ASSESSING EMERGENCY CAPACITY – EMERGENCIES IN ICELAND'S SEARCH AND RESCUE REGION

How is emergency and disaster management capacity evaluated and does the Icelandic response system have an acceptable capacity when it comes to emergencies in its search and rescue region?

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- Emergencies in Iceland's Search and Rescue Region

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Abstract
The capacity of an emergency response system is a deciding factor in its design and development, as well as its consequent success. Given this perspective, it is obvious that it is meaningless to do a risk analysis of a system without examining or knowing its capacity first. But how is capacity evaluated? A literature study was done to find existing methods and it revealed that capacity is a concept most people assign some meaning to but upon further inspection it is quite ill-defined and vaguely used in risk management texts. The project tried to illuminate the concept of capacity and from there bring forth an applicable emergency capacity assessment method. The main conclusion of the literature study was that there is a lack of available emergency capacity assessment methods. A method rooted in decision analysis did however prove to be both operative and enlightening. The decision analysis method was then applied to a case study and its main conclusion was that according to the design criteria chosen for said method, the emergency response system in Iceland cannot be considered to have suitable capacity. Improvement suggestions were made.

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Executive Summary

A system's capacity is a deciding factor in its design and development, as well as its consequent success. Capacity assessment is therefore an important research area within risk management engineering. This generated the research question:
How is emergency and disaster management capacity evaluated and does the Icelandic response system have an acceptable capacity when it comes to emergencies in its search and rescue region?
The goal of this project was to analyze how capacity is evaluated and apply such a method to a case study dealing with actual circumstances. The first thing to do was therefore to find and highlight existing emergency capacity assessment methods. This was done through a literature study, which revealed that published texts on the subject were scarce. The methods uncovered were then examined, which lead to the conclusion that capacity is an ill-defined concept. It is used in some texts to represent a certain idea and in other text to describe something entirely different. A deeper inspection of the concept of capacity was thus in order. Realizing that capacity is a conditioned concept, a definition was adopted called the emergency response capacity triplet. It is essentially the answer to the following questions:
*What can happen when an actor is performing a specific task given a specific context?
*How likely is it?
*What are the consequences for the performance measures defined for that particular task?
With this in mind the methods found in the literature study were abandoned and decision analysis approach was assumed. That approach is based on the fact that emergency response systems fall under the realm of design science and the quality of the system was therefore judged based on how well it fulfilled certain design criteria. For the case study it was decided to have two criteria: time and suitable equipment. The goal of the case study was twofold; to display the applicability of the chosen approach and therefore assess its value and to bring useful information out in order to contribute to its improvement. The specific setting of the case study was to analyze the emergency response capacity of the Icelandic response system when it comes to emergencies in the country's search and rescue region at sea. The search and rescue region the system is responsible for covers over 1.8 million square kilometers. A lot of expensive equipment, preparedness and knowledge is required to uphold acceptable safety levels in such an extensive marine area and considering that the natural conditions in large parts of it are some of the most extreme in the world it becomes apparent that it is no simple task. To add to the pressure, recent climate changes have over the past few years opened up new sailing routes around the country, so traffic is steadily increasing.
The main conclusion of the project is that the chosen emergency capacity assessment method is indeed very enlightening, giving a simple framework to analyze complicated systems. With this method it was shown that it can not be said that the Icelandic response system has suitable capacity when it comes to saving lives and protecting nature in the search and rescue region. Considerable improvement, possibly raising the capacity up to a suitable level, can however be reached without demanding extreme costs or making dramatic changes of the system. Suggestions were made to support that claim.

CONTENTS:

1. INTRODUCTION

Risk management is a burgeoning field of study. Its active dialogue frequently breeds new theories and the rapid development has lead to great progress in the general awareness and appliance of systematic risk management work in society. This advancement does not mean that risk managers can, or strive to, eliminate risks and hazards but they do work towards providing a systematic framework based on scientific principles to understand and manage various kinds of risks. (Kolluru 1996) Risk management is also about being alert to possible threats, disruptions and consequences as well as controlling sources of exposure.

Engineers' involvement in risk management, whether it be in design or operational matters is well-established and very contributory. (Benson 1977) Organized risk management work is crucial when dealing with difficult decisions, because common sense is often riddled with emotional impulses, prejudice and personal views. Risk management engineering is about finding and using data to get an objective standpoint for problem solving and decision-making. Thus reaching well-substantiated judgments as well as eliminating misleading messages. The scientific engineering part of risk management is of course only one part of a larger puzzle, with other important aspects lying for example within politics and economics. (Kolluru 1996) The engineering part does however indeed provide the groundwork for all other interested parties and it is the part of risk management that is the subject of this project.

There are many research areas within risk management engineering, such as risk analysis, risk assessment and cost benefit analysis to name a few. One that is very important, but under represented in literature is the area of capacity assessment. To give a crude example; risk management activities would be very different with regards to a person on a rowboat depending on whether said person has a lifejacket on or not. The lifejacket increases the system's capacity to successfully save the person from harm by giving responders more time. Responders can therefore design their response system with regards to that timeframe. The capacity of the system is thus a deciding factor in its design and development, as well as its consequent success. Given this perspective, it is obvious that it is meaningless to do a risk analysis of a system without examining or knowing its capacity first.

The tricky part is to grasp the system's capacity. Capacity is an ill-defined concept even though most people are quick to assign a certain meaning to it. It is used in some texts to represent a certain idea and in other text it's used to describe something entirely different. So what constitutes a capacity? Is it: increased awareness, a certain amount of equipment or streamlined regulations? Is it all of the above or maybe none? That is of course to some degree dependent on the system at hand but there must be some distinguishing features that are common in every case and until they are highlighted, capacity will go on being an ambiguous concept, kept in a dark corner, briefly mentioned in literature where suitable to the author or even completely discarded.

I tried to shed some light on the concept of capacity in this study. My point of departure was emergency capacity assessment. I chose the emergency and civil protection viewpoint because of its large scale and broad appeal. The case study was set in Iceland, where organized risk management work is relatively new and very few large scale capacity assessments have been made. Iceland's current situation, with the extremely poor state of the nation's treasury, does not bode well for future risk management activities. It is therefore extremely important to analyze its response system capacities and realize which parts are strong and which are not, in order to fight cutbacks in sensitive areas. Informed arguments should be made to protect the system and uphold acceptable security levels. A single master's thesis can of course not cope with the whole system. This project is only an attempt to tackle a small but critical part of it, namely response capacity for emergencies in the sea around Iceland. The focus point of the case study was chosen in consultation with high ranking experts within civil protection in Iceland as an area that's a source of great concern. Iceland has an economic zone reaching 200 nautical miles (nm) out to sea from its shores. This is a vast area, which the country fought for ruthlessly, and an area where the Icelandic fleet has sole authority to fish. The search and rescue region that the Icelandic coast guard is responsible for is about twice as large in surface area as the economic zone and covers over 1.8 million square kilometers. The greatness of the area becomes even more apparent when it's put in context with the size of the nation, which only counts about 300 thousand inhabitants.

A lot of expensive equipment, preparedness and knowledge is required to uphold acceptable safety levels in such an extensive marine area and considering that the natural conditions in large parts of it are some of the most extreme in the world it becomes apparent that it is no simple task, no matter what the size of the nation is. To add to the pressure, recent climate changes have over the past few years opened up new sailing routes around the country, so traffic is steadily increasing. All this makes up for an interesting yet demanding project as will hopefully be demonstrated in the following text.

1.1 Background

Emergencies are unexpected events or situations that pose risk to life, nature or structures and require immediate action. They vary greatly in scale but the probability and consequence of a certain emergency are usually inversely proportional, meaning that minor emergencies are common but major emergencies are rare. It's necessary, in order for society to function, that there are actors preparing and responding to all scales of emergencies. Government actors are usually responsible for planning and preparation for larger scale emergencies, which includes analyzing and evaluating risks the system is faced with. That also means that before undertaking a risk filled endeavor the capacity to respond to threats and possible disasters generated by that affair must be evaluated. The kind of capacity of interest here is emergency and disaster management capacity.

