Oil Spill Response Capability Assessment: Describing Tasks and Effects

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Lund 2020

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Number of pages: 46
Illustrations: 3

Keywords
Operational oil spill response, capability estimation, capability description, response capability

Abstract
Oil spills require more or less significant response efforts to be controlled. While the frequency of severe oil spills has decreased, an increase in marine traffic is forecasted in the future. Research has found that capability to respond to adverse events is often understood and assessed based on resources, which in practice has shown to provide an insufficient understanding of the capability to respond to offshore oil spills. The study takes a point of departure from this problem and a potential solution found in theory, which proposes a new definition and description of capability including tasks and their effects in response to certain events, providing a better basis for decision-making. The study engages in a first step toward applying the capability description in the field of offshore oil spill response. By utilizing the experience and expertise of subject matter experts through interviews, and output from research and practice through a literature study, the research concludes on tasks and event parameters essential in describing oil spill response capability. Furthermore, inconclusive results on certain tasks and how to best describe their effect are discussed. Finally, broader methodological insight is presented on how to approach the capability description in practice, and the way forward for utilizing the research results and handling of the remaining uncertainties.

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Acknowledgements

This rewarding, at times challenging, experience coming to an end I want to thank those who have assisted me in accessing the fascinating field of oil spill response and those who have participated making the research possible. I also want to thank my supervisor Hanna Lindbom for guiding me through this process, and particularly for reminding me that “it´s complex” is seldom the answer. Finally, I want to express my gratitude to friends and family for the love and support.

Summary

Oil spills at sea stem from various sources, ranging from operational to accidental spills, involving offshore vessels and installations. Detrimental spills have through the last decades instigated advancements in national and international frameworks for prevention, causing a significant decrease in spills since the 1970s. Nevertheless, marine traffic is forecasted to increase toward 2025, further increasing traffic in already accident-prone narrow straits, harbours and coastal areas. As a consequence, advancements in preventive measures should be accompanied by increased preparedness to respond to oil spill events. This to reduce the losses if a spill is to materialise.

Whether response systems meet set requirements or need increased response capability can be determined based on assessments. Research has found that the understanding of capability is commonly equal to resources, which in practice has shown to provide an insufficient base for decision-making regarding oil spill response. The study considers this a problem in need of improvement, where a potential solution is identified in theory. A new way of defining and describing capability focuses on the tasks conducted by an agent in response to a specific event. To estimate response capability and further assess whether it is adequate, the event triggering response is described alongside the tasks initiated to affect the outcome. The assumed effect of the tasks is reflected in the consequences and as a result, whether the response efforts sufficiently influence the outcome in a positive direction or not may be assessed.

Guided by design science research, the study assumes that the design of a capability description of offshore oil spill response may function as a solution to the identified problem, applying the new understanding of capability as its theoretical foundation. The study does not seek to conduct a full design process, but to engage in a first step toward applying the capability description in the field of oil spill response. Based on experience and expertise in the field utilised through an interview and literature study, the research concludes on relevant knowledge to function as input to further design efforts. First, the reduction of environmental impact is found to be an essential task to estimate in capability description. This comprised by reducing the volume of oil in the environment and preventing its spread to shores. To produce realistic estimations of the effect of these tasks, it is further found that parameters within six main categories are essential to describe as part of the event due to their influence on these effects. Additionally, inconclusive results on both the tasks themselves and which consequences best reflect their effect are discussed. The research being a first attempt to investigate the theoretical construct in a practical context, the study provides insights on methods to do so. Based on the experiences from exploration and application of methods, their suitability is found to seemingly be affected by the characteristics of the event and response type, in particular, the frequency of events and the degree of routine in response efforts. Finally, the way forward is discussed regarding the utilisation of the results and needs to lower uncertainty, and a recommendation is given to refine the findings though design processes engaging with practice through evaluation and field testing.

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1. Introduction

The magnitude and cause of oil spills at sea ranges from accidents involving smaller recreational crafts to more detrimental tanker collisions or platform blowouts. With the development of the modern crude oil tankers in the 1950s larger quantities of oil could be transported at sea, with the largest tankers having a capacity of 17,000 deadweight tonnage (DWT) (Chen, Zhang, et al., 2019; Lun, Lai, Goulielmos, Cheng, & Hilmola, 2013). Capacity expanded fast, and in 1975 tankers were developed exceeding a capacity of 560,000 DWT (Lun et al., 2013). With larger quantities of oil transported at sea, the severity of oil spills increased. Events such as the grounding of the oil tanker Torrey Canyon in 1967–releasing 119,000 tons of crude oil–made it evident that the evolution of oil tankers had surpassed the technical and institutional abilities to handle such events (Chen, Zhang, et al., 2019). Since, large oil spills have initiated advancements in national and international institutional frameworks to prevent, mitigate and respond to oil spills (Walker, 2017) such as the International Convention for the Prevention of Pollution from Ships in 1973 (International Maritime Organization, 2019).

Oil tankers are not the sole source of marine oil spill risk. Any modern vessel carries bunker fuel, making groundings and collisions potential sources of oil spills. Additionally, activities related to offshore petroleum production and exploration pose a significant oil spill risk. The infamous 680,000-ton spill from the 2010 Macondo Well blowout in the Gulf of Mexico has been deemed a non-outlier in research, i.e. an event that based on global historical spill data would fit the expected risk (Eckle, Burgherr, & Michaux, 2012). Nevertheless, historically ships account for the highest frequency of spills and tons of oil spilt (Eckle et al., 2012). Alongside spills originating from ships, production platform accidents have instigated alterations and refinements of marine pollution policy and regulation (European Maritime Safety Agency [EMSA], 2013).

Decades engaging in prevention have proved to be successful. Spills from oil tankers have decreased considerably since the 1970s (Burgherr, 2007; International Tanker Owners Pollution Federation Limited [ITOPF], 2019) and incidents involving other vessels have shown similar trends (EMSA, 2018). Nonetheless, toward 2025 maritime transportation is forecasted to grow globally (International Transport Forum, 2019) which entails more traffic in narrow straits, harbours and coastal areas, which are already prone to vessel accidents (EMSA, 2018). As a consequence, preventive measures should be accompanied by efforts to increase preparedness, which could include an increase in response capability to contribute to a reduction of losses is a spill to materialise.

1.1 The problem and a potential solution

National preparedness for oil spill events generally entails the development of national contingency plans and the establishment of responsibility for offshore response within a competent authority (Walker, 2017). Within such competent authorities, adequate capability to respond must be achieved (Aurand & Stevens, 2008). Deciding whether response systems meet set requirements for preparedness or if investments in capability are needed is often based on assessments of capability (see, e.g., Yebao, Xin, Xiang, & Xiangyang, 2018). Such assessments depart from what is considered capability, which has been found to be rarely defined, with understandings commonly centring around resources (Lindbom, Tehler, Eriksson, & Aven, 2015). An example is found in the U.S. where competent jurisdictions have defined oil spill response capability purely based on equipment (Salt, Cox, Cramer, & Davidson, 2014). Limitations of focusing on resources can be seen in the light of uncertainties concerning how investment in equipment feeds into the increase of capability and hence, reduction of losses. This becomes evident when again considering the Macondo Well blowout, where capability based on equipment by far exceeded the needs in theory; however, only a small share of the spilt oil was removed in practice (U.S. Department of Homeland Security, 2011). The incident substantiates widening the understanding of capability beyond resources alone.

Doing so, research has suggested going beyond resources by viewing capability as the ability to do something, rather than a set of resources. Lindbom et al. (2015) propose a new perspective on assessing capability, departing from capability being something inherently connected to an agent, and this agent's ability to perform in a specific setting. Hence, capability is comprised of the tasks conducted by the agent in a particular event and the effects that are associated with such efforts, reflected in the consequences (Lindbom et al., 2015). Followingly, to estimate capability, the authors suggest a capability description. The description is a matter of describing an initiating event; the assumed performed task; its associated effect on the consequences; the uncertainty regarding what these consequences may be, and the knowledge functioning as a basis for the estimate (Lindbom et al., 2015).

The capability description is yet to be tested and implemented in practice. However, an experimental study has found benefits of describing capability in this manner related to decision-making. This since the description of tasks has shown to contribute to the perceived usefulness of estimations of capability in decision-making regarding capability enhancements (Lindbom, Hassel, Tehler, & Uhr, 2018). Based on an estimation of capability including the tasks conducted in response, decision-makers may assess whether the effect is adequate or not. This may be difficult based on resources alone, as shown in the case of the Macondo Well blowout. However, resources may still play an essential role through the knowledge base, feeding into the estimation of the effect of conducting the tasks (Lindbom et al., 2018).

1.2 Aim and research questions

Based on limitations identified in practice regarding the understanding and assessment of capability and suggestions on improvements found in research, the thesis aims to serve as a contribution to both theory and practice by engaging in a first step toward applying the capability description in the field of offshore oil spill response (OSR). This to, in the long-term, facilitate the reduction of losses of adverse events in general, and oil spills in particular.

To contribute to the fulfilment of the aim, two research questions are set out to be answered:

1) Which tasks, consequences reflecting engagement in these tasks and event parameters are essential in describing OSR capability?

Due to the suggestion on how to describe capability so far being a theoretical construct yet to be explored and applied in practice, the answering of the first research question is dependent on the answering of the second:

2) How should tasks, consequences reflecting these tasks and event parameters be identified in practice?

While research question 1 is sought answered through data collection and analysis, research question 2 is treated through the exploration and application of research methods.

1.3 Scope

The research focuses on operational response to oil spills at sea. When oil reaches–or threatens to reach–land, response activities are initiated onshore. Investigating the topic including both onshore and offshore response could be beneficial due to the interrelation of the two activities. However, restrictions in time and resources required narrowing the scope, excluding onshore response, which is considered appropriate due to the two responses being conducted by separate organisations.

Furthermore, in some cases, the oil type and environmental conditions may cause the best strategy to be leaving oil at sea with no further response actions taken than continuous monitoring. Due to the focus of the research revolving around response capability, this–known as the “do-nothing strategy”–was given no consideration.

Finally, the geographical scope of the study was set to Northern Europe, including the Baltic Sea countries. The choice of geographical scope is further described in section 3.2.

2. Theoretical and conceptual framework

In the following, the theoretical foundation of the research is presented. This to provide the reader with insight into the theoretical origin of the capability definition and description, conceptual explanations and an illustrative example of application.

2.1 The new risk perspective

The theoretical framework applied in the research is based on the new risk perspective in general, and the capability definition and description suggested by Lindbom et al. (2015) in particular. The new risk perspective provides a definition of risk that broadens the significance of uncertainty to go beyond probabilities–which is the focus in the traditional risk perspective–and accounts for the uncertainty of the knowledge base that serves as a foundation for estimations of risk (Aven, 2010; Aven & Ylönen, 2018). In the new risk perspective, Aven and Renn (2009) define risk as "uncertainty about the severity of the events and consequences (or outcomes) of an activity with respect to something that humans value" (p. 6). Hence, it is comprised by events (A), consequences (C) and uncertainty (U), emphasising uncertainty regarding if and when the event will materialise and what consequences it will generate (Aven, 2011). Consequences are expressed through what is gained or lost with regards to what is valued, for example, fatalities expressing consequences regarding the value of human life (Aven, 2011). Furthermore, the risk definition is separated from its description (Aven, 2010). In describing risk, the estimated uncertainty (Q) regarding A and the estimated consequences (C') is included, together with the background knowledge (K) on which Q is based (Aven, 2010). In other words, the description of risk puts the uncertainty in the spotlight.

2.2 Capability definition and description

In line with the new risk perspective, Lindbom et al. (2015) separate the definition of capability from its description. The authors define what comprises capability through the task conducted by the agent (T) in response to an event (A) that has consequences (C_T) which reflect the effect of the tasks (Lindbom et al., 2015). Uncertainty (U) is highlighted in the definition, and the definition is written out as "the uncertainty about and the severity of the consequences of the activity given the occurrence of the initiating event and the performed task" (Lindbom et al., 2015, p. 47). Thus, capability is expressed as: (C_T, U | A, T).

