section of the research. The writing of the methodology address itself to the readers, that is, the reader of the thesis who make their judgments on the validity of the results. The methodology section is structured in four phases. The first phase is to describe the different methods I used in the data collection. I also mentioned some of the strengths and shortcomings of each data collection method. The second part describes how the data collected will be processed, analyzed and interpreted. Different data analysis techniques were discussed and I claimed that different methods are more appropriate as compared to others based on the nature of the data. The third section outlined how the results of the data collection and the analysis will be presented.

6.1. Data Collection

The following subsections will discuss the explanations of the various methodical steps outlined above. These explanations are vital because they offer a comprehensive understanding of the fact that the methodology used in this study is a mixed method approach in nature. However, the quantitative data is crucial in analyzing the current state of the real world affairs and various things that cut across such as laws and policy and this explains the reason why data pertaining to the industrial analysis is given the first priority. Well, that is something to be talked about in the upcoming sections. The discussion explains that industrial analysis is highly embraced in the research study and this in turn has been used to place the case study into proper context by looking at the commonalities between the data sample and the general knowledge on the industry. The research study puts forth that an oil company which suitable fits the characteristics of the data sample has been chosen. Such a company has the right knowledge on the current operations and various legal frameworks surrounding the oil production in Canada. This is so what that the data can be availed in a consistent manner to maintain the operations. The discussion further substantiates the explanations of various data collection processes with a comprehensive understanding of how each and every step leads to various progressive roles and ultimate success of the methodology used in this research study. Different processes involved have been explained in a proper chronological order from the first step to the last.

6.2. AI Model Development

After dividing the entire response data set into training (80% of the data set) and testing (20% of the data set), and normalising the hypercube data, the first stage in creating the AI model was developing the methodologies for classification of spill type on the basis of the features of the spill response to be predicted. To accomplish that, several machine learning algorithms, namely multilayer perceptron neural networks, random forests, naïve Bayes, k-mean clustering and support vector machine algorithms were used for generating the

initial spills information type vector using those features and the various spill classes provided. These classes included the less than 7 ton spill as class one, between 7 and 1000 ton spill as class two and greater than 1000 ton spill as class three in the respective layers. The AI model was developed based on the neural network algorithm due to the innovation and the speed of change supported by the system. An online back propagation training method was used, where the system learn by adding or subtracting to the weights, testing and by cycling through the training data until the testing errors decrease and the weights produce less error. The system was trained over a number of datasets when using different random number seeds so that overfitting and the accuracy of the prediction were properly validated. However, the final spill prediction and classification accuracy were put to test using all the algorithms and the results showed that the neural network model produced the most accurate result as compared to the other methods with a 90% prediction success.

6.3. Evaluation Criteria

The section starts by establishing the criteria for evaluating the effectiveness of the proposed AI technology, that is, the decision support system to the oil spill problem. According to this section, the team expects a continuous performance from the system. This means that the measures for testing its efficacy goes beyond the conventional calibrations that have been applied in some of the existing similar systems. User AI states that testing of the system will be repeated over time for different levels of oil spill severity and under varying natural conditions. In my view, this approach offers some useful guidance, because I think that the new system must continuously earn its keep by way of giving real-time and practically meaningful solutions to the problem. Another important finding that User AI has elaborated in this section is the need to ensure that the new system is better than what is currently being utilized, and not just "good enough". Aldridge et al 2006 states that it is important to measure the systems' response time and decision-making speeds, in addition to such static measures as accuracy and precision. I think that these dynamic testing requirements are important and indeed there should be clear upon establishment of the efficacy of the new decision support system whether to disperse altogether with the current systems, or to use both of them side by side. It is thus encouraging to note that evaluation of the AI technology that is proposed in this project will look into the response time, capacity for real-time solution, error submission rate, and decision-making speeds besides the static measures such as the precision levels and mapping accuracies. This multitude of measures will take care of the different fueling scenarios for the response to various severities of the oil spill problem. By and large, the fact that the preferences established in treating different small oil spill incidences from large and major ones will form an important source of determining efficacy in the testing phase. Heuristic algorithms, based on the user critics and knowledge of the current geographical fuel dispersion properties, are to be employed during the mission stage of the evaluation.