Disaster management involves planning and preparing for response, coordinating assistance, developing policies on reconstruction and maybe most importantly confronting vulnerabilities before any harmful events have taken place. The development of a national disaster response system is a broad field, stretching from policy formation in central government to community responsibilities, all the way down to individual preparedness. A large variety of conflicting stakeholders must plan together, trying to match competing goals and highly variable needs must be reconciled. (Burnham 2006) When building capacity, the crisis management authority must tap into its own strengths and at the same time maintain a critical perspective to spot weaknesses and use this knowledge to enhance its power to deal with critical events. Systems must uphold performance in face of emergency and counteract disturbances in such a way so that they will not develop into serious consequences. Put more simply, when a disturbance happens, the regulator responds to it and therefore reduces the consequences, whereas if there were no regulator, the consequences would only be determined by the disturbance. (Casti 1996) (H. Tehler correspondence) So rather than planning a response to failures of current infrastructure or systems with the consequent overwhelmed systems and feelings of powerlessness, successfully designed system with adequate capacity makes the consequences of an extreme event less severe from the outset and reduces the time required to get back to normalcy. (Kapucu 2007) Suitable capacity levels are therefore critical for successful responses to disasters and without the appropriate capacity, contingency plans either provide a false sense of security or more simply are impossible to make because of the lack of resources. That in turn poses the danger of rendering risk and crisis management work useless.

1.2 Inspiration for the Project

Evaluating capacity is not a simple task and the lack of common procedures when it comes to emergency capacity assessment is what sparked interest to undertake this project. Capacity assessment is defined as "a structured and analytical process whereby the various dimensions of capacity are measured and evaluated within the broader environmental or systems context […]." (Hu 2005) In order to do this, the general existing response and preparedness status must be known and for a focused discussion, the scope must be limited to certain set of risk scenarios. Theoretically, constructing a formal model to describe the dynamic relationship of demand and capacity in disaster operations is quite complicated. Different environments generate various types of demands that lead to the formation of particular types of response patterns based on different levels of capacity in the system. (Comfort 2004) On top of that, high performance in catastrophic disasters requires an ability to assess and adapt capacity rapidly and restore disrupted communications as well as flexible decision-making. These requirements are imposed on conventional bureaucratic systems that rely on relatively rigid plans, exact decision protocols and formal relationships that assume uninterrupted communications. (Kapucu 2007) Money is also a large limiting factor and all activities must be deemed cost effective in order to get clearance. Bearing all this in mind, the motivation for this project is to systematically collect existing theories on response capacity assessment, analyze prevailing methods and recognize knowledge breaches. From there construct an applicable approach and apply the findings to a case study.

1.3 Research Question

The project is divided into two parts. The first part consists of a literature study of available emergency capacity assessment methods and a discussion of their substance and adequacy. From that discussion, the best considered approach is either to be derived from existing models or constructed using other means. The second part then consists of a case study, where an existing system is presented and analyzed according to the chosen approach. The goal of the case study is twofold; to display the applicability of the chosen approach and therefore assess its value and to bring useful information out in order to contribute to the response system's improvement. These factors are what initiated the study and the research question was chosen to be the following:

How is emergency and disaster management capacity evaluated and does the Icelandic response system have an acceptable capacity when it comes to emergencies in its search and rescue region?

1.4 Method

The method used in this project in the quest to answer the research question was the following. When researching man made subjects, like capacity assessment methods, it is fundamental to get to know what has been written and what progress has been made at this point. The first step was therefore to conduct a literature study in online databases. Certain key words were chosen as search strings and the articles generated were reviewed for relevancy. (See chapter 2.1) The emergency capacity assessment methods uncovered in this search were then analyzed and their applicability discussed. (See chapter 2.2) Even though the search did yield some advanced assessment methods, none of those methods were considered suitable for the purpose of this project and adjustments were not regarded as a viable option. The shortcomings of the methods were discussed and their abandonment reasoned. (See chapter 2.3) In order to find the origin of this knowledge breach, i.e. the lack of an appropriate emergency capacity assessment method, a deeper analysis of the concept of capacity was carried out. (See chapter 2.4 and 2.5) Building on that foundation a different approach to capacity assessment was chosen, one that was not included in any of the texts found in the literature study. The course taken was to discard the methods found in the literature study which were either too rigid (index methods) or not suitable for operational purposes (the three non-index methods) and rather view the problem from a design science point of view and apply decision analysis. (See chapter 2.6) This scenario-based method gives much better foundation for decision-making and presents clearer options for improvement than the methods found in the literature study. The next step was then to apply those findings to a case study.

A system was chosen for assessment and from there on, the step-by-step process was to first of all get as much information on said system as was possible. Interviews were conducted with the main actors within the system to get an idea of the system's current capacity and its general functioning. The definition of emergency capacity established in chapter two was used as a basis for the inquiry so that the goal of the consultation was known to the interviews subjects from the get go. More questions were then asked in order for the researcher to form a holistic view on each organizations role and purpose. Finally there was a general discussion on day-to-day activity and individual emergency response experiences. The interview process is described in more detail in Appendix C.

When enough information on the system was acquired to be able make informed decisions, a decision analysis framework was set up. (See chapter 2.6) That was done by first establishing design criteria and concluding that all design alternatives that fulfilled said criteria would be considered suitable options. It was decided to settle for two design criteria factors, which were chosen for their relatively good measurability: *appropriate equipment* and *time.* All design alternatives the system had to offer, where appropriate equipment was provided with minimal time to the presented scenarios were reviewed and compared and scenarios that had suitable design alternatives available were highlighted as well as those that did not. In the instances where no suitable design alternatives were to be found, suggestions for improvement were made with their cost effectiveness in mind. (See Case Study, chapter three)

1.5 Objectives

The first objective of this project was to find and highlight existing emergency capacity assessment methods. No such method is currently being universally applied in the field of risk management or generally accepted as a holistic approach. Moreover,

the fact that capacity assessment methods are hardly mentioned in the curriculum of the degree finishing with this project was an indicator of the lack of text on the subject. It is maintained here that this is not the result of the insignificance of the matter but rather to be explained by how relatively young the field of systematic risk and disaster management is, how dramatically it has evolved in that time and how evasive the concept of capacity assessment is. Contributing further to the scarce amount of literature was the shortage of a definite wording or structure of words to describe the search criteria. On one hand, multiple word combinations were used to describe the process of what could be considered to be capacity assessment, and on the other, there were instances of the same names being assigned to processes that could not be considered to have the same goal. As a result, some search strings had to be chosen as the most likely to give results as is discussed below in the literature study.
These findings lead to the second objective that is, to examine the existing methods. The results of the examination are found in detail in chapter two, but quality of found methods was not as high as had been expected. This led the focus back to the evasiveness of the concept of capacity, which brought about the third goal; to bring more clarity to the idea of capacity in general. The concept of capacity was therefore inspected in more detail, which brought about the fourth goal of getting a clear and straightforward approach to capacity assessments. The final goal was then to apply this constructed approach to a case study with the hopes of extracting from it both an establishment of suitable practice as well as highlighting sensitive areas.

1.6 Concepts

Since the syntax of emergency capacity assessment literature is not very homogenous, there are a few vocabulary remarks to be made. In this project the words “capacity” and “capability” will be used interchangeably, as if identical. Similarly, when search strings in the literature study were chosen the combinations of “capacity assessment” and “capacity evaluation” were taken to be identical as each resulted in the findings of emergency capacity assessment methods. These search strings were then combined with the inquiry “disaster management” as “risk management” yielded too broad results and “emergency management” did not yield appropriate texts for the subject.
Another concept that must be clarified is “risk”. The concepts of risk and emergency response capacity are entwined, as the need for capacity is directly related to the level of risk posed to a system. Risk is however a subject that has received considerably more dialogue, so it’s beneficial for all discussion on capacity to have risk as the point of departure. According to Fischhoff et. al. (referenced in Jönsson 2007) there is no general consensus on the definition of risk but the designated definition of this discussion is a quantitative operational definition, called the risk triplet. (Kaplan 1981)
When using the risk triplet to determine risk in a system, scenarios[1] that deviate from the status quo or in other words “success” scenario, S_0, must be identified. Those scenarios are called risk scenarios, S_i. Probability, L_i, and consequence, X_i, for each risk scenario is then estimated completing the set of three, which constitute the risk in the system. The risk triplet therefore answers three questions: “What can go wrong?”, “How likely is it?” and “What are the consequences?”
This definition brings the concept of risk out of the subjective realm of qualitative definitions and allows for it to be presented with clear scenarios and numerical values. Realizing that the system is not reality but merely a representation of it, one can assign

[1] A scenario is the advancement of a system over time. (Jönsson 2007)

as much detail as is considered necessary to it and from there reach easily justifiable results. The risk triplet is used later in this project to support the definition of capacity. Finally, it is important for all risk management work to realize what kinds of threats[2] the system is supposed to deal with. Threats have sometimes been divided into three categories; natural forces, technological errors and intentionally generated attacks. The last two categories could be grouped together as man-made threats but this is of course a simplification of reality and disasters have been generated by threats that could not be categorized so easily but are found somewhere in the grey area on the borders of the categories. The categorization can make the identification of risk scenarios easier but it should only be viewed as a tool to increase clarity because even though there are some distinctions between the features of disasters produced by each category, the consequences are generally similar for both individuals and societies regardless of the source of the disruption. Risk management planning is therefore more directed towards preparing and mitigating certain levels of disruption than specific risks. This approach is followed in the case study.