The event triggering response will impact to which degree tasks will affect the consequences, i.e. the capability to manage a specific event. In line with the above definition, a capability description includes the event (A) triggering the engagement in the tasks, together with a description of what the task entail (T) and the estimated effect of the performed tasks on the estimated consequences (C'_T) (Lindbom et al., 2015). Additionally, since we cannot predict the future entirely, the uncertainties regarding the effect of the performed tasks on the estimated consequences must be made explicit (Q) either quantitatively or qualitatively (Lindbom et al., 2015). This is further supplemented by descriptions of the uncertainty residing in the background knowledge (K) that has shaped these descriptions (Lindbom et al., 2015). Thus, the description of capability is expressed as (C'_T, Q, K | A, T).

Lindbom et al. (2015) illustrate the capability description through the rescue services task to protect residents in the event of a two-meter flooding, as depicted in Figure 1.

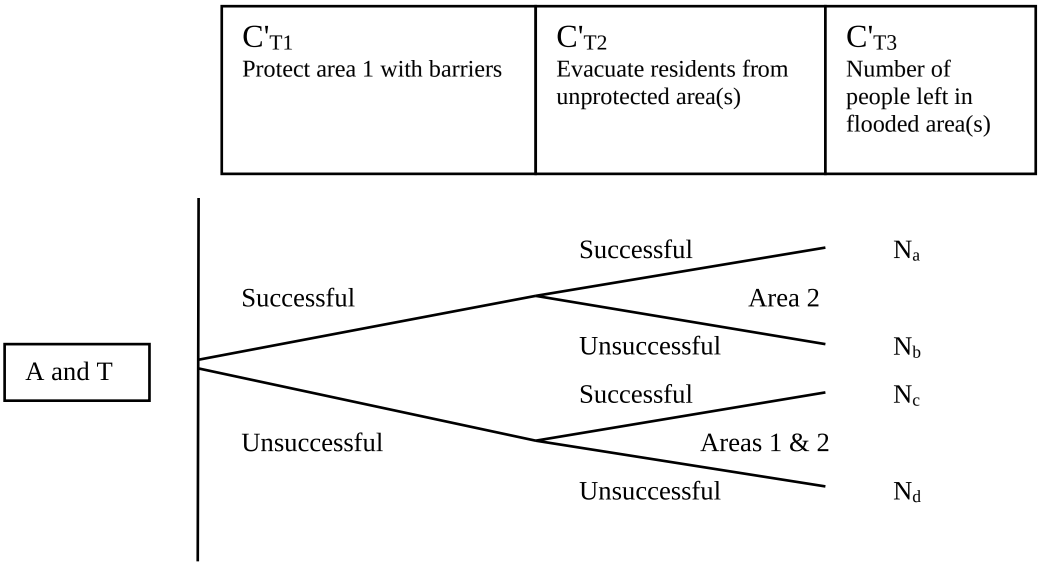

Figure 1. Illustration of capability description from Lindbom et al. (2015).

Figure 1 illustrates that a task may be described on different levels of abstraction. In the present example, the task of protecting residents in the event of flooding, hereinafter the main task, is described as comprised of two parts, hereinafter sub-tasks. The first sub-task is erecting mobile barriers in area 1, and the second is to evacuate residents in unprotected areas (Lindbom et al., 2015). The effect of conducting the sub-tasks are reflected in associated consequences, whether protecting area 1 with barriers and evacuating residents from unprotected areas is successful or not (Lindbom et al., 2015). A consequence per se may be described in both negative and positive terms. However, the focus in describing capability being describing what can be done to alter the outcome of an event in a positive direction, Lindbom et al. (2015) propose describing consequences related to what can be achieved.

The effect of conducting the main task as a whole as a reaction to a particular event is reflected in a certain outcome. In Figure 1, the main task is reflected in the number of people left in flooded areas. Depending on the effects generated by erecting barriers and evacuating residents, the number of people left in flooded areas will vary (Lindbom et al., 2015).

When defining capability based on the tasks carried out when responding to a particular event, the characteristics, and hence the severity, of the event will impact the effect generated by engaging in the task. Followingly, capability may be considered sufficient in the case of an event of a certain severity, but insufficient in another (Lindbom et al., 2015). Furthermore, the perspective of a capability description may be altered while still accounting for the same aspects of the system of which capability is sought to be estimated. Returning to the example described above, Lindbom et al. (2015) exemplify how a change of perspective may be done by including one of the sub-tasks in an extended description of the initiating event. Thus, one can assume already in the event description that the protection with barriers is successful, and thereby removing this uncertainty from the estimate (Lindbom et al., 2015).

3. Methodology

To identify the theoretical concepts of tasks, consequences reflecting their effect and event parameters in practice, the research had to engage in methodological exploration to conclude on how to do so. Section 3.1 presents the logic guiding the research, section 3.2 the methodological exploration, section 3.3, 3.4 and 3.5 the methods ultimately applied in data collection and analysis and finally, section 3.6 presents research limitations.

3.1 Design science

The logic guiding the research was influenced by design science. Herbert Simon describes in The Sciences of the Artificial (1996) how "Engineers are not the only professional designers. Everyone designs who devises courses of action aimed at changing existing situations into preferred ones" (p. 111).

Design science research (DSR) is a process involving the application environment, the design research and the knowledge base connected through three cycles as illustrated in Figure 2 (Hevner, 2007; Hevner, March, Park, & Ram, 2004). The application environment is where the problem or need has emerged and in which the output of DSR, hereinafter the design, is sought to function as a solution. The relevance cycle relates to the identification of the problem and the field testing of the design to conclude on whether it improves the application environment or requires further iteration. The knowledge base contains the relevant knowledge applied in the design in the form of, for example, scientific theories and expertise on the application environment. The rigour cycle relates to the appropriate and effective utilisation of relevant knowledge, and rigour is sought through the use of scientific data collection and analysis methods. Finally, the design research is where the development of the design takes place, through iterative construction, evaluation and refinement in the design cycle. Designs and experiences from the design process further feed into the knowledge base.

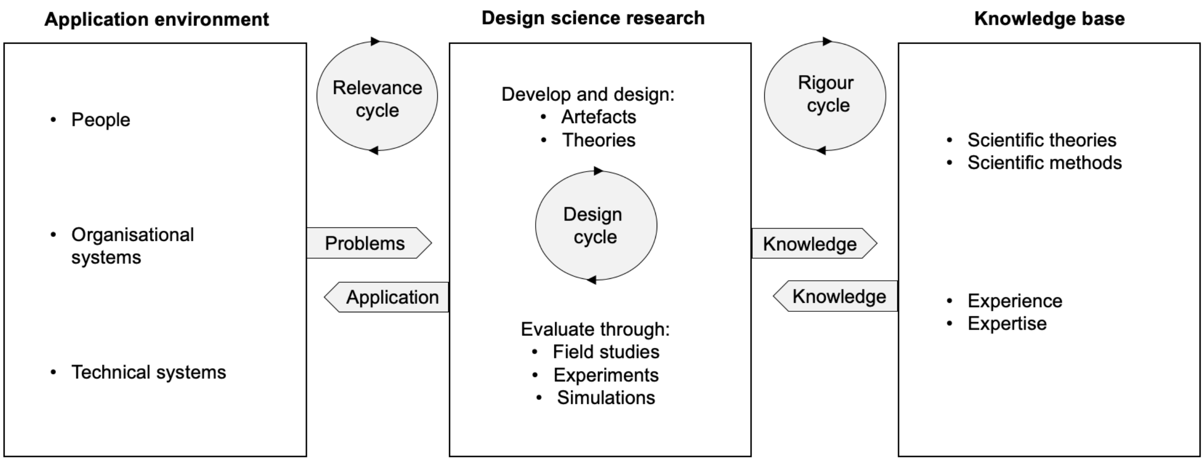

Figure 2. Illustration of design science research adapted from Hevner, Park, March & Ram (2004) and Hevner (2007).

Based on i) the problem identified in the organisational systems of the application environment on how capability is understood and assessed and ii) a potential theoretical solution identified in the knowledge base, an assumption was made that the development of a design to assess OSR capability through capability description may serve as an improvement in the field. However, the thesis did not seek to conduct a full DSR process, but to engage in a part of the process which will serve as an initial step.

The research focused on the knowledge base and rigour cycle by identifying relevant knowledge to function as input to DSR. The capability description, including descriptions of tasks, their estimated consequences and parameters relating to the event as described by Lindbom et al. (2015), served as the theoretical foundation. Since the foundational theory primarily is a theoretical construct not yet examined in practice, the knowledge base did not yet contain any concrete guidance or best practice regarding the identification of the theoretical concepts in practice. Hence, the research focused on the rigour cycle by exploring and utilising methods to extract knowledge from research and practice into DSR.

Based on the above, the research aims more specifically to contribute to practice through initial engagement in the design of a problem solution. Furthermore, a contribution to theory is sought through engaging the capability description with practice and the exploration of methods to do so.

3.2 Exploration of methods

To identify relevant knowledge in practice, two sources of experience and expertise in the knowledge base were deemed appropriate and feasible to include in the research: individuals with subject matter expertise in operational response and output from research and practice, hereinafter literature.

Through initial communication with individuals in the field, it was described how the number of people possessing subject matter expertise on operational response in non-oil producing countries is low, later confirmed in the recruitment of informants. Hence, it was concluded that to facilitate the achievement of a sufficient empirical basis, an international scope was necessary. However, although OSR being a topic of relevance worldwide, a global scope was deemed unfeasible considering purposive engagement of subject matter experts. Hence, the inclusion of informants was decided to be narrowed to northern Europe, including the Baltic Sea countries. The choice was based on pre-established connections within the scope and the included countries being connected through bilateral and multilateral agreements on OSR.

Due to the topics of inquiry in the research being suspected to require clarifications, an interview study was deemed the most suitable method to engage subject matter experts. Interview studies requiring considerable time for preparation and implementation, it was concluded unfeasible to design the study through repeated trials. Hence, the design was chosen and implemented, which is further described in section 3.3. The method to utilise experience and expertise in literature was, on the other hand, designed through an iterative process. This process is described below.

3.2.1 Operationalisation of theoretical concepts

Initial examination of a sample of literature consisting of scientific papers and conference proceedings proved the theoretical concepts not to be readily available for extraction from the body of text. In practice, this meant that concepts, such as tasks, seemingly were not commonly applied in the particular field. Hence, operationalisations of the concepts were developed. The operationalisations were in many cases developed through an iterative process, applying them in analysis of the sample of literature and altering them where needed if proven not to yield relevant data.

In the research, tasks were understood as a main task comprised of several sub-tasks. The main task was operationalised as an overarching purpose, reason or goal guiding overall efforts made in response or reasons for engaging in response. In practice, this was identified in sentences such as “the main purpose of combatting oil spills at sea is to minimise environmental damage”. Followingly, sub-tasks comprising the main task were operationalised as activities conducted in operational response. The operationalisation was applied, and sub-tasks such as “spraying dispersants” were identified. However, it was found that these activities are not static in response. This meant that engaging in the main task is not always comprised by the same activities, i.e. dispersants are not necessarily applied in the event of a spill. As a result, it was concluded that the operationalisation could not identify sub-tasks essential in capability description due to the sub-tasks themselves not necessarily being essential in response. In the second trial, sub-tasks were instead operationalised as the motive or reason for conducting the activities. In practice, these were identified in sentences such as “dispersants are applied to prevent oil from spreading to the shore”. As a result, preventing oil from spreading to the shore was understood as a sub-task, which may be achieved through various activities. In this way, certain activities can be accounted for in the assessment when relevant for achieving a specific sub-task and left out if not relevant given a particular event. The operationalisation was deemed suitable for its purpose and was utilised in the analysis.