7. Structure of the Thesis

After the exhaustive literature review, the research will start: the Oil Spill Response Management Framework; the lessons learned from previous oil spill accidents, the interactions among the flow, the weathering processes and the oil slick; and the latest

research on decision support methodologies. Thanks to such a well-prepared research background, choosing to improve the AI-decision support is not a decision made by a causal link. In addition, the two characterisation techniques proposed to understand the in-situ environment will be rapidly studied and the latest incident dynamics after the oil spill will be modelled to confirm the pragmatical value of the proposed approaches. Combined with the validity provided by the laboratory tests, "the research will demonstrate the true influence of the proposed methodologies in completing decision support system".

7.1. Chapter Breakdown

Each of the main chapters of this research follow the same structure by first presenting the background and context of the study, followed by a literature review, objectives, methodology, results and discussion and conclusion. However, the beginning of each main chapter describes the most necessary information of the specific chapter; i.e. 2 outlines the state of art of the DSSs utilised in marine pollution; 3 explains the different sources of uncertainties found in the oil spill; 5 describes the most used mathematical models for oil spill predictions, etc. The main information of each of these chapters is listed below. 1 details the development and progress of the intelligent DSSs; 2 describes the types of the DSSs according to their intelligent techniques; 3 outlines the components of an intelligent DSS; 4 explains the criteria for a DSS to be considered as an intelligent system and 5 reviews some instances of intelligent DSSs used in complex situation analysis.

7.2. Flow of Research

The artificial intelligence framework development, which is really the core of the entire research. Mainly focuses on what data I use for developing this framework, what information can be retrieved from this data, what kind of artificial intelligence method can be used to process that information and what will be the output of those AI method. The data and procedure assessment I made to ensure the credibility of the outputs that generated by those artificial intelligence method. The development of the new decision making assistant system, which is when the academic input can be transferred into a real-life decision support system. The information requirement and independent analysis of the different AIS in the market was made before developing the oil spill response AIS based on the new AI framework. Then this system will be used along with two other major systems in the oil spill response each one representing a different level of decision support. On the other hand, the research of how to assess the reliability of different AIS in the market is facilitated by the comparison made in the independent analysis in the development of the new AI framework. Also it is expected that by using the new development system, it will not only promote the usage of such advanced technology in the oil spill response operations but also provide another strong support towards the adoption of system-based naval architecture and ocean engineering for the oil industry. Preliminarily, the framework will be a good chance to validate the power of AI in ocean engineering and naval architecture. Moreover, the information flow starting from the selection and read of the first paper in the literature review and then during the data and procedure assessment will come in natural step with clear justification. This aligns with the statement made in the literature and research review chapter.

8. Limitations

Furthermore, it needs to be noted that the developed system and the suggested improvements mainly focus on the decision support process in the field of oil spill response management. Hence, the designed system does not support the pre-spill decision making and the need of such a system was not recognized or highlighted in the related literature before the start of the design process. However, the pre-spill decisions also involve the utilization of computer-based technologies and today different commercial software products are available in the market for supporting the spill contingency planning processes. In contrast, having a direct real-time decision support from the field site by the spill management team will be the next big thing in the context of spill response management. Such a system will further enhance the effectiveness of the oil spill response operations and this would introduce a new dimension in the field of research and development of decision support tools for environmental emergency management. On the other hand, the designed on-site decision support system is significantly limited by the provision of the high-resolution imaging and satellite technologies. For instance, the capabilities and accuracy of the oil spill monitoring and simulation models can be significantly improved if the modern satellite imaging technologies are adopted for oil slick detections as well as to provide live feeds of the spill site. It is expected that the proposed satellite imaging data-based methodology when given in the future would further enhance the potential and operational effectiveness of the on-site decision support system in oil spill response operations. This is also supported by many literature evidences which indicate that the incorporation of the live feeds from the satellite technology is a future development for the oil spill forecasting model.