1.7 Restrictions

The subject of emergency capacity assessment is broad and has many aspects worth exploring. A project of this size can however only tackle a limited part of that scope for it to have any focused results and given the time and resources assigned to it, it is necessary to make some clear restrictions. Restrictions in the literature study were mainly twofold. First of all, there had to be a limitation of search strings. After careful consideration and experimentation with different word combinations, the strings expected to give the best results were chosen. It's highly likely that some capacity assessment method literature available in the databases was not covered by these search strings and therefore was not detected in the literature study. Second of all, after reviewing the results of the search inquiries, all articles that claimed to include some kind of a capacity assessment method, were deemed relevant. In that case, methods were not sorted or separated based on whether they were supposed to assess a whole system's capacity or directed towards specific hazards. Interest in the assessment models was methodological, so their situational end product was for the most part beside the point. The discussion of the models was similarly focused on their design process, so individual models were only briefly introduced, before being grouped and analyzed further as a part of an ensemble with certain features. Their main aspects were that way highlighted and discussed.

Restrictions were also made in the case study since there was only room for a limited amount of scenarios to apply the chosen assessment method to. Selection of scenarios was done by contacting high-ranking actors in the Icelandic civil protection system and requesting their judgment on the area most in need of capacity assessment and improvement suggestions. Further limitations in the case study were regarding the design criteria in the assessment method. Arguments for how and why the chosen aspects were decided on are given in the case study, chapter three.

[2] In the following discussion the words "hazard" and "threat" are considered to be synonyms.

2. LITERATURE STUDY – EXISTING MODELS FOR CAPACITY ASSESSMENT

In this chapter a comprehensive search was made in seven databases for emergency capacity assessment models.

Databases	1. Capacity[1]	2 "Disaster Management"	3 Capacity Assessment[2]	1+2	Search field
Engineering Village[3]	53929	1500	**7**	**10**	controlled
Emerald[4]	589	649	**1**	**1**	keywords
Web of Science[5]	>100,000	969	**848**	**6**	topic
JSTOR	16161	10	**4**	**1**	abstract
CivilEngineeringDataBase/ASCE[6]	4071	68	**484**	**6**	all text fields
CSA technology[7]	95873	83	**16**	**2**	keyword
OVID[8]	18862	58	**125**	**13**	keyword

[1]Capacity: search string is "capacity" OR "capability"
[2]Capacity Assessment: search string is "capacity assessment" OR "capacity evaluation" OR "capability assessment" OR "capability evaluation".

Table 1. Results of database search

2.1 Search In Databases

The approach chosen to find existing models for emergency capacity assessment was to conduct a literature study in extensive online databases. Seven databases were chosen and four different searches were carried out in each one. The choice of each search string posed a bit of a dilemma since the subject of emergency capacity assessment modeling does not seem to have a fixed phrasing syntax as of yet. Articles on capacity assessment models can be found under a variety of keywords but after some experimenting with different word combinations, the strings chosen are represented in the first line of Table 1. Various research genres have relevance to the field of emergency capacity but the technical domination of an assessment model made the database choice simpler. Search results continuously yielded publications on the subject of capacity building, a matter closely related to this subject, but since the goal was to review models on capacity assessment the selection was limited. The number of

[3]http://www.engineeringvillage2.org.ludwig.lub.lu.se/controller/servlet/Controller?EISESSION=1_94257f12379d023977cfcses3&CID=quickSearch&database=2105347
[4]http://www.emeraldinsight.com.ludwig.lub.lu.se/Insight/menuNavigation.do;jsessionid=31A8220E9F78D6D69976A618706FCF7A?hdAction=InsightHome
[5]http://apps.isiknowledge.com.ludwig.lub.lu.se/WOS_GeneralSearch_input.do?product=WOS&search_mode=GeneralSearch&SID=Z1IGDFl6Ah9EBhm1iFc&preferencesSaved=
[6] http://cedb.asce.org/
[7]http://csaweb108v.csa.com.ludwig.lub.lu.se/ids70/select_databases.php?SID=j2r3bd6huotn6i935qln7crmn1
[8]http://ovidsp.ovid.com.ludwig.lub.lu.se/ovidweb.cgi?T=JS&MODE=ovid&NEWS=n&PAGE=main&D=icon

hits in each database is presented in Table 1 and all hits in bold font were reviewed for relevancy.

2.1.1 Engineering Village 2 (Compendex and Inspec)

A search in Engineering Village 2 for the search term capacity assessment yielded seven hits and based on their abstracts, two articles were considered relevant to the subject. The ten hits for the combination of disaster management and capacity resulted in three significant papers.

2.1.2 Emerald

After going through the abstract of the only hit containing the search terms regarding capacity assessment, the article was deemed irrelevant to the topic. The same applied to the single hit containing the capacity and disaster management search terms.

2.1.3 Web of Science

Capacity assessment produced 848 hits and after going through all of the abstracts, nine articles were considered appropriate. Out of the six hits containing the search terms regarding capacity and disaster management, none was considered relevant.

2.1.4 JSTOR

JSTOR produced only four hits on capacity assessment and one for capacity and disaster management. After reading the abstracts, none of those was considered suitable.

2.1.5 Civil Engineering Database

Representing the scarce selection of fitting articles, the search for capacity assessment gave 484 hits with only one article of use. The search for capacity and disaster management produced much fewer hits, total of six, and one of those was applicable.

2.1.6 Cambridge Scientific Abstracts

When searching in Cambridge Scientific Abstracts (CSA) only the Technology search field was chosen. That decision was based on the previous mentioned technical nature of an assessment method. Sixteen articles were reviewed regarding capacity assessment but none was fitting. Out of the two articles containing the search terms capacity and disaster management there was also no relevant article.

2.1.7 OVID

A search in OVID for capacity assessment supplied 125 hits, but none of them was useful. When the search term was changed to capacity and disaster management only thirteen hits were produced but two of them were viewed as applicable.

2.1.8 Results

After going through more than 1500 abstracts, a meager number of eighteen articles were appropriate for the subject. To further decrease that number, six of the nine articles from Web of Science only had the abstracts available in English while the published language of the full texts is Chinese. Two of the hits from Engineering Village 2 had the same limitation. The number was therefore reduced to ten articles. Not being satisfied with that, a decision was made to broaden the field. The search was expanded to less structured databases, with a search at Elin “snabbsök” feature. The search string “Emergency response capacity” yielded three hits with two useful articles and “Emergency response capability” yielded 29 hits with three more suitable texts accounting for duplicates. Furthermore the resource citations in the acquired articles were reviewed and that way, a couple of more interesting papers were found. When looking at all the data collected this way, there certainly are some existing methods for emergency capacity assessment. Following is a discussion of the most comprehensive ones.

2.2 Short Description of Assessment Methods

In this chapter the methods found in the literature study will be reviewed.

2.2.1 Capacities and Vulnerabilities Analysis, (C&V Analysis)

The first capacity assessment approach reviewed here is Capacities and Vulnerability Analysis. C&V Analysis was established by the International Relief/Development Project of Harvard's Graduate School of Education in 1990 where lessons of past experiences in emergencies were used to develop guidelines for agencies involved in providing emergency assistance. (Anderson 1990) The method is quite simple and straightforward and possibly speaking of its time and the amount of progress that has been made, the sheer idea of considering capacity is viewed as somewhat revolutionary in the text. The basic claim is that in order for a development and response initiative to be sustainable it has to build on existing capabilities and eliminate ingrained vulnerabilities. Throughout the years it has been used by NGOs[9] such as the Red Cross when dealing with disaster response and preparedness. (Morgan 1997)
Table 2 along with the ideas it presents is called the Framework for Analyzing Capacities and Vulnerabilities.