The activities comprising the sub-tasks were utilised in the identification process regarding the event component of capability description. The research did not seek to define a specific event to apply in capability description per se. This since describing the future is inherently uncertain and choices of event characteristics applied in assessment being considered an aspect connected to the practical assessment process. Rather, the research strived to define essential parameters to account for. A parameter was understood as a factor which state should be set in describing the event, which can be described differently to decrease or increase the severity of the event in focus. Event parameters were first operationalised as factors affecting OSR as a whole. However, when tested, it was found that such factors were mainly described in relation to specific activities, i.e. activities comprising sub-tasks. This facilitated for highlighting the connection between variabilities in the event and choice of activities in sub-tasks. As a result, the operationalisation was altered and applied in the analysis. Now event parameters were understood as factors affecting engagement in or effectiveness of individual activities, which will affect the sub-tasks followingly the overall capability to manage a certain event. These were identified in sentences such as “booms are not effective in perpendicular currents”, understanding currents as an affecting factor.

Consequences reflecting engagement in a task were operationalised rather broadly as descriptions of consequences, outcomes and effects related to the separate tasks and descriptions of their measurement, success and effectiveness. The operationalisation was applied and yielded very few results. However, it was concluded that this was not solvable through a changed operationalisation but was rather due to a general lack of attention in the literature, further discussed in chapter 6.

3.2.2 Literature types

The exploration of methods included exploration of which types of literature could serve useful in the analysis and strategies to identify such literature.

It was assumed that several types of literature could prove useful in identifying relevant knowledge. Initially, main types of literature examined were scientific papers, conference proceedings, reports, scientific textbooks, international guidelines and manuals, national contingency plans and case studies. While the usefulness of scientific literature and conference proceedings had already been established through the development of operationalisations, the usefulness of the remaining literature types was unknown.

Certain grey literature was deemed ill-fit after an examination. Having scrutinised the response manuals of multilateral agreements between countries within the scope[1], it was found that such manuals mainly focus on guidelines on cooperation. Additionally, the International Maritime Organizations manual on oil pollution was only available through purchase. The research being unfunded, such purchases were deemed unfeasible. Based on these experiences, international guidelines and manuals were deemed non-useful in the analysis. Furthermore, five contingency plans were studied, which proved tasks, associated consequences and event parameters rarely being identifiable. This due to the documents mainly revolving around legislation and division of responsibility, only one yielding data on tasks. As a result, national contingency plans were deemed unsuited to include in the analysis. Finally, case studies were examined, but due to severe oil spills being rare even on international bases with only a few events the last decade[2], recent case studies were deemed too rare to function as an empirical basis.

3.2.3 Identification of literature

The operationalisations of theoretical concepts were tested on a sample of literature identified prior to the formal literature identification process. Hence, a strategy for identifying a set of literature to include in the analysis had to be chosen, and several strategies were explored. Searches in different databases utilising specific search strings comprised by either theoretical or operationalised concepts were completed. However, it was soon apparent that little or no literature was entirely focusing on these topics. Serving as an example, examining the results of the Scopus database search: TITLE (“Offshore oil spill response” AND purpose OR reason OR goal), three articles were identified particularly discussing the purpose of OSR. As a result, a broader strategy was chosen. Opposed to identifying literature targeting a specific topic of inquiry, the topics were investigated in a set of literature describing OSR more broadly. Furthermore, in the initial examination phase, it was also found that seemingly, a large share of literature on the topic was produced in North America with few contributions from northern Europe. Hence, the literature study was not restricted to a particular geographical scope. The specifics of the method utilised for literature identification is further elaborated on in section 3.4.

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[1] The Helsinki Convention, Bonn Agreement and Copenhagen Agreement.
[2] See statistics in ITOPF (2019).

The exploration of methods, as described above, resulted in the design applied in data collection as described in the following sections.

3.3 Interview study

An interview study was conducted for the collection of data in the pursuit of identifying tasks, consequences reflecting their effect and event parameters essential in capability description. This by incorporating the knowledge of subject matter experts on operational response.

A semi-structured approach was utilised, departing from an interview guide of open-ended questions (see Appendix 1). This to allow for going beyond the guide and facilitate for follow up questions (Brinkmann, 2013; Jacobsen, 2015). The interview guide was created to transform the topics of inquiry in the research into questions which could be directed directly to the interviewees (Brinkmann, 2013). One aspect of the interviews that is important to highlight is the one of abstraction. In an attempt to identify tasks on a similar level of abstraction, interviewees were asked to describe approximately three sub-tasks. Furthermore, the interview guide was distributed to interviewees beforehand to facilitate reflection before the interview.

The interviewees were selected through purposive sampling, which was conducted based on inclusion criteria (Guest, Namey, & Mitchell, 2013). The criteria were for interviewees to possess subject matter expertise on operational response, including an overarching knowledge of the response process. Operationally this translated into interviewees being competent in the wider process of operational OSR, not isolated parts or subjects. Such informants were primarily identified within competent authorities responsible for national OSR and private OSR organisations connected to shipowners and the petroleum industry. Contact was established with informants directly or through entry points, utilizing chain referral (Blaikie, 2009). E-mail and phone calls were used as recruitment technique and the research aimed at engaging around 10-15 informants, which is considered generating a volume of data feasible to handle practically while still securing detailed understanding (Brinkmann, 2013).

In total, 22 invitations for participation were distributed, and interviews with 10 subject matter experts from nine countries within northern Europe and the Baltic Sea region were conducted between February and March 2020, an overview found in Table 1. The identification parameters are based on interviewee preferences regarding anonymity, where only parameters agreed on by all informants are displayed.

Table 1. Informant code, position and organisation type.

Code	Current position	Organisation type
A	Technical Expert	Private
B	Advisor	Public
C	Technical Advisor	Private

D	Technical Team Manager	Private
E	Operations Expert	Public
F	Technical Expert	Public
G	Advisor Operations	Public
H	Manager Operations	Public
I	Operations Specialist	Public
J	Technical Advisor	Public

Since informants were recruited internationally, interviews were conducted through video-link, phone calls and on one occasion face-to-face. Face-to-face interviews being described to best facilitate the exploration of specific themes (Brinkmann, 2013), it was nevertheless found that video-link provided many of the benefits found in face-to-face interviews due to its audio and visual character.

Recording of the interviews and terms for participation[3] was discussed and agreed on at the beginning of each interview. All interviews were recorded and lasted for 40–80 minutes. The variation in duration was mainly due to how much informants elaborated their answers, especially regarding consequences associated with the tasks.

3.4 Literature study

As the interview study, the literature study was conducted to identify relevant knowledge in the form of essential tasks, consequences reflecting the effect of these tasks and event parameters essential in capability description. This to facilitate a substantiation of the results of the interview study and to detect potential differences.

The identification of scientific and grey literature was based on a snowball approach described by Wohlin (2014). The approach is suggested as an alternative to full database searches which may lead to missing out on, for example, grey literature and certain journals (Wohlin, 2014). The above served as the main argument for the use of the snowballing approach in the research. The approach includes the identification of a starting set of literature, of which reference lists and citations are examined to identify additional literature (Wohlin, 2014).

A starting set was identified to function as the point of departure for the snowballing process. A criterion for document inclusion was set for both the starting set and further snowballing, which encompassed documents covering either a specific topic of interest in the research or a broad focus on OSR. Documents with a narrow topic not relevant for the research were excluded, a title example being *Integration of the CDOG deep water oil and gas blowout model with the NOAA GNOME trajectory model*. Throughout the literature identification process, this led to a high number of documents being examined in the abstract examination phase since the inclusion criteria were often not easily assessed based on titles alone.

[3] Terms for participation related to the degree of anonymity preferred by the interviewee and information about the right to at any time withdraw their consent.

To identify the starting set, two databases were used: Google Scholar and Scopus. Google Scholar was chosen due to including both academic and grey literature while also yielding results from relevant journals and platforms in the OSR field, such as the *International Oil Spill Conference Proceedings*, which do not appear in Scopus searches. Furthermore, Scopus was used due to Google Scholar ranking results based on an algorithm affected by previous searches made by the user. The Google Scholar search string was formulated as: “Offshore oil spill response” OR “Oil recovery operations” OR “Operational oil spill response”, where the former refers to the broader response system and the latter to the handling of oil offshore. Due to having encountered the two terms being used interchangeably, both were included. Finally, “Operational oil spill response” was included to capture literature targeting the activity of response itself, opposed to for example policy. The Scopus search string was formulated in a similar way, the only difference being a language selection: (TITLE-ABS-KEY (“offshore oil spill response” OR “oil recovery operations” OR “operational oil spill response”) AND (LIMIT-TO (LANGUAGE, “English”)).

The search in Google Scholar yielded 5130 results[4], of which 1000 titles were screened. The search in Scopus yielded 536 results, all titles screened. After identification of relevant titles, the abstract and later the full length of literature was examined to decide on inclusion in the starting set. Additionally, relevant scientific textbooks[5], grey literature and scientific papers identified prior to the database searches were included as a supplement. The starting set consisted of 14 documents (see Appendix 2). Each document was examined through backward and forward snowballing, screening reference lists and citations (Wohlin, 2014). Followingly, documents tentatively included based on titles were retrieved, and a final inclusion was based on first examining the abstract, and finally examining the document as a whole (Wohlin, 2014). Citations were searched in Google Scholar. After having included documents from reference lists and citations, the next iteration was made. When further inclusions were no longer made, the search was finalised (Wohlin, 2014). In total, 29 documents were included in the analysis (see Appendix 2).

3.5 Data analysis

In the following, the procedure for analysis of the literature and interview transcripts is described.

The recorded interviews were transcribed, which involved transforming spoken word into text, where the level of detail was set based on the purpose of the research (Brinkmann, 2013; Gibbs, 2012). The research not focusing on, for example, forms of speech, a rougher transcription method was applied, leaving out aspects of conversation such as pauses and laughter (Brinkmann, 2013).

The content of the transcripts and literature was analysed through two iterations of coding, utilising the Nvivo software. This involved linking passages of text representing the same idea through a common word or phrase, a code (Gibbs, 2012; Saldaña, 2013). Parent nodes were

[4] Google Scholar only displays the first 1000 results.
[5] Scientific textbooks included in the starting set are published by scientific publishers and authored by acknowledged experts in the field.

constructed to reflect the theoretical concepts. Followingly, a conventional method was applied, deriving codes from the body of text (Hsieh & Shannon, 2005) guided by the conceptual operationalisations. Serving as an example, one informant expressed how “reducing environmental damage is always our main purpose”. In this case, the segment of text was coded as the child node “Environment” under the parent node “Main task”. Where relations were sought to be tracked, a node hierarchy was created. Serving as an example, the event parameter “currents” was coded as a child node of the activity which it affects, in this case, the use of booms. Hence, the child node “Booms” was created under the parent node “Parameters” to indicate the relation. In the specific case of parameters, these were later categorised to facilitate for their presentation in the results chapter. To provide an overview, the node hierarchies were structured in tables (see Appendix 4 and 5).

3.6 Research limitations

Regarding limitations of the literature study, scientific papers originating from China were often only included up until the full-text examination phase, when found to have no full-text translation. Additionally, certain conference proceedings were only available for purchase at onepetro.org, examples shown in Appendix 3. As described in section 3.2, purchases were deemed unfeasible, and exclusions were made due to financial reasons.

Regarding the interview study, as described in section 3.3, subject matter expertise was in many cases found in a small number of people within one competent authority. Serving as an example, it was experienced how only two people within a country were described as fulfilling the inclusion criteria. As a result, failing to recruit such individuals occasionally resulted in no participation from that country. Furthermore, since expert knowledge is found in a small group of people, workload was often described as high and hence impeding participation despite willingness. In one case, research was impeded due to national guidelines regarding research on the specific type of personnel[6].

The above may have caused certain perspectives being lost in the research. However, there have been no indications during the research that any certain country or community of experts hold significantly differing views on the field in general.