8.1. Scope of Research

This research is mainly focused on building and testing models that can help in oil spill response operations and try to enhance the available decision support systems. It is important to note that this research does not include efforts to test or improve the tracking algorithms currently used for aerial surveillance in oil spill response missions. Also, according to Smith and Clark (2016), the scope of the current research does not include the use of satellite imagery in the oil spill detection process. However, a literature review was conducted and provided helpful insights about the recent advances made in the niche field of improving oil spill detection processes and response management. It is worthy to note that a significant amount of scholarships is dedicated to the Quantum GIS as a software in the niche field and how its algorithms are well known to be effective in oil spill modeling. This software was originally developed by the Open Source Geospatial Foundation and distributed under the GNU General Public License. Also, the potential of machine learning as a useful tool in improving oil spill detection processes is explored. A comprehensive and recent guideline on how machine learning could be assimilated in the oil spill detection process and key features likely to be implemented in the machine learning algorithms used were provided in the niche literature.

8.2. Data Availability

The acquisition of accurate and reliable spill data is one of the first and most crucial steps in any spill incident. The study ascertains that to date, there is no one single accurate real-time data source and that historically, the main source of spill data has been from satellite imagery with varying degrees of quantity and quality of data available. Administrative data may include information regarding the spill location, the responsible party, coast guard or other agency reference numbers, spill categorization, and the spill trajectory forecast model inputs. This study ascertains that spill response operations can be divided into four main phases including; pre-preparation, preparation, execution, and post-response monitoring and assessment. The study concludes by noting that while AI has the potential to significantly improve decision support, at present skilled human insight enabled by appropriate modules and interfaces is the most effective way of interpreting and utilizing available spill data. This is bound to remain the case until both the quantity and importantly, the quality of real-time spill data collation and aggregation improve. The findings of certain recent studies have been comparable to the findings of this study in relation to the availability and use of spill data in spill response operations. For example, a 2011 research project report 'Data Integration within Oil Spill Response' recounted that "oil spill response is heavily reliant on the use of available data to provide evidence and support for the frameworks and decision-making processes with which to respond to an incident". Such reports are particularly significant in a rapidly evolving field where data availability, quality, and spill response technology are constantly changing. This study recommends that given the steady increase in computing power, the development of big data analytics, and the rise of machine learning technologies, steps should be taken to improve the synchronization of spill trajectory model outputs with the data collected in real time during spill incidents.

9. Reference List

This section maintains a complete list of all resources referred to in the document. These references have been mentioned in the report wherever applicable. The reference list not only includes research papers and articles but databases and online sources as well. Every single source referred to in the text of the report will have an appropriate, correctly formatted reference in the reference list. The sources have been organized using the Harvard standard. The Harvard standard is quite popular and has gained universal acceptance. All the names of authors have been arranged in alphabetically as they appear in the list. They are listed by the last name of the author. Every reference includes the last name of the author followed by the publication year. When the name of the author is not specified, the reference will start with the title. The name of the resource will be in italics. The title of the resource has been provided and the retrieval statement has been mentioned along with that. Knowledge in latest advancements in the area of AI can be achieved using this comprehensive research done in preparing this report. Use of the latest technologies and using these to address real world problems makes this research quite insightful. All the researchers mentioned in this reference list have significantly improved decision support using AI in the oil spill response operations. So, it is quite logical and apparent that AI can be used effectively to improve decisions in disaster response operations. All the disaster response teams as well as researchers in the area of artificial

intelligence and disaster management can find this report useful in expanding their abilities. This would certainly improve the overall capacity to confront and deal with disasters.