	Vulnerabilities	**Capacities**
Physical/material: What productive resources, skills and hazards exist?		
Social/Organizational: What are the relations and organization among people?		
Motivational/Attitudinal: How does the community view its ability to create change?		

Table 2. Capacities & Vulnerabilities Analysis Matrix (Anderson 1990)

While filling in the matrix, one should strive to only keep to the facts and leave all opinions and judgment or evaluative comments out of it. (Anderson 1990) That way C&V analysis can help to determine the features and degree of risks facing a community, what it’s effects will be and how prepared the community is to deal with it and what it needs to strengthen. (Morgan 1997)

[9] Non-Governmental Organizations

The C&V analysis framework can be used to evaluate instantaneous situations but it can also be used to dynamically show changes over time. In that instance it should be filled in at different times during crisis or development. For example it can represent the situation before an event, immediately after it, while response is under way and when relief work is done. Furthermore, the framework can and should be in the appropriate instances be used to do C&V analysis all the way from the local level, through the regional level and up to national or international levels. Each level has different capacities and vulnerabilities in a complicated interaction so a level based analysis could prove valuable insight. (Anderson 1990)
There are a few downsides to the C&V analysis. The approach requires expertise and experience and a good knowledge of the system at hand. Some factors are also very hard to judge and it can sometimes even be hard to determine whether a factor is a capacity or vulnerability or if it is either. In addition to that, the simple format of the framework means that it doesn't lead the expert into great detail so the work has to be done creatively and thoroughly. (Morgan 1997)

2.2.2 Local Institutional Capacity Evaluation

The next approach reviewed here is called Local Institutional Capacity Evaluation and was developed by The Canadian Rural Revitalization Foundation in 2004. Institutions play a crucial role in all contingency planning and this approach emerged as most of the existing literature at the time in institutional capacity was from the perspective of developing nations. (Briscoe 2004) When speaking of institutional capacity, what is being referred to is the capability of an institution or a network of institutions to perform key functions effectively and efficiently as well as having the ability to carry out mandate operations and produce results by utilizing the necessary resources within the appropriate structural context. (Briscoe 2004)
The conceptual definition given is: "Local institutional capacity is understood as a community-level measure, where institutional capacity is the competence of institutions to access and manage resources, to carry out key functions, and to initiate structural reform when necessary in order to maximize the first two capacities and ensure institutional sustainability." (Briscoe 2004)
This method looks towards the adaptability of institutions as well as their potential to work harmoniously in a given situation. It's grounded on indicators that allow for diagnostic and comparative analysis and it's divided into three levels:

1)The capacity to access and manage resources
2)The capacity to carry out key functions
3)The capacity to initiate structural changes and ensure sustainability

The method is quite thorough and it combines qualitative and quantitative measures. It however relies on data that can be difficult to acquire.
Index tables can be seen in Appendix A, A.1.

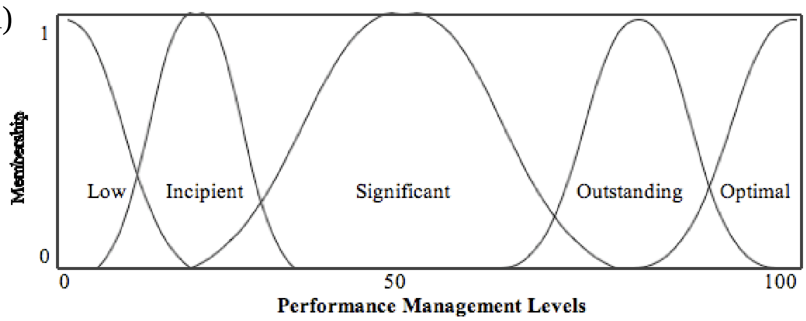
2.2.3 Resilient Capacity Assessment Method

The third method reviewed is called Resilient Capacity Assessment Method and it was designed to evaluate capacity in geological failure areas. It's however quite broad and suitable for generalization because it targets both communities and resident (workers) for the capacity assessment. So its results could be enlightening. The method adopts a framework from 2005 by Y.T. Wang where the resilient capacity of communities is divided into a five level hierarchy. (Chen 2009). The weight of each indicator in the

hierarchy was then decided by sending questionnaires to experts and 38 were returned. Here, these numbers will be considered fixed. From those numbers the total weight of each indicator was determined. The next step, and the first step when applying the method, is to send out a checklist to community leaders where they are asked to assign values on the scale of 0-60 to all of the sixteen end indicators referring to the CRD: community resources for disaster resilience. Simultaneously, a questionnaire is given to residents with regards to the DRC: disaster resilience capacity of residents that has ten end indicators on the subject. The scores given in each of the questionnaires are then calculated with the indicator weight and from there a single number derived which represents either a poor or a good resilient capacity.
Table representing the method can be seen in Appendix A, A.2.

2.2.4 Disaster Risk Management Performance Index

The authors of the next approach claim that their evaluation method, which they call the Risk Management Index, RMI, is the first systematic and consistent international index developed to measure risk management performance. (Carreño 2007) They rightly point out that measuring risk management capacity is a great challenge from all aspects of the academic spectrum, from the conceptual to the scientific because it requires using data with incommensurable units and linguistic estimates. The authors claim that the method should be applicable at different points in time to compare past and current situation and assess the development over time periods. The index they designed provides a quantitative criterion based on qualitative goals that risk management efforts strive to achieve. This way the distance between current conditions and the goal can be known.
The RMI quantifies four public policies, each being made up of six indicators. The first one is a measure of individual and social risk awareness and perception called The Risk Identification Index. The next one is called Risk Reduction Index and involves prevention and mitigation measures, the third one is the Disaster Management Index representing response and recovery and the fourth one, Financial Protection Index refers to adequate governance and financial protection which are fundamental for sustainability. The RMI is the average of the four composite indicators.
The estimation of each indicator is based on five performance levels, with low corresponding to the numerical value 1, incipient has value 2, significant has value 3, outstanding has value 4 and optimal has value 5. (See Figure 1) Experts in the area where the RMI method is being applied determine these values and the weight of each indicator is then found with the Analytic Hierarchy Process, AHP, technique. AHP calculates the relative weights of the indicators using an eigenvector technique.

a)


b)

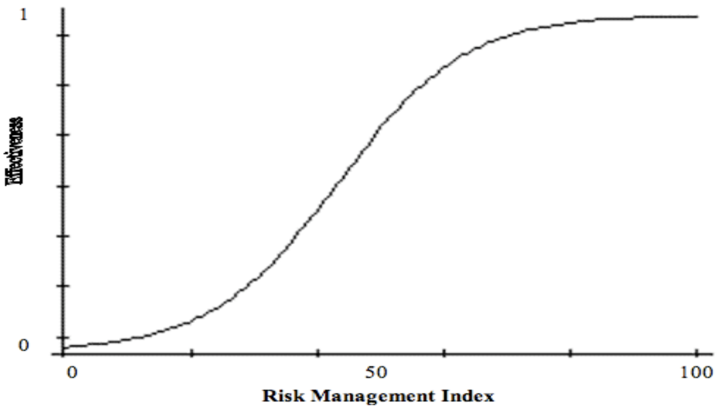


Figure 1. Disaster Risk Management Performance Index

As can be seen in b), the effectiveness of risk management is not linear. Increasing risk management is a complicated procedure with slow improvement for the first degrees of effort but once becoming more advanced the effects increase more rapidly. Perfection is never acquired so the upper levels see again a decrease in the speed of improvement.

Looking back at the mathematics of the method, when both the estimation and the weight are known, the bell curves of each indicator of each public policy are subject to union and defuzzification and from there value of each composite indicator is found. The final value is then obtained by calculating the average as was previously mentioned.

Table representing the method can be seen in Appendix A, A.3.

2.2.5 Public Health Emergency Response Capacity

The next approach discussed does not claim to be an operable model, but only a preliminary framework. Like with many other capacity assessment methods it has focus on a certain field, in this case public health, but its proposal is considered to be adequately thorough to be presented here. The authors define capacity assessment as "a structured and analytical process whereby the various dimensions of capacity are measured and evaluated within the broader environmental or systems context, as well as specific entities and individuals within the system." (Hu 2005) Using this definition as their point of departure and The United Nations Development Programme for reference, a three level capacity model is suggested; The broader system, the entity and the individual. (See Appendix A, A.4.)