Limitations of the chosen methods will be further discussed in section 5.2.

[6] In certain countries research involving the organisations of interest demanded a research permit. In one case, this permit was not granted.

4. Results

The interview and literature study were conducted to answer research question 1: *which tasks, consequences reflecting engagement in these tasks and event parameters are essential in describing OSR capability?* In the following, the compiled results from the analysis of the two studies are presented, divided into sections according to the separate topics of inquiry. The answering of research question 2 is attended to in section 5 and 6.

4.1 Main task in OSR

All interviews and 15 documents yielded results on the main task of OSR. The full descriptions can be seen in Table 2, which revolved around reducing environmental impact. By some informants and in certain literature, four aspects were described in various combinations in addition to reducing environmental impact. These aspects consist of reducing economic impact, reducing time for environmental recovery, meeting public expectations and protecting human life and health. Furthermore, two documents describe the main task as reducing adverse impact (Fingas, 2017; Aguilera, da Fonseca, Ferris, Vidal, and de Carvalho, 2016).

Table 2. Full main task descriptions.

Description	Informant	Literature Source
Reduce environmental impact	B, F, E, G, H, I,	Nordvik, 1995; Federici & Mintz, 2014; Al-Majed et al., 2012; Perry, 1999; Ornitz & Champ, 2002
Reduce environmental impact and meet the expectations of the public	J	
Reduce environmental impact and time for environmental recovery		Baker, 2008
Reduce adverse impact		Fingas, 2017; Aguilera et al., 2016
Reduce environmental and economic impact and protect human life and health		Chen, Ye, Zhang, Jing, & Lee, 2019; Walker, 1995; Tuler et al., 2007; Li et al., 2016; Kuchin & Hereth, 1999
Reduction of environmental and economic impact	D	
Minimise damage to environmental and economic resources		International Petroleum Industry Environmental Conservation Association (IPIECA), 2000; Stevens & Aurand, 2008
Reduce environmental impact and protect human life and health	A, C	

OSR being driven by the purpose of reducing environmental impact or damage was emphasised by all informants. This particularly related to reducing environmental impact both due to the spill itself, but also concerning the technologies applied in the response (D). Reduction is a leading word since the damage is done once the pollutant enters the environment and response efforts may only reduce damage and not entirely prevent it (A).

Four informants mentioned additional aspects of the task of reducing environmental impact. Response efforts seek to protect human life and health in events where human life and health is at risk (A, C). When asked whether lifesaving operations is a formal task of their organisations, it was described how the organisations are not specialised in such activities, but how assistance in doing so would be given at the cost of combatting the spill if needed. Reduction of economic consequences was described by one informant and related to fisheries, tourism, shipping and port activities (D) and meeting the expectations of citizens was emphasized by another (J).

4.2 Consequences associated with main task

Consequences reflecting the outcome of the event and the performed task were identified in relation to the task of reducing environmental impact, but also the four aspects found to accompany it. An overview of the consequences is found in Table 3.

The task to reduce adverse impact could not be connected to any specific consequence, which could be reflected in all, or none, of the consequences found in Table 3 depending on how it is to be understood.

Table 3. Consequences reflecting the reduction of environmental impact and its four associated aspects (consequences presented in the bullet lists).

Reduction of environmental impact	Reduction of time for environmental recovery	Reduction of economic impact	Protection of human life and health	Meeting public expectations
• Oil in environment • Visible oil in environment • Oiled birds • Decrease in animal populations • Destroyed habitats • Time for recovery • Damage to flora, fauna and ecosystems	• Recovery time flora • Recovery time fauna • Recovery time ecosystems	• Economic loss in industries • Economic loss in fisheries • Time for economic recovery • Damage to amenity beaches • Disruption in industries • Tainting of seafood • Fouling of equipment and boats	• Physical health issues among response personnel • Mental health issues among affected populations	• Pollution of shores • Impact on tourism

Informants struggled to define consequences reflecting the outcome of OSR and answers were characterised by stemming from spontaneous ideas rather than practice. Furthermore, some informants expressed hesitation to share such spontaneous thoughts. Similarly, identifications were rarely made in the literature.

In the following, the identified associated consequences are presented.

Reduction of environmental impact

Overall, how consequences are to be understood and best measured is not yet completely clear in the field, especially regarding environmental impact (E, I).

The time for the environment to recover from an oil spill would reflect the outcome of efforts to reduce environmental damage (D). So would the number of oiled birds, deceased number of marine animals and destroyed habitats (I). However, damage stretches far beyond such consequences (I). Another suggestion is the volume of oil remaining in the environment (G, H). This volume should include oil that is not removed at sea and as a result, continuously polluting either the aquatic environment or shores (G). Additionally, this could include dispersed oil due to posing a risk to, for example, micro-organisms (G). The volume of oil left in the environment may also be measured through the volume of visible oil, which is a measurement applied in practice (J).

Oil that is not recovered will in one way or another continuously pollute the environment (H). However, different oil types will evaporate at different rates, and a low value (i.e., a low volume of oil remaining) could be due to evaporation and not human intervention which is challenging to estimate (B).

In the literature, reducing environmental impact relates to consequences of oil spills on flora, fauna, ecosystems and habitats (Al-Majed, Adebayo, & Hossain, 2012; Baker, 2008; Fingas, 2013; Jernelöv, 2010). Environmental impact materialises in multiple ways, and to estimate such consequences, they must first be defined and later measured through several metrics (Tuler, Seager, Kay, Webler, & Linkov, 2007). Exemplifying through oiled birds, consequences may be measured by number affected, recovered, cleaned and released or released and surviving in the long term (Tuler et al., 2007).

Reduction of time for environmental recovery

In the literature, environmental recovery is connected to the recovery time of flora, fauna, habitats and ecosystems after a spill (Baker, 2008; IPIECA, 2000) which may stretch up to three decades (Baker, 2008). A problem remaining to be solved is related to what is to be understood as recovery, and whether this entails a pre-spill state (IPIECA, 2000).

Reduction of economic impact

Efforts to reduce economic impact relate to economic losses in for example aquacultures, tourism and fisheries, which may be measured in time for economic recovery (D).

Similarly, the literature associates economic impact with economic damage on tourism though loss of amenity beaches, disruptions in industries, tainting of seafood and fouling of fishing equipment and boats (Baker, 2008; Perry, 1999).

Protection of human life and health
The protection of human life and health is in the literature related to response personnel and affected populations. This focusing on health issues among response personnel due to exposure to toxic gasses and mental health-related issues among affected populations (Li, Cai, Lin, Chen, & Zhang, 2016).

Meeting public expectations
Meeting the expectations of the public mainly relate to consequences regarding oil reaching shores, which if materialising, would have a negative impact on tourism (J).

4.3 Sub-tasks in OSR

In the following, the identified sub-tasks comprising the main task in OSR are presented together with descriptions of the related activities. Through the literature and interview study, six sub-tasks were identified:

- Gaining an overview of the spill
- Preventing further spillage
- Reducing the volume of oil in the environment
- Preventing spread to shores
- Preventing spread to sensitive environments
- Preventing spread to economic resources

In the literature, 21 documents explicitly described one or several sub-tasks, the full overview seen in Appendix 4. The results show that each sub-task is associated with several activities. Additionally, in many cases, more than one sub-task is associated with each activity.

Gaining an overview of the spill
Gaining and upholding a sufficient overview throughout the response operation is emphasised by informants and literature. This in terms of location, volume and spread of the spill to deploy the necessary resources (A, E, F, G, I). This may be achieved through direct communication with for example a leaking vessel (F). However, this is not always sufficient (E). Furthermore, achieving an overview is challenging, and in darkness impossible, from the position of a vessel (G) and remote sensing by aircraft and satellites are vital (A, E, G, F, I). Thickness (A, I) and oil type (I) are also at times possible to determine using such methods. Additionally, the use of the human eye from an aircraft is the best way of overviewing a spill in combination with the various technologies (E).

A sufficient overview of the spill is vital to assess the safety of personnel before deployment (B, F). Knowledge on the toxicity, evaporation and ignitability of the oil type decides when, if and what activities are initiated based on the risk it poses to response personnel and equipment (F). Furthermore, modelling the spill is essential to gain an overview of potential future trajectories of the spill (F, I). This as a way to attempt to understand how the spill will behave further on with regards to for example spread (I). The overview of the spill must also be retained to track the progress of implemented response measures to evaluate their effect and appropriateness (A).

In the literature, several aspects connected to the overview are described. The location, type and spread of the spill must be confirmed to guide the deployment of resources (Fingas & Brown, 2018) and to estimate which areas and resources are at risk of contamination (Aurand & Stevens, 2008). Additionally, the oil type spilt and its characteristics must be established to decide on the use of technologies (Yang et al., 2017). A range of activities are associated with gaining the overview. Remote sensing through aircraft and satellites is used to retrieve information on location, spread, thickness and sometimes type of oil spilt (Fingas & Brown, 2018). Oil samples feed into spill models, which alongside input on for example weather provide an estimate of the future behaviour and trajectory of the spill (Fingas, 2013; Sayed, Serrer, & Mansard, 2008).

Preventing further spillage

Preventing further spillage from the source was emphasised by five informants (B, E, F, G, I) where success increases the chances to reduce contamination of for example shores (E, G). The cause of the spill determines how, and if, this may be done and whether activities have been initiated before all oil has escaped (G). Stabilising and lightering damaged vessels are common strategies (G). However, spills originating from for example shipwrecks, the location of the source and the source itself may not be known, hampering the prevention of further spillage (I). Additionally, whether preventing further spillage is a task conducted by response organisations or not varies. One informant described how efforts to prevent or stop further spillage has a high impact on the overall consequences of the spill, but how such measures would not be a responsibility of the response organisation (C).

In the literature, it was described how the outflow of oil may be stopped by physically preventing the outflow or through lightering activities, removing the remaining oil from the source (Etkin et al., 2017). Hence, stopping the flow of oil having to be handled at sea (Walker, Ducey, Lacey, & Harrald, 1995). Salvage activities also contribute to preventing additional spillage. However, whether this is a responsibility of response organisations is described by Perry (1999) to vary.

Reducing the volume of oil in the environment

All informants described reducing the amount of oil in the environment as central in OSR. This should preferably be conducted as close to the source as possible, avoiding spread to sensitive environments and shores (A). Oil should be removed from the environment promptly (E, J) and the activities to do so vary from event to event. However, mechanical recovery using skimmer systems are emphasised as a preferred method by five informants (B, E, F, G, H).

Oil removed from the sea may re-contaminate the environment in a different area through insufficient handling of retrieved oil and contaminated equipment (D). Followingly, oil volume should not be reduced at sea to later be released elsewhere (D).

The reduction of volume of oil in the environment was commonly described in the literature through several activities. Reduction of the volume of oil relates to the separation the pollutant from the environment which it threatens (White, 2001) and doing so as close to the source as possible directly and indirectly reduces shoreline contamination (EMSA, 2010). Oil may be removed by skimmer technology brushing the oil from the sea surface (Fingas, 2013; Nordvik, 1995). Additionally, in-situ burning–a technique comprised of collecting and igniting oil–may be used to reduce oil quantity (EMSA, 2010; Federici & Mintz, 2014). Applications composed by different materials can absorb the oil, which when saturated are removed and replaced (Chen, Ye et al., 2019). Finally, biodegradation may be sought by applying bioremediation agents. The strategy involves enhancing natural processes of organisms feeding on the oil compounds by applying agents that stimulate the increase of such organisms (Al-Majed et al., 2012). Additionally, the recovered oil and contaminated equipment must be treated and disposed of carefully to not cause a re-location of the spill, thus releasing the contaminant back in the environment (Baker, 2008; IPIECA, 2000).

Preventing spread to shores

In the interviews, all informants described the prevention of oil reaching the shoreline being a crucial task in OSR. Setting up protective booms and sorbent applications are main activities related to the prevention of spread to shores described by all informants. However, the application of dispersants may be necessary when the spill is of a significant size (C, H, I).

In practice, full prevention of shoreline contamination may not always be realistic. This when the spill occurs in the close vicinity of an island or the mainland, which will cause the oil to reach land immediately (D, E) or when controlling the spill has been less effective (C, H). In these cases, activities will be focused on achieving the prevention of additional shoreline contamination through protection with booms (D, E). Different areas will also be prioritised based on their sensitivity when full prevention is not possible (A, E).

In the literature, oil being prevented from reaching the shore is one of the most commonly described sub-task. This seen in relation to the difficulties found in removing oil once it has stranded onshore compared to while it is still at sea (Baker, 2008; Jernelöv, 2010). Preventing oil from reaching the shore is dependent on the quantity of oil removed at sea and can be done through protection with booms preventing the oil from washing ashore (Chen, Ye, et al., 2019; Fingas, 2013; Ventikos, Vergetis, Psaraftis, & Triantafyllou, 2004). However, such prevention may also be achieved through dispersing the oil, i.e. reducing the oil into small droplets and breaking interfacial tension, by spraying such chemicals on the sea surface (Aguilera et al., 2016). Dispersed oil mixes more easily with the water, and the concentration of oil is decreased, removing the spill from the sea surface (Al-Majed et al., 2012).

Preventing spread to sensitive environments

Four informants emphasise preventing oil from reaching sensitive environments (A, C, G, H). Similar to the protection of shores, the protection of sensitive environments is dependent on the volume of oil removed from the spill site (H). Prioritizations are made based on sensitivity mapping (A, H). Additionally, sensitive environments are not necessarily located onshore but include aquatic environments inhabited by sensitive species which may or may not be affected by the level of protection of shores (A, C). Oil may be directly toxic to aquatic animals (G), and in addition to pollution affecting them directly, damaging effects on aquatic vegetation may, in turn, affect populations of species both long and short term (H).

In the literature, preventing the spread of oil to sensitive environments mainly relates to the protection against pollution of areas with sensitive flora or fauna, both onshore and offshore. Whether an environment is sensitive can be static but may also change depending on factors such as time of year. For example, an area may be more sensitive during breeding seasons (Baker, 2008). An area may also be considered sensitive due to long estimated recovery times (IPIECA, 2000). Preventing oil from spreading to such areas is conducted similarly as when preventing spread to shores; preventing its spread and protection of the sensitive area (Baker, 2008). Dispersants may be used to protect some sensitive areas from thickly concentrated oil, while other sensitive areas may be negatively impacted by their use (Ventikos et al., 2004). Dispersing oil may protect for example birds but increase exposure to organisms breathing in water (Jernelöv, 2010).

Preventing spread to economic resources
Prevention of oil reaching economic resources was described by four informants (B, D, F, H). Activities associated with protecting such resources may coincide with the protection of shores and sensitive environments, but this varies depending on the location of the spill (H). Vessels travelling through oil-contaminated water risk costly mechanical failures (B, F) and re-routing traffic is often connected to financial losses, especially when oil is contaminating port inlets (D). Furthermore, livelihoods are at risk due to for example contamination of fishery equipment or tourist attractions, which may and may not be located onshore or in sensitive environments (H).

In the literature, the prevention of spread to economic resources is achieved through the same activities as the protection of shores (Chen, Ye, et al., 2019; Ventikos et al., 2004). Economic resources may be diverse, and considerations are typically made regarding livelihoods such as fisheries and tourism (IPIECA, 2000). A sensitive environment may also be considered an economic resource. This for example if the particular area is important for livelihoods (IPIECA, 2000). Protecting all economic resources and sensitive environments at risk may not always be achievable, and prioritizations must be made (White, 2001).

4.4 Consequences associated with sub-tasks

In the interviews, informants found it challenging to express consequences reflecting the effect of sub-tasks, and the topic was rarely discussed in the literature. This specifically regarding consequences associated with gaining an overview of the spill, for which no concrete associated consequence was identified.

An overview of the consequences associated with the sub-tasks can be seen in Table 4, which does not include the sub-task of gaining an overview of the spill.

Table 4. Consequences associated with five of the sub-tasks.

Prevention of further spillage	Reduction of oil in environment	Prevention of spread to shores	Prevention of spread to sensitive environments	Prevention of spread to economic resources
• Eliminated spill risk: tons • Eliminated spill risk: percentage of total volume at risk of spilling	• Total amount of oil removed: percentage of total volume spilt • Total volume of oil removed: tons • Volume remaining in environment: percentage of total spill	• Degree of protection: share of oil volume posing a risk prevented from reaching shore • Prevented damage: length of area protected	• Degree of protection: share of oil posing a risk prevented from reaching sensitive environments • Prevented damage: length of area protected	• Economic loss in industries • Economic loss in fisheries • Time for economic recovery • Damage to amenity beaches • Disruption in industries • Tainting of seafood • Fouling of equipment and boats

Below, the identified consequences associated with the sub-tasks are presented. Findings regarding consequences associated with the prevention of spread to economic resources coincide with the findings on consequences associated with reducing economic impact and are described in section 4.2.

Eliminated spill risk

Informant E, G and I suggested reflecting the prevention of further spillage in eliminated spill risk. This through spill risk eliminated in tons (E) or percentage of eliminated spill risk based on tons at risk of spilling and tons prevented from spilling (G, I). Measures must be based on the volume of oil that is realistic to assume posing a risk of spilling in the sea (G). Such estimations might be coarse since it is difficult to estimate precisely how much oil is posing an actual risk of leaking from the source (G). Additionally, the measure comes with limitations since the risk varies with time (I). This exemplified through how remaining oil in a grounded vessel may be secure at one point of time but risk ruptures due to changes in weather conditions later on (I).

Oil removed or remaining in environment

Four informants described how the reduction of oil in the environment might be reflected in the total amount of oil removed through efforts made by the response organisation (A, B, F, H). This through the percentage removed of the total volume spilt (B, F) or the amount removed in tons (A). However, oil will evaporate at different rates, and the percentage removed may be very low due to large amounts having evaporated (B, F). An opposite consequence was also suggested, focusing on the volume of oil remaining in the environment. This through the percentage of total spill remaining in the environment (G).

In the literature, EMSA (2010) describes how the achievements regarding the reduction of oil are often expressed in the quantity or percentage of oil removed. This, however, only in relation to mechanical recovery.

Degree of protection
Two informants suggested how efforts to prevent spread to shores and sensitive environments may be reflected in their degree of protection (A, C). This by estimating the volume of oil posing a risk to the shore or sensitive environment and the share of this volume that is prevented from reaching them (A). Two informants suggested the measurement regarding shores only (H, I). However, the total volume of spilt oil may not be posing a direct risk of reaching the shore or sensitive environment, and hence an estimation of the actual volume posing a risk must be made (A, C, H, I). To do so, criteria must be set on what oil will be considered a potential risk and unclarities may emerge regarding sunken oil and oil which whereabouts are unknown (I).

Length of area protected/unprotected
Informant G suggested reflecting the effect of efforts to protect shores and sensitive environments in prevented damage. Informant E gives a similar description, however only related to shores. Both informants suggested an expression as the length of shore at risk protected from contamination in kilometres (E, G). Informant G was, however, uncertain regarding measurements connected to sensitive areas since aquatic environments are often difficult to demarcate. Additionally, protection caused by other factors than human intervention such as change of wind direction should not be accounted for (G). Measuring consequences related to protecting shores in length protected is common, but it is also considered to fail to give any insight into how much shore is polluted (H).

Similarly, EMSA (2010) describes how the length of shore protected or contaminated are common measures of achievement in OSR.

4.5 Event parameters

Through the literature and interview study, six categories of event parameters were identified, affecting the activities of the sub-tasks and by extension the overall outcome of OSR:

- Weather conditions
- Temperature
- Characteristics of the oil
- Characteristics of the location
- Characteristics of the source
- Time

The two data collection methods yielded similar results, with exceptions regarding characteristics of the source and time, only described in interviews. Below the identified event parameters are presented. To highlight the individual parameters within a category, these are italicised when first mentioned. Furthermore, in this section, results from the literature study are presented first to facilitate explanations of field specific terminology. An overview of event parameters and their connection to the activities of the sub-task found in the literature can be seen in Appendix 5.

Weather conditions

In the literature, weather conditions emerge as a category of parameters with a considerable influence on the activities comprising the sub-tasks. *Wave height* has the ability to affect the functionality of equipment and systems used to collect oil from the sea. Depending on the equipment, wave height over a certain level will severely impede its effectiveness and eventually make deployment impossible (Baker, 2008; Ventikos et al., 2004). Technology to contain oil is also impeded by even somewhat moderate wave conditions, either by oil travelling over or under the booms (White, 2001). In addition to affecting the performance of technology, waves of a certain height may cause a malfunction in equipment used to contain and recover oil (Nordvik, 1995). The potential of in-situ burning is also described as affected by weather conditions (EMSA, 2010; White, 2001), not effective with waves over around one meter (Al-Majed et al., 2012) and certain *wind speeds* (Potter & Buist, 2008).

Weather conditions do not only affect technologies used in response but the state of the oil itself. Once oil is exposed to the environment, a range of processes start generally described as weathering. Two such processes are spreading and emulsification, spreading changing the shape and location of the spill and emulsification its volume due to oil mixing with water (Fingas, 2017; Ornitz & Champ, 2002). Spread may hamper containment, recovery and the application of dispersants due to spills breaking up (Perry, 1999; White, 2001) and emulsified oil is challenging to handle both mechanically and chemically (Fingas, 2013). Finally, highly emulsified oil is challenging to ignite for in-situ burning (Potter & Buist, 2008).

Remote sensing technology may be impacted by weather conditions. Several technologies may be used such as IR, radar and visual satellite imagery to detect, map and follow up oil spills (Fingas & Brown, 2018). The use of different technologies suffers from different challenges. Reduced *visibility* due to clouds and sea states challenge the use of some remote sensing technologies, while others may be unaffected (Fingas & Brown, 2018; Ornitz & Champ, 2002). However, different technologies yield different data, and a specific weather parameter may only affect the collection of a particular data type (Fingas & Brown, 2018).

In the interviews, weather conditions were the most commonly identified category of event parameters. As described by all informants, weather causing rough sea states affect, in one way or the other, most response strategies and technologies available. Rough sea conditions may impede efforts to reduce additional pollution through stabilising and lightering leaking vessels (E, G). Collection and containment equipment may be damaged by waves (B, E, G, H, I, J) and in severe conditions not work at all (A, B, C, G, H). Additionally, rough weather may cause oil to sink before removed from the surface, making a reduction of volume nearly impossible (E). The functioning of sensors may also be impeded by *precipitation* such as snow and heavy rain (C, E) and even too calm seas may challenge remote sensing (D). However, certain weather conditions impeding one activity may be related to the ease of another. Heavy fog might impact visibility, but there is rarely fog and strong winds at the same time, hence easing mechanical recovery (F).

Temperature
Water temperature is described in the literature as affecting the effectiveness and range of activities. This mainly in relation to oil viscosity, meaning that depending on the characteristics of the oil regarding viscosity and the temperature of the sea, the oil will pour more or less easily which affects the effectiveness of recovery technology (Chen, Ye, et al., 2019; Hollebone, 2017). Additionally, viscosity impacts the effect of dispersants (Baker, 2008; Hollebone, 2017) and sorbents (Federici & Mintz, 2014). Low water temperature further hampers the effect of the application of bioremediation agents (Al-Majed et al., 2012).

In the interviews, viscosity in combination with water temperature is described as affecting the ease to collect oil mechanically (C).