An emergency plan or system can be evaluated based on how well it scores on this list but a lot of work has do be done by the researcher since it's necessary to identify all organizations and individuals in the given system and the corresponding function of each organization or individual. The authors propose that considering each function of this list should be used as a general requirement of a country's emergency response system.

List representing the method can be seen in Appendix A, A.4.

2.2.6 Fuzzy Assessment Method

The next method considered is the Fuzzy Assessment Method constructed to evaluate emergency response capability in hazardous materials transportation. The method like the previous specific ones can comfortably be generalized with a few tweaks. The

method is founded on an emergency response capacity index system with two layers, where thee factors are in the first layer and eleven factors are in the second.
The three emergency response capability factors in the first layer are related to management before, during and after sudden accidents and the second layer factors are the aspects that each first layer factor is made of. (Shang 2007)

First layer factors (u_i)	**Second layer factors (u_{ij})**
The capacity for predictive accident management (u_1)	monitoring […] (u_{11}) early warning and preventing (u_{12}) formulating emergency plans (u_{13}) emergency plans practice (u_{14})
The capacity for accident site management (u_2)	commanding and rescue (u_{21}) operating and executing (u_{22}) organizing and cooperation (u_{23}) logistical emergency support (u_{24})
Accident management (u_3)	disposal of [threatening factor] (u_{31}) disruption recovery and renew (u_{32}) The capacity for post-education of the public (u_{33})

Table 3. Index system of emergency response capabilities (Shang 2007)

U is an aggregation of every influencing factor in regards to emergency ability and $U = \{u_1, u_2, u_3\}$ and $U_1 = \{u_{11}, u_{12}, u_{13}, u_{14}\}$ and so forth. Similarly the assessable aggregation of emergency ability is a group made up of a five rank system both assigned in qualitative wording and quantitative numerical values in the shape of $V = \{v_1, v_2, v_3, v_4, v_5\}$ = {best, good, ordinary, bad, worst} = {95, 85, 75, 65, 55}.
Moreover, the importance of each factor in both layers must be reflected with a corresponding weight aggregation in the form of: $P = \{P_1, P_2, P_3\}$, etc. Experts or the AHP technique determine the weight. With these vectors set the first step of fuzzy mathematical assessment is building the three matrices accounting for the first layer, the second layer and the emergency ability value.
They are:

$$\underset{\sim}{R_1} = \begin{pmatrix} r_{111} & r_{112} & r_{113} & r_{114} & r_{115} \\ r_{121} & r_{122} & r_{123} & r_{124} & r_{125} \\ r_{131} & r_{132} & r_{133} & r_{134} & r_{135} \\ r_{141} & r_{142} & r_{143} & r_{144} & r_{145} \end{pmatrix} \quad \underset{\sim}{R_2} = \begin{pmatrix} r_{211} & r_{212} & r_{213} & r_{214} & r_{215} \\ r_{221} & r_{222} & r_{223} & r_{224} & r_{225} \\ r_{231} & r_{232} & r_{233} & r_{234} & r_{235} \\ r_{241} & r_{242} & r_{243} & r_{244} & r_{245} \end{pmatrix}$$

$$\underset{\sim}{R_3} = \begin{pmatrix} r_{311} & r_{312} & r_{313} & r_{314} & r_{315} \\ r_{321} & r_{322} & r_{323} & r_{324} & r_{325} \\ r_{331} & r_{332} & r_{333} & r_{334} & r_{335} \\ r_{341} & r_{342} & r_{343} & r_{344} & r_{345} \end{pmatrix}$$

Where r_{111} represents best predictive monitoring and r_{145} expresses the worst predictive emergency plan practice.
The comprehensive assessment aggregation of the factors in *i* layers is then:

$$\underset{\sim}{B_i} = P_i \circ \underset{\sim}{R_i} = (b_{i1}, b_{i2}, b_{i3}, b_{i4}, b_{i5}) \quad (i=1,2,3)$$

The second step aggregation is therefore:

$$B = P \circ \underset{\sim}{B} = (b_1, b_2, b_3, b_4, b_5)$$

From this the overall evaluation model is established:

$$W = [b_1, b_2, b_3, b_4, b_5] \circ [V_1, V_2, V_3, V_4, V_5]^T$$

The scores are calculated with this evaluation model formula, giving a representation of the capacity.

2.2.7 Evaluation Index System

This approach is based on the AHP assumption that the evaluation index system of emergency plans consists of three layers: the Target layer representing the emergency capability of emergency plans, the First-level index layer consisting of the pillars that make up the capacity and the Second-level index layer where the specifics of each layer are defined. To determine what the pillars of emergency planning are, the authors take seventeen National Special Emergency Plans as samples and analyze their contents. Their method to select the First-level indices is to perform a statistical analysis on their first-level headings and the Second-level indices are determined from the second- and third-level headings.
They find that the contents of all the emergency plans can be split into seven categories, that is: general rules, organization system and their responsibility, early warning and prevention mechanism, emergency response, after-event disposal, emergency guarantee and supplementary articles. Those seven categories are therefore set as the First-level indices. The second- and third-level headings produce 83 categories and by applying a hybrid of Self-Organizing Map (SOM) network and K-means algorithm they finally get the emergency capability evaluation index system with three layers into a graphic form. (Yang 2008 [2])
When executing this approach, one therefore has to analyze a given emergency plan by going through all the indices in each layer, determining how well the plan undertakes each task.
Figure representing the method can be seen in Appendix A, A.5.

2.2.8 Emergency knowledge supply and demand matching

This method is based on matching of the knowledge supply and demand derived from an emergency plan. The authors claim that not only can this evaluation method give comprehensive evaluation results but it can also locate the exact deficiencies in a given emergency plan and that way provide specific and on point suggestions on improvement and revisions of said plan. (Yang 2008) Emergency knowledge demand is defined as the knowledge that is demanded in a given emergency response. These five sets are abstracted from the general work flow of emergency response.
(1)Subject-set (S): All the participants in the emergency response
(2)Object-set (O): All the emergency problems caused by the emergency event.
(3)Task-set (T): All the work done by all the subjects for solving emergency problems.
(4)Resource-set (W): All the resources needed in emergency response.
(5)Relation-set (R): All the relations among subjects, objects, tasks and resources.
The general work flow of emergency response is therefore described by the following statement: $F = \{R \mid S, O, T, W\}$
Emergency knowledge supply is acquired from emergency plans by going through each paragraph of the plan step-by-step and making rhetorical questions on the content. This way a Problem-set is made with all the problems retrieved, their answers are one-to-one and all the answers constitute the knowledge supply of the given emergency plan. This knowledge is then matched in a graphic scheme generated by the five elements of emergency response.

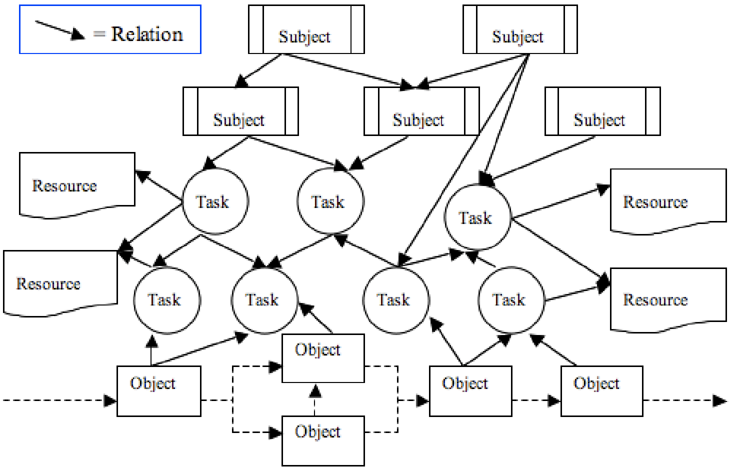


Figure 2. Supply and Demand Matching Scheme

The emergency response capability of a given emergency plan is evaluated according to the degree of matching it has. That is, if the matching is completed, it means the plan is well established but if there are unmatched entities, the plan has certain deficiencies and needs to be revised and improved.
The protocol is to first organize the subjects, objects, tasks and resources necessary in a certain event by using the scheme above and then break down all the emergency knowledge demand units of this event into problems. This will represent *n* problems.
The next step is to analyze the emergency plan for this event to get the Problem-set. Finally the knowledge supply is matched with the demand and this way *m* problems in the *n* problems from the first step will be matched.
Now the emergency response capability of the plan for this certain event can be evaluated by the following equation:
C = m/n*100%