Characteristics of oil
Different types of oil will have different characteristics, and hence act differently once released into the environment (Hollebone, 2017). As described above, oil *viscosity* impacts the effectiveness of technology and is an inherent property of the oil spilt (Chen, Ye, et al., 2019). Additionally, weathering processes are not only affected by the environment it is spilt in but also by the very characteristics of the type of oil spilt (Nordvik, 1995). Different oil types also make the spill more or less easy to detect through remote sensing and by the human eye due to different *appearances* (Fingas & Brown, 2018).

The characteristics of the oil regarding *thickness* also affects the effect of a range of activities and technologies. For effective in-situ burning, the slick thickness needed for successful ignition depends on the state and type of the oil (Potter & Buist, 2008). Mechanically recovering oil is typically also more effective in thicker concentrations of oil (Al-Majed et al., 2012). Thickness is, however, not only a result of the oil type but spreading on the sea surface stretches the spill and hence reduces thickness (Ornitz & Champ, 2002).

In the interviews, seven informants describe the different characteristics of oil having an ability to impede the activities comprising the sub-tasks. *Evaporation* rates and how the oil emulsifies is connected to its properties, which influence the opportunities for different strategies and technology (A, E, H, I) and new challenges are emerging with the development of new oil types. As the composition of compounds sometimes is kept confidential by producers, it is unknown how efficient existing technology will be (E, G, H, I). The *toxicity* of a particular oil may also impede response due to posing a danger to responders' safety (B, F). Furthermore, oil evaporating ignitable gasses will cause a need for explosion-proof vessels and equipment (B, F, G).

Characteristics of location
The characteristics of the location of the spill is a factor emphasised as affecting several activities in OSR. *Currents* influence the effectiveness of mechanical recovery (Li et al., 2016; Ventikos et al., 2004) and may sweep contained oil under booms if not perpendicular (Aguilera et al., 2016; EMSA, 2010). Furthermore, the presence of *ice* in the spill location challenges both containment of oil (Li et al., 2016) and mechanical recovery (Al-Majed et al., 2012; Aurand & Stevens, 2008).

The location of the spill itself is described by six informants as having the ability to pose a challenge if located far away from resources and infrastructure (A, E, G, H, I, J). This *distance* is, however, not constant for a specific location since resources such as response vessels typically patrol areas continuously (H, I). Finally, the presence of ice can significantly impede the reduction of oil in the environment by nearly ruling out the use of mechanical recovery equipment (G, H).

Characteristics of the source

In the interviews, several informants describe limiting factors for response connected to the source of the spill. First, its *reason for spilling* oil is affecting the tasks and their activities in general, which may be exemplified through the difference between an accident and an operational spill (H). *Fires* may prevent engagement in all activities (C, E, H, I) and may also cause additional spillage (E). The source of the spill being on fire, difficulties in reaching the spill may emerge (E), and efforts may be mainly directed toward extinguishing the fire or rescue operations (H). Whether the source is *leaking* continuously and at which rate is also a potentially limiting factor (A, G). Finally, the *general state* of the source is emphasised. For example, a sinking vessel will pose different challenges compared to a stable one (I).

Time

Time is emphasised by three informants. This regarding *how early a spill is detected* (F, I, J) determining how much the spill will have evolved from its original state when the response is initiated (I, J). The longer the time between the spill and initiated combat, the more weathered the oil will be (F, J).

5. Discussion

In the following, the findings of the study are presented and discussed in order to answer the research questions. The first section further analyses and discusses the essentiality in a capability description of the tasks, associated consequences and event parameters identified in the study. The second engages in a discussion on the exploration of methods and their implications and limitations. This in light of DSR on capability description in general, and OSR in particular. The third section discusses the practical application of the capability description based on the findings and the broader implications of the research.

5.1 Discussion of results

This section further analyses and discusses the results presented in chapter 4, to answer research question 1: *which tasks, consequences reflecting engagement in these tasks and event parameters are essential in describing OSR capability?* The discussion is structured according to the separate topics of inquiry and supports the aim of a contribution to practice.

5.1.1 Essential tasks

Tasks are a core concept in the understanding of capability by enabling the estimation and assessment of the ability to do something given the occurrence of an event (Lindbom et al., 2015). The results indicate that reducing environmental damage is an essential main task guiding OSR. Nevertheless, OSR can also be guided by considerations moving beyond environmental concerns by encompassing a broader focus. That said, comparing how informants describe main and sub-tasks as seen in Table 5, no clear pattern emerges in how the framing of the main tasks impact what is described to comprise it. Informants describing a similar main task do not necessarily describe a similar set of sub-tasks. Furthermore, protection of economic resources is accounted for in descriptions given by informants exclusively focusing on the reduction of environmental impact (see H & B).

Table 5. Overview informant descriptions of main task (beyond reducing environmental damage) and sub-tasks (grey filling indicates a described sub-task).

Informant	A	C	J	D	E	F	G	H	I	B
Aspects of main task / **Sub-tasks**	*Human life and health*		*Public expectation*	*Economic impact*	*N/A*	*N/A*	*N/A*	*N/A*	*N/A*	*N/A*
Reduce volume of oil	■	■	■	■	■	■	■	■	■	■
Prevent spread to shores	■	■	■	■	■	■	■	■	■	■
Gaining overview of spill	■				■	■	■		■	
Prevent further spillage					■	■	■		■	■
Prevent spread to sensitive environments	■	■					■	■		
Prevent spread to economic resources				■				■		■

Moreover, aspects included in the main task as described by some informants are accounted for in the sub-tasks by others. On the one hand, informants A and C described the protection of human life and health as an aspect of the main task guiding OSR. On the other hand, considerations regarding human safety were connected to the sub-task of gaining an overview of the spill by informant B and F. Similarly, the reduction of time for environmental recovery is described by Baker (2008) as an aspect of the main task but described by informant D as a consequence reflecting the effect of the main task of reducing environmental impact. This may perhaps suggest that similar considerations are made in OSR despite differences in how the main task is framed.

Overall, the results suggest the main task of reducing environmental impact, comprised of the sub-tasks of reducing the volume of oil and preventing it from reaching the shore to be essential in describing OSR capability. However, one may argue that the remaining identified sub-tasks should not be viewed as outliers, due to all being substantiated by literature and a minimum of three informants. On the one hand, which sub-tasks are essential for describing OSR capability apart from removing oil and preventing it from reaching shorelines may vary between, for example, countries. If so, returning to how the new risk perspective connects consequences with what is valued (Aven, 2011), variations with regards to values, i.e. which consequences OSR seeks to affect through various efforts, may serve as an explanation to the differences found in the described sub-tasks. On the other hand, all sub-tasks identified in the interviews being substantiated by international literature, vast differences in national values appear unlikely.

Additionally, the descriptions of the sub-tasks at times overlap. As illustrated in Figure 3, the prevention of spread to shores, sensitive environments and economic resources can be interrelated where a specific object or area belongs to all three categories as described by informant A, C, E, G and H. With this in mind, an informant not explicitly describing the protection of sensitive environments or economic resources may perhaps be accounting for these, to some extent, in the protection of shores.

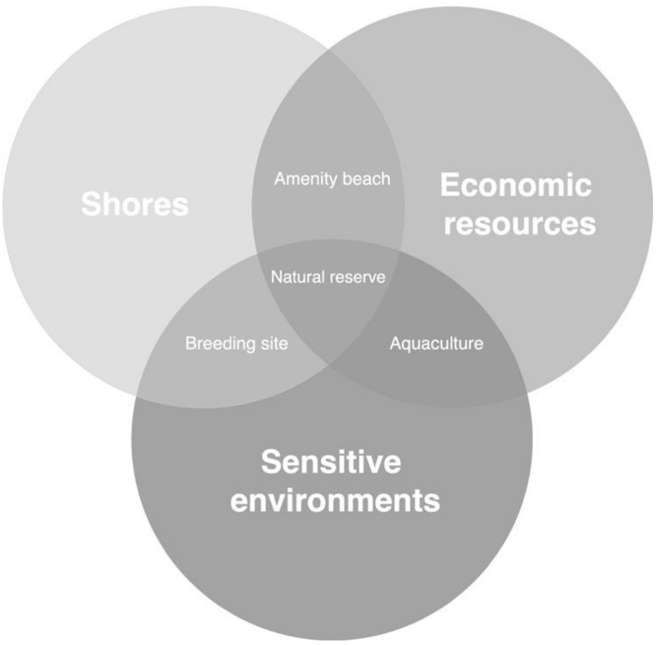

Figure 3. Overlapping sub-tasks with illustrative examples.

Importantly, it must be kept in mind that informants have not been given the opportunity to describe an exhaustive set of sub-tasks, nor evaluate the compiled findings. Hence, there is no evidence to conclude that a specific sub-task is considered irrelevant by any informant. This except preventing further spillage, which would be a task conducted outside of the organisation of informant C. Lindbom et al. (2015) describe a possibility to change the perspective of capability descriptions while still accounting for the relevant aspects of the system in interest. This facilitates taking this difference into account, where a capability description may treat the prevention of further spillage as an aspect of the event or the task depending on the specific agent.

5.1.2 Essential consequences reflecting engagement in the tasks

Lindbom et al. (2015) suggest reflecting the effect of conducting the tasks in associated consequences. Which consequences are essential to reflect the effect of efforts in OSR in capability description remains somewhat unclear, with data proven challenging to obtain and results being inconclusive. Additionally, the associated consequences that were identified are based on only a few sources of data, further discussed in section 5.2.

The results show that consequences reflecting the various aspects of the main task are described somewhat differently regarding the level of detail. Serving as an example, descriptions of associated consequences of reducing environmental damage spans from the more specific number of oiled birds to the more generic tons of oil remaining in the environment. Returning to how Aven (2011) describes consequences as expressing what is gained or lost with regards to what is valued, it can be argued that the identified consequences associated with the main task may vary in how well they account for the specific value, i.e. the environment. Serving as an example, the amount of oil remaining in the environment can be said to more holistically align with the environmental value compared to, for example, the number of oiled birds, and hence better reflect efforts to protect it. This based on an argument that a focus on birds only displays one isolated aspect of environmental consequences, neglecting others. However, as described by Tuler et al. (2007), the consequences of oil spills are multifaceted and best measured through several metrics. As a result, reflecting the effect of the task in more far-reaching consequences could prove too coarse. Questions emerge regarding which of the associated consequences best connects to a certain value, and whether focusing on one aspect of a consequence is sufficient. Furthermore, some consequences being considered challenging to estimate (G, I) raise questions on how rough estimates can be while still serving its purpose in capability description. That said, estimating response capability is not a matter of analysing potential consequences. On the contrary, the consequences are simply used to reflect effect of efforts in response. This may suggest that more generic measurements of consequences suffice in capability description.

Concerning the sub-tasks, no data on consequences associated with gaining an overview of the spill was obtained, which causes a need for further inquiry. For the remaining sub-tasks, associated consequences were identified, however with slightly varying descriptions of either the consequence itself or how it may be measured to reflect the effect of a specific sub-task. Lindbom et al. (2015) describe that to reflect the effects of the sub-tasks, consequences should be described in relation to what is achieved as opposed to what is not achieved. Furthermore, several measurements of consequences have the ability to, at the same time, express both capability and incapability by being described in a share or percentage, information likely to be useful in an assessment context. This suggests that certain aspects of consequences and their measurement may be considered more suitable in capability description than others. Based on this logic, the reduction of oil in the environment is best described in amount of oil removed in the percentage of oil spilt; the prevention of spread to shores in the share of oil posing a risk prevented from reaching it; prevention of spread to sensitive environments in the share of oil posing a risk prevented from reaching it and prevention of further spillage through eliminated spill risk in the percentage of total volume at risk of spilling. However, such reasoning sheds no further light on reflecting efforts to prevent spread to economic resources, for which all identified consequences relate to losses only.