2.2.9 Capability Assessment for Readiness, CAR

The Capability Assessment for Readiness report is the product of the initiatives of the American Federal Emergency Management Agency, FEMA, to evaluate the United States national capacities. The U.S. Senate Committee on Appropriations called for national-level criteria to assess performance in the areas of mitigation, preparedness, response and recovery. (CAR 1997) CAR focuses on the following13 Emergency Management Functions where each function then has several distinct attributes and the attributes have even more specific characteristics:

1. Laws and Authorities (contains 12 attributes)
2. Hazard ID and Risk Assessment (contains 2 attributes)
3. Hazard Management (contains 8 attributes)
4. Resource Management (contains 8 attributes)
5. Planning (contains 38 attributes)
6. Direction, Control, and Coordination (contains 11 attributes)
7. Communications and Warning (contains 8 attributes)
8. Operations and Procedures (contains 43 attributes)
9. Logistics and Facilities (contains 26 attributes)
10. Training (contains 22 attributes)
11. Exercises (contains 12 attributes)
12. Public Education and Information (contains 8 attributes)

13. Finance and Administration (contains 12 attributes)

To gather data, FEMA asked states to conduct a self-assessment based on the thirteen functions. The states were required to assess themselves at least at the attributes level and were encouraged to enter the characteristics level. The attribute or characteristic was then given a number on the scale of 1-3 but in the instances where a number could not be specified, Not Applicable (N/A) was assigned.
The significance of the numbers was:
3 - Always or consistently meets attribute/characteristic
2 - Normally meets attribute/characteristic
1 - Needs additional work to meet the attribute/characteristic
To further define the basis of evaluation, the States had to indicate whether their assessment was based on the following:
RW- Real-World Experience
EE - Exercise Experience
UT - Untested
All attributes and characteristics were given equal weight even though some should definitely be considered Core Competency performance indicators and thus have more leverage. Finally when evaluating the numbers an average of each attribute or characteristic was derived and a score on the range 2,5-3 indicated an Area of Strength, a score of 1,5-2,5 meant that the attribute or characteristic was normally met and a score of 1-1,5 represented Areas Needing Improvement.

2.2.10 Synthetic Evaluation Indicators System

The final method reviewed is the Synthetic Evaluation Indicators System. It is based on another method called Interpretative Structural Modeling, ISM, and constructs an indicator system to evaluate city public department emergency management capability. The authors hold the view that a complete emergency system should consist of four mainstays, i.e. the organization system, the operation mechanism, the legal foundation system and the emergency safeguard system. (Xiong 2007) The indices are selected on four principles:

(1) The Objectivity principle, since the selection process should not be influenced by subjective factors.
(2) The Integrity principle. The selection should represent a complete system.
(3) The Representation principle, as all aspects of law, management, equipment and so forth must be represented, so the indices must be suitably comprehensive.
(4) The principle of combining capability evaluation and capability construction, so evaluation work can give suggestions on construction.

With this in mind the factors of emergency management capability are determined.

Serial Number	Factors	Mark
0	City public department emergency management capability	S_0
1	Monitoring and early warning capability	S_1
2	Rescue handling capability	S_2
3	Emergency safeguard capability	S_3
4	Society control capability	S_4

5	Restore reconstruction capability	S_5
6	Legal construction	S_6
7	Emergency information system construction	S_7
8	Organization command capability	S_8

Table 4. Synthetic Evaluation Indicators System (Xiong 2007)

The next step is then to analyze the mutual relations between the elements in the table and determine their correlation. With matrices the following hierarchy is found:

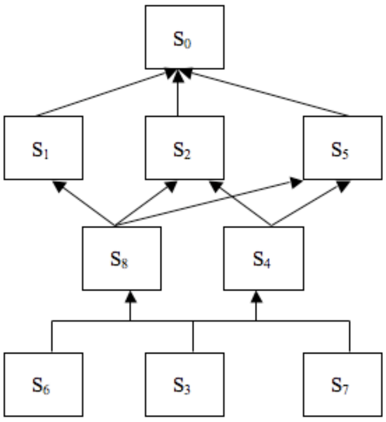


Figure 3. Hierarchy

The hierarchy is then broken into a table representing the first-level and second-level indicators of city public department emergency management capability as can be seen in Appendix A, A.6.

2.3 Summary

After reviewing these ten different approaches it's appropriate to delve further into their value to inspect whether they in fact do what they claim to, i.e. give plausible capacity assessment methods. But what renders a capacity assessment method plausible? There are various degrees of demands put on their effectiveness. For example, Eriksson and Gustafsson (Eriksson 2007) who dealt with similar issues in their 2007 thesis, have quite high expectations when it comes to capacity assessment models. Their specific agenda was to find a holistic capacity and vulnerability assessment model with a national perspective and found no such existing models fulfilling the criteria of being commonly accepted. It is however interesting that by "capacity and vulnerability assessment model" they are referring to: "a model from a national perspective which includes a holistic assessment of *all areas* that affect the Disaster Management Capacity."[10] Disaster Management Capacity is a complicated concept with no universal definition. Even the term capacity is used in various contexts and often without any clear definition as will be further discussed below. What constitutes a Disaster Management Capacity on a national level has so many areas with complicated interactions that the factors affecting it in reality are surely infinite.

[10] Eriksson, O. and Gustafsson, M., *Disaster Management Capacity from a National Perspective*, Report 5232, Department of Fire Safety Engineerng and Systems Safety, Lund University, Lund 2007, page 23. Font change mine.

Models are, after all, only imitations of reality so it would be an unfair request to ask for a model that covers a holistic assessment of all areas of Disaster Management Capacity.
In fact, it might even be dangerous for such a dynamic field as emergency and disaster management is, if there would ever be a model claiming to include a holistic assessment of all areas that affect its capacity. If experts believed such a model existed they might comfortably rest when a good score was attained on said model and only be proven wrong when a new disastrous event presented obstacles not covered in the model. It is in the nature of disasters to be unexpected and as Eriksson and Gustafsson themselves point out, things that have never happened before happen every day. (Eriksson 2007) Instead of striving for perfection the goal should be improvement. With these more realistic expectations capacity assessment methods should be developed to give better assistance in the complicated process and in fulfilling that task be considered plausible. Capacity assessment models can never be enough on their own and as other models they should be used as basic tools in a long assessment process, a process that also needs rational and analytical thinking and creativity.
With this in mind it is in order to shift focus back on the results of the literature study. The first striking aspect is that out of ten methods, seven can be categorized as index models. Being index models means that they have in common the procedure of giving numerical values to assigned indicators and from there derive a single number index to symbolize capacity. The possible range of this final number is defined in order to clarify whether it represents a positive situation or not. A shift in this number, when analyzed at a different time, expresses an improvement or a setback. It is certainly an enticing idea that a whole capacity system can be reduced to a single number and just by monitoring that number can one be in control of the circumstances. A single number is also easily explained to policy makers or other influential actors and index models are simple and straightforward in application. It is actually a common approach in risk management work to reduce systems to their sub parts, analyze each part looking for the risks it incorporates and from there assemble the parts to build a risk assessment package. (White 1995) This is for example done in risk trees and it's also the basis for index methods. This analytic approach is well structured and easy to understand but most systems are much more elaborate than that, with various influences and factors that work together in an interlaced way. Complex, multifaceted systems cannot be understood as a sum of their parts and that reduction fails to consider the interface between the parts and the risks that their interactions bring forth. (O'Donnell 2005) (White 1995) Accidents can and will emerge from the system as a whole, so it's crucial to look at it from a wider perspective.
It's also inevitable to wonder what valuable information is lost when a whole system is represented in that way. A rise in a decimal of a multi-layered index method might certainly suggest improvement but the source of that improvement is not given. For example it would be much more useful to know that the estimated rescue time in case of a sinking ship is now two hours instead of eight, rather than seeing a rise in the single number for a whole system from 2,5 to 2,8. It can even be questioned whether a rise in the result number between different periods of time is a real improvement since deterioration in a few aspects could be overwritten by a significant strengthening in one area.
In the single number results, there are no particular areas highlighted for their strengths and weaknesses so if the capacity number were not on par with expectations it would be difficult to give suggestions on where to start development work. Spokesmen for index methods might argue that the specifics could be traced back to the indicator