5.1.3. Essential event parameters

Lindbom et al. (2015) describe how the initiating event impacts capability to manage it by influencing to which degree the consequences of the event are affected by response efforts. The results suggest that multiple factors have the ability to affect the effect of tasks in OSR. As discussed in section 5.1.1, it may be argued that essential tasks in capability description could differ based on, for example, national values. By contrast, event parameters may be considered widely generalisable. This based on logical reasoning that while, for example, weather conditions may affect effects differently depending on the specific technologies used, no technology will be completely unaffected by weather. Furthermore, the differences found between the literature and interview study regarding characteristics of the source and time may be explained by the interconnectedness of the parameters. Serving as an example, literature discussing weathering processes by default consider time. Based on this, the following discussion is based on the assumption that the findings regarding event parameters are widely generalisable.

Overall, the results indicate that to facilitate a realistic estimation of the effect of tasks, it is essential to carefully account for weather conditions, temperature, time and characteristics of the oil, the location and the source. The findings also suggest a highly complex interrelation between event parameters resulting in emergent properties of the oil which in themselves may have an impact on the effect of tasks. As a result, emergent properties of the oil appear to be equally essential to account for in estimating capability. Further considering such emergent properties, it is fair to assume that it might be challenging to manually interpret the severity of the event studying the individual parameter values alone. This regarding understanding the severity of the event both in capability estimation, assessment and perhaps also in the communication of the results. Returning to the example from Lindbom et al. (2015), while keeping in mind that it is only intended to be illustrative, it can be argued that the severity of two-meter flooding is more easily comprehended than the severity of for example a certain water temperature in combination with a particular oil type.

5.2 Discussion of methods

This section discusses the exploration and application of methods in the research to answer research question 2: *how should tasks, consequences reflecting these tasks and event parameters be identified in practice?* The discussion is fuelled by experiences made in the process of reaching the answer to research question 1 and supports the aim of a contribution to theory.

Engaging in the rigour cycle as described by Hevner et al. (2004), the methods to identify relevant knowledge to serve as input to the broader process of DSR yielded varying results. In the analysis of the literature, scientific papers, conference proceedings, reports and scientific textbooks were found to be useful in the identification of relevant knowledge. By contrast, exploring various types of literature as described in section 3.2, the usefulness of international guidelines and manuals, national contingency plans and case studies were found to be limited, both due to content and accessibility. That said, the above may be argued to only provide some insight into the structure of the particular knowledge base investigated. Nevertheless, it may also more generally point toward the method to derive relevant knowledge for DSR for capability description having to be adapted to the knowledge base itself, which may differ due to various reasons. Serving as an example, it is reasonable to assume that regarding events more frequent than oil spills, case studies will be more accessible. Similarly, focusing on response operations carried out based on a higher level of routine, as opposed to the bespoke nature of OSR, sub-tasks could be more easily identified in international guidelines and national contingency plans.

Overall, utilising the experience and expertise found in both literature and subject matter experts proved vital in the identification of tasks, associated consequences and event parameters. Utilising several segments of the knowledge base proved particularly important regarding the consequences associated with the tasks. Data on associated consequences were almost exclusively derived from the interview study. This data would have, at large, been lacking if only consulting literature. Nevertheless, as seen in section 5.1, some limitations of the applied methodology are essential to highlight. Two main aspects of the results will function as a basis for this discussion: first, inconclusive results regarding tasks and associated consequences and second, a shortage of data regarding consequences.

Regarding inconclusive results on certain sub-tasks, as described in section 5.1.1, their role as relevant knowledge in DSR cannot be fully discarded due to uncertainty whether these differences stem from differences found in practice. Nevertheless, it is relevant to engage in a discussion assuming so, were this to be the case. A methodological conflict may have emerged between the number of individuals with expert knowledge in the knowledge base and the choice of scope. Subject matter experts on OSR typically being few nationally, a national scope was considered not to yield a sufficient empirical basis for the study, and an international scope was applied. Were differences to stem from practice, the wide scope may have shown to be a disadvantage, facilitating inconclusive results.

This would perhaps suggest implications for engaging in DSR on capability description in practice. Doing so in fields with limited sources of experience and expertise requires research to be conducted on a particular agent (e.g., organisation or country) which capability is sought to be estimated and assessed. Having said that, this would have certain consequences. First, the generalisability of the output would decrease, only being valid for the particular agent. Furthermore, in DSR regarding the description of response capability to rare events, the design may be constructed on a knowledge base which does not contain experience from severe events in practice. Furthermore, the potential disadvantages of the international scope were accompanied by certain advantages. This since it may be considered to have widened the applicability of the relevant knowledge concluded to be essential in capability description. This by pointing toward the reduction of environmental damage, reduction of oil in the environment and the prevention of oil reaching shores alongside the identified event parameters being essential in describing OSR capability in a broader context.

Regarding the shortage of data and inconclusive results on consequences, this may be seen in relation to the knowledge base itself. First, consequences of oil spills and their measurement was described as not entirely clear in the field (E). Second, the results obtained were mainly based on the spontaneous thoughts of the informants as opposed to experience from practice. Third, some informants were hesitant to share such spontaneous thoughts. This suggests that the specific knowledge was not readily extractable from the knowledge base. Again, the rarity of oil spills (ITOPF, 2019) may have had an effect. An event never or rarely having required substantial response efforts, it is fair to assume there is limited experience with measuring the effects of such efforts.

5.3 Discussion of the application of the capability description in practice

The thesis engages in a first step toward applying the capability description in the field of OSR. Given the discussion of the findings in section 5.1, it is clear that the necessary components of a capability description, i.e. tasks, associated consequences and event parameters, can be identified in context of OSR, facilitating its application in practice. However, based on the discussion in section 5.2, certain aspects, such as the generalisability of sub-tasks and how to best reflect and measure their effect may be argued to require revisiting the rigour cycle, i.e. returning to the knowledge base, to determine their essentiality in capability description. Depending on what results such efforts would yield, conclusions could demand multiple iterations. For DSR on capability description in general, this suggests that relevant knowledge may not always be readily extractable from the knowledge base, where specific knowledge requires to be refined alongside, or perhaps before, the design process. That said, attempting to analyse future turn of events–such as estimating response capability–can never become an exact science. On the contrary, uncertainty is inevitable, and the question is rather what level of uncertainty is acceptable than how to eliminate it. It can be argued that in decision-making processes on investments in capability, estimations only require an accuracy that is sufficient for its particular purpose. It is reasonable to assume that decision-making on significant investments in capability requires broad indications on the effect the response system currently can generate. Processes to produce such estimates may not benefit from extensive efforts to reduce uncertainty in a way that compensates for the resources necessary to do so.

As emphasised in the new risk perspective and by Lindbom et al. (2015), uncertainty is inherent in descriptions of risk and capability, and essential is to make them explicit. It may be argued that a similar logic can apply regarding utilising the results of this research. The choice of consequences to reflect the effect of tasks serving as an example, no matter the choice, the estimate will inherently to some degree be uncertain. Likewise, which consequence objectively best reflects the effect of a particular task may regardless of further investigation be subject to uncertainty. Hence, it may be argued that there is a need to strike a balance between producing sufficiently accurate estimates and efforts to lower uncertainty. This to be able to move forward with the process of estimating capability in practice, as a means to contribute to the reduction of the losses connected to oil spills in the long-term.

Based on the arguments posed above, the way forward can be further engagement in the rigour cycle to reduce the highlighted uncertainties. However, as previously argued, lowering these uncertainties may demand significant resources which may not be in balance with the quality it adds to the estimate of capability. Hence, the relevant knowledge identified through the study may function directly as a basis in initial practical implementation. This by utilising the knowledge in the application environment by moving forward with evaluation in the design cycle for the knowledge to be refined, later to be field-tested through the relevance cycle. After such engagement with practice, the need for and value of returning to the rigour cycle may be more easily judged.

5.3.1 Broader implications

In practice, the common understanding of resources reflecting capability (Lindbom et al., 2015) has shown to come with drawbacks since it may provide a somewhat misleading sense of preparedness (see U.S. Department of Homeland Security, 2011). However, the research shows that a design to describe capability may require significant efforts in the development phase. How extensive efforts would be required is, through the experience of this research, found to partially depend on to what degree relevant knowledge is readily available in the particular field. As a result, focusing on resources might come forward as a less resource-demanding and potentially quicker way of estimating capability.

However, assuming that reflecting capability in resources could come with greater ease does not necessarily cause a reason to argue that resources shall retain their current position in reaching estimates of capability. By contrast, the capability description is to provide an output more useful in decision-making (Lindbom et al., 2018), facilitating the reduction of losses through increased capability where needed, not to serve as an analytically less demanding process. Additionally, by developing designs for capability description in a way facilitating its validity in a broader context could function as a contribution to the knowledge base. As a result, as opposed to requiring full design engagement, efforts to develop agent-specific capability descriptions could be lessened by being partially reduced to contextualisation.

6. Conclusion

The thesis aimed to contribute to practice by initial engagement in the design of a problem solution for capability assessment of OSR. Furthermore, a contribution to theory was sought through the experiences made in engaging the capability description with practice. Below, conclusions for the questions posed in the research are summarised alongside recommendations on how to utilise the findings of the research.

Which tasks, consequences reflecting engagement in these tasks and event parameters are essential in describing OSR capability? Consulting the experience and expertise in the field through an interview and a literature study, it is found that in estimating OSR capability, it is essential to describe the task of preventing environmental damage. This comprised by reducing the amount of oil in the environment and preventing remaining oil from reaching shores. However, an environmental focus does not prevent additional considerations being made. Additionally, a variation is found in how sub-tasks are described, which in one case is traced to differences in responsibilities. In the remaining cases, the cause of these variations cannot be concluded, but differences appear unlikely to stem from vastly differing societal values. Explanations are more likely to be found in for example overlapping descriptions of tasks. To make a realistic estimation of the effect of these sub-tasks, a range of parameters including emergent properties of the oil are found essential to account for in describing an event. Weather conditions, temperature, time and characteristics of the oil, the location and the source of the spill are categories of parameters all found to have the ability to affect the effectiveness of efforts made in response. Where the aforementioned conclusions can be drawn, which consequences best reflect these effects remain partially unclear. Nevertheless, certain consequences are argued to better serve the purpose of reflecting effects than others.

How should tasks, consequences reflecting these tasks and event parameters be identified in practice? The exploration of methods to utilise different segments of the knowledge base are found to have proven important in the pursuit of identifying the theoretical concepts in practice. In the research, where certain sources of information were proven useful in the analysis, others were not. Additionally, a wide scope proved to serve both as a potential drawback and an advantage. Based on the experiences made, a method to identify tasks, associated consequences and event parameters in practice is found to require adaptation to the particular knowledge base connected to the field of interest. This since characteristics of the response and event type sought to be described if found to likely have an influence on how the capability description is best approached in practice. This relating particularly to the frequency of the event type influencing the level of experience of both the event and response in practice, and whether the response type is driven by an extensive degree of routine.

Having engaged in a first step toward applying the capability description in practice, a piece of knowledge is produced to, in the long-term, contribute to facilitate the reduction of losses of adverse events. The insights gained from the exploration of methods can be utilized by informing future efforts to design capability descriptions for various types of response organisations.

For describing OSR capability, the way forward is twofold. The findings may feed into further engagement in the rigour cycle by returning to the knowledge base in the pursuit of lowering uncertainties. However, since the extent of such efforts will not necessarily be reflected in the quality of the estimates of capability, the findings are recommended to be utilised in segments of DSR engaging more closely with the application environment in practice, refining the knowledge through evaluation and field testing.

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Appendices

Appendix 1: Interview guide questions

Number	Question
I	Name
II	Current position
III	Experience in OSR field and main expertise
1	How would you describe the purpose or reason guiding operational response?
1.1	Could you describe what this means in more detail?
2	How do you know when this is met or fulfilled in operational response?
2.1	Are there any specific consequence(s) that particularly reflect the outcome of OSR, considering its purpose?
2.2	How do/would you measure the level of achievement?
3	Can you describe how the purpose is sought to be achieved in response, what is essential to do? For analytical reasons, please limit these to around three (a, b and c).
3.1	Can you elaborate on why these are considered essential?
3.2	Could you describe what a, b and c entail in more detail?
3.3	Do a, b and c have the ability to affect each other?
4	How do you know when a, b and c has been achieved?
4.1	Are there any specific outcomes or consequences that particularly reflect the level of achievement?
4.2	How do/would you measure the level of achievement?
5	What would you say are the main factors influencing the effectiveness of and engagement in a, b and c?

Appendix 2: Literature study documents

* Indicates starting set

Title	Author	Year	Type	Country
Marine Oil Spills-Preparedness and Countermeasures*	Chen B., Ye X., Zhang B., Jing L., Lee K	2019	Book chapter scientific textbook	Canada
Oil Pollution	Baker B	2001	Book chapter Scientific textbook	Netherlands
Oil Spills First Principles: Prevention and Best Response*	Ornitz, B E., Champ M A	2002	Scientific textbook	U.K
The Basics of Oil Spill Cleanup*	Fingas M	2013	Scientific textbook	Canada
Introduction to Spill Modeling	Fingas M	2017	Book chapter scientific textbook	Canada
Quantification of Oil Spill Risk	Etkin D S., French McCay D., Horn M., Landquist H., Hassellöv I., Wolford A	2017	Book chapter Scientific textbook	Canada
Oil Physical Properties: Measurement and Correlation	Hollebone B	2017	Book chapter Scientific textbook	Canada
Chemical Fingerprints of Crude Oils and Petroleum Products	Yang C., Brown C E., Hollebone B., YangZ., Lambert P., Fieldhouse B, Landriault M., Wang Z	2017	Book chapter Scientific textbook	Canada
Developing a conceptual framework to evaluate effectiveness of emergency response system for oil spill*	Wang H., Ren J., Wang J., Yang J	2014	Scientific paper	China
A Capabilities-Based Framework for Disaster Response Exercise Design and Evaluation: Findings from Oil Spill Response Exercises*	Greenberg B., Voevodsky P., Gralla E	2016	Scientific paper	U.S
A high-level synthesis of oil spill response equipment and countermeasures*	Ventikos N P., Vergetis E., Psaraftis, H N., Triantafyllou	2004	Scientific paper	Greece
Modelling performance variabilities in oil spill response to improve system resilience*	Aguilera M. V. C., da Fonseca B B., Ferris T. K., Vidal M. C. R., de Carvalho P. V. R	2016	Scientific paper	Brazil
Offshore oil spill response practices and emerging challenges	Li P., Cai Q., Lin B., Chen B., Zhang B	2016	Scientific paper	Canada
The technology windows-of-opportunity for marine oil spill response as related to oil weathering and operations	Nordvik A B	1995	Scientific paper	U.S
Implementing an Effective Response Management System	Walker A H., Ducey, D L., Lacey S J	1995	Conference proceeding	U.S
Myths and realities of oil spill planning and response: The challenges of a large spill.	Perry R	1995	Conference proceeding	U.S
A Review of Oil Spill Remote Sensing	Fingas M., Brown C E	2018	Scientific paper	Canada
Action Plan For Oil Pollution Preparedness and Response*	European Maritime Safety Agency	2010	Report	Lisbon
A sustainable approach to controlling oil spills	Al-Majed A., Adebayo A R., Hossain E	2012	Scientific paper	Saudi Arabia
Choosing Spill Response Options to Minimise Damage*	IPIECA	2000	Report	U.K
Criteria for Evaluating Oil Spill Planning and Response Operations*	Aurand D., Stevens L	2008	Report	U.S
Oil Spill Drift and Fate Model	Sayed M., Serrer M., Mansard E	2008	Book chapter Scientific textbook	Netherlands
In-situ burning for oil spills in arctic waters: State-of-the-art and future research needs	Potter S., Buist I	2008	Book chapter Scientific textbook	Netherlands
Oil Spill Response- Experience, Trends and Developments Following Major Incidents*	White I	2001	Report	U.K
The Threats from Oil Spill: Now, Then and in the Future*	Jernelöv A	2010	Scientific paper	Sweden
Oil Properties and Their Impact on Spill Response Options*	Federici C., Mintz J	2014	Report	U.S
Defining and selecting objectives and performance metrics for oil spill response assessment: A	Tuler S., Seager T P., Kay R., Webler T	2007	Report	U.S

process design integrating analysis and deliberation*				
Measuring Response: A Balanced Response Scorecard for Evaluating Success	Kuchun J., Hereth L L	1999	Conference proceeding	U.S

Appendix 3: Examples of documents available through purchase

Title	Author	Year	Type	Country
Emergency Facility Deployment model based on Degree of Satisfaction in Response time to Marine Oil Spill	Lu M., Wu G	2010	Scientific paper	China
Designing Capability for Offshore Response- A Consultant Perspective.	Barber L., Varghese G	2012	Conference proceeding	Australia
Oil spill contingency planning using geomatic system	Assilzadeh H., Mansor S B	2003	Conference proceeding	U.S
Marine oil spill contingency planning	Qiao B., Chu J., Zhao P., Yu A., Li Y	2002	Scientific paper	China
Recent Advances in Oil Spill Response Technologies.	Nedwed T	2013	Conference proceeding	U.S
Oil Spill Response Options in the Outer Continental Shelf.	Bruce H., Mitchell W	2016	Conference proceeding	U.S
The Evaluation of Oil Spill Contingency Plans and Oil Spill Response Readiness	Owens E., Taylor E	2007	Conference proceeding	U.S
Development of a Cost-Effective Oil Spill Response Program	Indrebø G., Singsaas I	2000	Conference proceeding	Norway
Alternative Oil Spill Response Technology: Results from the Deepwater Horizon Response	Cortez M., Rowe H G	2012	Conference proceedings	U.S
Risk Assessment and Planning for Offshore Oil Spill Response Preparedness	Cox R	2014	Conference proceedings	U.S
Introducing a Risk Based Dynamic Oil Spill Response Regime for the Norwegian Continental Shelf	Brekne T., Skeie G M	2002	Conference proceedings	Norway

Appendix 4: Overview sub-tasks literature study

Sub-task	Activity	Source
Prevent spread to shores	Contain	Fingas, 2013; Greenberg et al., 2016; Chen, Ye et al., 2019; Baker, 2008; Ventikos et al., 2004; Aguilera et al., 2016; IPIECA, 2000; Federici & Mintz, 2014
	Disperse	Fingas, 2013; Ventikos et al., 2004; Aguilera et al., 2016; Al-Majed et al., 2012; Federici & Mintz, 2014
Prevent spread to sensitive environments	Contain	Fingas, 2013; Greenberg et al., 2016; Baker, 2008; Ventikos et al., 2004; IPIECA, 2000;
	Disperse	Ventikos et al., 2004; IPIECA, 2000; Jernelöv, 2010
Prevent spread to economic resources	Contain	Greenberg et al., 2016; Chen, Ye et al., 2019; EMSA, 2010; IPIECA, 2000
	Disperse	Fingas, 2013; Ventikos et al., 2004; EMSA, 2010
Reduce volume of oil in environment	In-situ burning	Baker, 2008; EMSA, 2010; Nordvik, 1995; Federici & Mintz, 2014
	Mechanically recovery	Fingas, 2013; Baker, 2008; EMSA, 2010; Nordvik, 1995
	Application of sorbents	Chen, Ye et al., 2019; Federici & Mintz, 2014
	Bioremediation agents	Chen, Ye et al., 2019; Al-Majed et al., 2012
Gain overview of spill	Remote sensing	Li et al., 2016; Chen, Ye et al., 2019; Etkin et al., 2017; Wang et al., 2014; Fingas & Brown, 2018
	Modelling	Chen, Ye et al., 2019; Fingas, 2013; Fingas, 2017; Sayed, Serrer & Mansard, 2008
	Sampling	Chen, Ye et al., 2019; Wang et al., 2014; Yang et al., 2017
Prevent further spillage	Lightering	Etkin et al., 2017; Aguilera et al., 2016; Walker et al., 1995
	Salvage	Perry, 1999
	Stop outflow	Etkin et al., 2017

Appendix 5: Overview event parameters literature study

Category	Affected activity	Parameter	Source
Weather	Mechanical recovery	Spread	Baker, 2008; White, 2001; Perry, 1999; Al-Majed et al., 2012
		Emulsification	Ornitz & Champ, 2002; Fingas, 2013
		Wave height	Baker, 2008; Chen, Ye et al., 2019; Ventikos et al., 2004; White, 2001; Nordvik, 1995; Li et al., 2016; Federici & Mintz, 2014; Stevens & Aurand, 2008
	Containment	Wave height	Baker, 2008; Chen, Ye et al., 2019; Ventikos et al., 2004; White, 2001; Nordvik, 1995; EMSA, 2010; Al-Majed et al., 2012; Jernelöv, 2010, Stevens & Aurand, 2008
		Wind	Ventikos et al., 2004; White, 2001; Nordvik, 1995; EMSA, 2010; Al-Majed et al., 2012; Potter & Buist, 2008
		Spread	White, 2001; Perry, 1999; Al-Majed et al., 2012
	Dispersants	Emulsification	Baker, 2008; Chen, Ye et al., 2019; Federici & Mintz, 2014; IPIECA, 2000, Fingas, 2013
		Spread	White, 2001
	In-situ burning	Waves	Baker, 2008; White, 2001; Perry, 1999; Nordvik, 1995; EMSA 2010; Al-Majed et al., 2012
		Wind	Potter & Buist, 2008
		Emulsification	Potter & Buist, 2008
	Remote sensing and surveillance	Visibility parameters	Fingas & Brown, 2018; Ornitz & Champ, 2002
Temperature	Mechanical recovery	Oil viscosity	Baker, 2008; Chen, Ye et al., 2019; Ventikos et al., 2004; White, 2001; Li et al., 2016; Federici & Mintz, 2014; Hollebone, 2017
	Dispersants	Oil viscosity	Baker, 2008; EMSA, 2010; Federici & Mintz, 2014; Hollebone, 2017
		Water temperature	Chen, Ye et al., 2019; Al-Majed et al., 2012; Federici & Mintz, 2014
	Bioremediation	Water temperature	Al-Majed et al., 2012
	Sorbents	Oil viscosity	Al-Majed et al., 2012; Federici & Mintz, 2014

Characteristics of location	Mechanical recovery	Currents	Ventikos et al., 2004; White, 2001; Nordvik, 1995; Li et al., 2016
		Presence of ice	Li et al., 2016; Al-Majed et al., 2012; Federici & Mintz, 2014; Stevens & Aurand, 2008
	Containment	Currents	Chen, Ye et al., 2019; Ventikos et al., 2004; White, 2001; Nordvik, 1995; EMSA, 2010; Al-Majed et al., 2012; Aguilera et al., 2016; Baker, 2008
		Presence of ice	Li et al., 2016
Characteristics of oil	Mechanical recovery	Spread	Baker, 2008; White, 2001; Perry, 1999; Al-Majed et al., 2012
		Emulsification	Ornitz & Champ, 2002; Fingas, 2017
		Viscosity	Baker, 2008; Chen, Ye et al., 2019; Ventikos et al., 2004; White, 2001; Li et al., 2016; Federici & Mintz, 2014; Hollebone, 2017
		Slick thickness	A-Majed et al., 2012
	Dispersants	Viscosity	Baker, 2008; EMSA, 2010; Federici & Mintz, 2014; Hollebone, 2017
		Emulsification	Baker, 2008; Chen, Ye et al., 2019; Federici & Mintz, 2014
	In-situ burning	Thickness of slick	Chen, Ye et al., 2019; white, 2001; Li et al., 2016; Al-Majed et al., 2012; Federici & Mintz, 2014; Potter & Buist, 2008
		Emulsification	Potter & Buist, 2008
	Sorbents	Viscosity	Al-Majed et al., 2012; Federici & Mintz, 2014
	Remote sensing and surveillance	Oil visibility on surface	Fingas & Brown, 2018