stage, where the specific area and its values can be identified. For example if looking at the “Disaster Risk Management Performance Index” (Carreño 2007), the improvement in the rescue time interval could be found in a better score of the DM3: “Endowment of equipments, tools and infrastructure”. But not only is that concept still extremely ambiguous, the shorter rescue time could be a combined factor of various indicators, such as monitoring, training and equipment. Consequently, sifting through the values of each indicator to pinpoint the origin of improvement would defeat the clarity of the single number vision. Another argument could be made that this reduction is a necessary tradeoff since models will, as was previously mentioned, always be simplifications of reality. That is certainly a valid point and one that will always present a challenge, but instead of accepting it, the way out could lie in the more open approaches such as “C&V Analysis” (Anderson 1990) and “Emergency knowledge supply and demand matching” (Yang 2008).
The shortcomings of index models suggest that either the capacity concepts of these approaches are too narrow and rigid or even worse, not defined at all. Capacity is explicitly defined in only two of the seven index method papers, as “the ability and competence […] to carry out mandated operations and produce outcomes by deploying the necessary resources within an appropriate structural context,” (Briscoe 2004) on one hand and “the managing and controlling ability, which is based on the principle of maximum benefit and minimum consumption (cost) in all procedures of dealing with an unexpected accident,” (Shang 2007) on the other hand. In both definition capacity is switched out for its synonym; ability and in the first one it’s also substituted by another synonym; competence. This kind of substitution is one of the three main characteristics of the phenomenon of folk models. Moreover, it’s quite unfulfilling to carve out a whole capacity assessment method without first defining what is meant by capacity and that absence of clarification is an indication that the authors assume that the reader instinctively knows what capacity is, which in turn is a further hint that in many instances capacity is a folk model. This leads to the conclusion that possibly the concept of capacity is not as easily understood as many ascertain.

2.4 Capacity and Folk Models

The idea of folk models refers to concepts that everyone feels they understand and readily associate something with but upon further inspection their intuitive meaning is not as solid as is predisposed. With concepts like these, people not only assume that they understand what is being inferred but they also assume that others understand the concept in the same way. (Dekker 2004) The main problem with folk models is that instead of their value being in their substance, it’s found in their common sense appeal. Therefore they may seem more believable than articulated models, and that is the greatest peril of folk models. In the instances of capacity assessment methods this is evident in the number of articles that did not believe it was necessary to define capacity, that it was such a common sense concept that the reader would readily know what the authors were referring to. That way whole discussions are conducted without defining the fundamentals of the topic, which of course results in very obscure findings. According to Dekker and Hollnagel (Dekker 2004) it is commonplace in the scientific community to use folk model labels so freely and uncritically, that after a certain period people no longer dare to ask what is meant by the concept out of fright of seeming incompetent in their own field, leading to “The Emperors New Clothes” syndrome.
There are three evident characteristics of folk models. The first one is that they are not defined by decomposition but by substitution. Instead of defining capacity by adducing

more fundamental and measurable aspects it's explained with the synonyms "ability" and "competence". What makes up an ability or competence is in equal need of clarification so they render attempted definition pointless. The second characteristic is that since the definition gives no declaration on the empirical reality, folk models are immune to falsification. They are therefore exempt to the most important scientific quality check and free from healthy critique. The effect of that and the third characteristic is then that when the definition is not rooted in empirical reality it becomes susceptible to over generalization and will be used to describe situations unfittingly. In the instances where capacity is defined, the definitions are quite diverging and as Hu et al. point out, the term capacity has a large number of different meanings and interpretations. What they do however have in common is that almost all of them are based on substitution. Hu et al. chose the definition of the United Nations Development Programme: capacity is the ability of individuals and organizations or organizational units to perform functions effectively, efficiently and sustainably. (Hu 2005). Once again, capacity is replaced by ability.
Below is a table presenting capacity definitions given in the ten texts found in the literature study.

	Reference	**Type of method**	**Definition**	**Description**
1	Anderson 1990	Non-index	*Not defined but reduced to three categories:* *-physical/material capacity: skills, assets and equipment.* *-social/organizational capacity: skills, knowledge, social relations.* *-attitudinal/motivational capacity: mental status.*	Masked as a definition but doesn't define capacity as much as give different aspects of it.
2	Briscoe 2004	Index	Institutional capacity is the ability and competence of an institution to carry out mandated operations and produce outcomes by deploying the necessary resources within an appropriate structural context.	Ability and competence.
3	Chen 2009	Index	*Not defined but what constitutes disaster response capacity is given in five layers.*	Capacity is explained in a hierarchical manner.
4	Carreno 2007	Index	Not defined	N/A
5	Hu 2005	Non-index	Ability of individuals and organizations or organizational units to perform functions effectively, efficiently, and sustainably.	Ability
6	Shang 2007	Index	The managing and controlling ability, which is based on the principle of maximum benefit and minimum consumption (cost) in all procedures of dealing with an unexpected accident.	Ability
7	Yang 2008 (2)	Index	Not defined	N/A
8	Yang 2008	Non-index	Not defined	N/A
9	CAR 1997	Index	Not defined	N/A
10	Xiong 2007	Index	Not defined	N/A

Table 5: Definition of capacity in text

Theses methods cannot be applied successfully if there isn't a consensus on the interpretations of the relevant concepts used. (Jönsson 2007) Considering this quagmire of poor definitions it's crucial for any further discussion to obtain a coherent definition of capacity.

2.5 Definition of Capacity

There is clearly a need for a more systematic and scientific definition, one that's presented without being tangled up in replacement or pre-condition. Jönsson, Abrahamsson and Johansson (Jönsson 2007) attempted to do just that and came up with an operational definition of emergency response capability. Their use of the word "operational" refers to the goal to give a definition that incorporates an applicable procedure to determine what is needed to accede with the definition. (Jönsson 2007) It is based on the risk triplet as well as incorporating the concept of vulnerability. Furthermore it builds on systems theory, where a system is a group of variables used to describe the world.

When looking towards capacity Jönsson et al. make a distinction between analyzing capacity and evaluating it and the operational definition only deals with analysis. According to them, capability is a conditioned concept so when being analyzed it must be related to the performance of a specific task. Therefore one asks not about capability in general but about the capability to perform a certain task. The capability definition therefore has three elements; an established task, measures of how well that task is executed and an account of factors that influence that execution.

The emergency response capability triplet is derived from there and corresponds to three questions:

*What can happen when an actor is performing a specific task given a specific context?

*How likely is it?

*What are the consequences for the performance measures defined for that particular task?

The answers to these questions, will be a neutral, matter-of-fact result with no judgment of whether that capacity is adequate or not, nor does it facilitate suggestions of improvement. It does however give a good analysis of capacity for a certain specific task and will be used here as a basis for the case study.

2.6 Capacity Assessment and Design Science

Since none of the ten methods found in the literature study was considered acceptable a different approach must be taken. A clear definition of capacity has been acquired but the emergency response capability triplet is not enough to constitute a framework for system analysis and evaluation. It's clear from previous discussion that for a successful framework application it's important to know the design of the system. (Abrahamsson 2009) In order to do that it's necessary to begin by considering the science of design. First there must be made a clear distinction between natural science and design science. Natural science is the field of science concerned with how things are and its research is aimed at understanding reality. (Simon 1996) Assertions in natural science must be observable and consistent with reality where only one negative instance is able to prove false a claim, despite a thousand positive ones. Natural science has two main activities: discovery and justification. Design science on the other hand has the basic activities of build and evaluation. (March 1995) Design science is concerned with creating things that serve human purposes and fulfill certain goals. Emergency response capacity is not a natural phenomenon, but an artificial one,

since it’s made up of human creations such as organizations, equipment, regulations and information systems. Research into it would therefore fall under the realm of design science. Using this fact as a point of departure the normal approach of only considering the current state of the system, for example giving an inventory of available equipment and a list of procedures, is avoided. (H. Tehler correspondence) Rather it guides researchers towards the much more interesting area of finding how the system should work in order to fulfill goals and make decisions.
Now, there is an existing system, which is facing certain risks so the step-by-step process is to establish design criteria, find possible design alternatives that accomplish the goals of those criteria and finally evaluate the alternatives based upon how well they solve the problem. The task is to seek satisfactory alternatives and find out whether they satisfy all the design criteria. The search is for sufficient and not necessary actions to fulfill these goals. (Simon 1996)

2.7 Conclusion

As was concluded in chapter 2.5, capacity is a concept that is not defined in general, but in context. Since the context of this project is disaster and emergency management, capacity was characterized as the answer to the three questions: “What can happen when an actor is performing a specific task given a specific context?”, “How likely is it?” and “What are the consequences for the performance measures defined for that particular task?” Those three questions were used as a basis for the interviews with experts that the case study was grounded on. The goal of the interviews was not to get exhaustive or quantitative answers since the emergency scenarios chosen for examination are so rare (most have never happened) that they cannot yield statistical data. (See choice of focus and scenarios in Case Study – chapter three) The questions were rather used as a foundation for a discussion leading the focus of the case study towards the situations and scenarios of biggest concern. The experts were asked to give their best professional assessment based on their knowledge and experience. That way a rooted knowledge of the current capacity of the system was acquired and therefore the means for analysis established. When the system and its capacity were known to a suitable level of detail, assessment work could begin.
There are numerous aspects that affect the performance of a system, and therefore could be considered in the design criteria, such as human resource qualification, flexibility of regulations and administrative structure of the system. Many of these aspects are subjective and difficult to quantify so for simplification of this project it was decided to put an emphasis on measurable features. From there, two factors were deemed most relevant to emergency response in this situation. The first one is time. Time is generally considered one of the most important aspects to emergency response activity and a quick reaction will often mark the difference between a disruption and a catastrophe. The other criterion is the appropriate equipment. A quick responding helicopter with the ability to take on fifteen passengers is of no use to a burning cruise ship with five thousand passengers. The available equipment must be on par with the emergency situation at hand, in order for any successful mitigation. Accompanying this criterion, it is assumed that people working with the equipment are qualified to do so. Articulated more concisely the design criteria were: “*Appropriate equipment should be available on site in a minimal amount of time from the reception of emergency signal*.”

3 CASE STUDY

The case study's focus was chosen in consultation with Icelandic experts in the field of disaster and emergency response as an area of great interest and concern.[11] Furthermore, when choosing the case study, the goal was to find a pressing matter that needed immediate attention and was current to an extent that those risk scenarios might come to be realized in the near future and would require the efforts of the Icelandic emergency response system. What stood out was the alteration of the Arctic landscape. One of the roles of the Icelandic emergency response system is to prepare, prevent and mitigate emergencies in the marine search and rescue region around the country. (See Figure B.2, Appendix B) Iceland is a remote island in the North Atlantic Ocean and throughout all its history the nation has relied heavily on naval activities as the source of its survival. The nation's fishing and freight fleet is therefore comparatively large. Iceland's location between Europe and North America furthermore means that there is ever increasing shipping traffic in the search and rescue region, and the recent discoveries of possible oil reserves in the Arctic have resulted in more activity than ever. Changing sea ice conditions have opened up new navigational routes for all kinds of traffic, be it oil tankers, cruise ships or hazardous goods transportation. (WWF 2007) This increased traffic has the inherent byproduct of increased risk and the number of adverse events almost doubled in ten years, from 1997-2006. That trend continues.

Event	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006
Ship sinks	7	8	4	10	6	4	7	16	7	4
Ship strands	10	14	7	14	10	11	7	16	16	21
Collision	4	2	8	6	11	7	4	3	9	12
Fire on board	7	6	3	8	15	5	3	5	10	5
Ship leak	1	0	0	3	1	5	8	10	7	7
Other	6	10	7	8	8	12	20	9	28	36
Injured people	55	63	56	64	63	103	85	89	88	83
Deaths	5	3	1	3	7	2	2	3	3	4
Total:	**95**	**106**	**86**	**116**	**121**	**149**	**136**	**151**	**168**	**172**

Table 6: Issues examined by the Icelandic Marine Accident Investigation Board 1997 – 2006 (RNS 2007)

This development has to be matched by the response system. In the following case study it was examined whether it has done so, that is whether the response system's capacity can be considered suitable under current conditions.

Activities in the area are threatened by multiple factors, such as extreme natural conditions, dynamic ice, prolonged fog, collisions with icebergs or other traffic, mass infection, fires and so on. Of the endless risk scenarios possible, emphasis was put on two factors: saving lives and protecting nature. The system is required to do both. The case study therefore focuses on the Icelandic response system's capacity to deal with serious events, posing threat to human lives or nature, within the search and rescue region.

[11] Dr. Björn Karlsson Director General for Iceland Fire Authority and Víðir Reynisson, Department Manager for Iceland Civil Protection Department.

Different design alternatives for the response system to fulfill that requirement were evaluated. Below, the Icelandic system will be introduced and the choice of focus explained. Then design criteria will be established and from there an analysis of the Icelandic system will follow, using the method described in chapter 1.4. Two main scenarios will be presented and then all resources the response system has to offer when dealing with those scenarios will be reviewed in order to point out suitable design alternatives. The best alternatives are those that reduce response time and enable suitable equipment to get on site. Special attention will be given to what improvement measures can be made to cost effectively reduce time and improve equipment. The case study is summarized in Figure 4, chapter 3.3.

3.1 Civil Protection in Iceland

The Icelandic people have considerable experience in emergency events given the extreme living conditions on a volcanic island but organized and methodical risk management work is relatively new in Iceland, ranging back a few decades. The last national emergency system planning process was finished in 2002. At the time the Civil Protection Agency was a comparably small institution so in 2003 a law was passed that changed it into a department under the National Commissioner of the Icelandic Police so responsibilities are delegated from there. (ICPD 2009)
Development has been extensive since then in both theoretical and practical work and new regulations[12] state that each community shall have a working civil protection group as well as instructing a thorough risk assessment and sensitivity analysis in each area. This is done in accordance with the proximity rule that says that “crisis should be managed on the lowest possible level in society,”(Kjeserud 2005) i.e. preparation and response is supposed to be mostly in the hands of those closest to the event. With each region being responsible for its own risk and crisis management, the police commander in the respective districts gains the managing control.[13] When a threat or an emergency is of such a scale that every day emergency response mechanisms cannot manage it safely, a state of Civil Protection is reached. Those instances call for more extensive and coordinated response where all actors involved in emergency management and mitigation, work together in accordance with one mutual effort plan. Civil Protection in Iceland falls under the Ministry of Justice with the exception of health and medical services, which are the responsibility of the Ministry of Health and Social Security. Additionally, acute pollution issues are on the responsibility of the Environment Agency of Iceland, which falls under the Ministry of Environment. Civil Protection responsibilities at the national level are delegated to the National Commissioner of the Icelandic Police, NCIP. The NCIP runs a Civil Protection Agency responsible for daily administration of Civil Protection matters, maintains a national co-ordination centre that can be activated at any time, and is in charge of the centre in emergency situations. (See Figure B.1 Appendix B)
The NCIP is also responsible for monitoring and supporting research and studies related to risk factors and natural catastrophes, and co-ordination and support measures aimed at reducing risks of bodily harm. On day-to-day basis it works on planning, training and maintenance of suitable equipment. (ICPD 2009) Each district has access to a standard plan that’s divided into two parts, A and B. Part A handles basic

[12] from summer of 2008

[13] This work has not been finished in Reykjavik but the planning phase is at the moment under way and the risk assessment should be almost complete at the end of 2009. The new plan is to be implemented in 2010 and the new system will be much more dynamic than the ones used before. It will allow for daily interactions and adjustments so the work process will be more flowing and up to date.

planning, infrastructure, managing, equipment of command centers, communication and distribution of assignments. Part B involves simple response instructions on emergencies caused by nature threats, technical failures or human actions.
In addition to this, special plans are made for certain events or threats and they are much more specific than the general plans. The Minister of Justice appoints a Civil Protection Council, which advises the cabinet of ministers as well as the National Commissioner of the Icelandic Police on issues of Civil Protection and has a consultative role in the implementation of legislation on Civil Protection. (ICPD 2009)
All these institutions are based in the capital city, Reykjavik. When events happen outside of Reykjavik, each municipality is responsible for civil protection in its province but, considering how small other communities are in comparison with the greater capital area, all events are managed in close cooperation with the state's institutions in Reykjavik. The police chief of each jurisdiction[14] is in charge of civil protection matters and the Civil Protection Agency provides support. An exception from the reigning control of the police is when events happen at sea. The Icelandic Coast Guard, ICG, is in charge of all search and rescue within the Icelandic search and rescue region around Iceland. (See Figure B.2 Appendix B) The region is vast, covering over 1.8 million km^2 around the country and the distance from Reykjavik Airstrip, BIRK, to the furthest corner, i.e. North East corner, is 710 nautical miles. (Ingason 2009) Within that area the ICG is responsible for instigation of all search and rescue activity but does not necessarily have to provide the resources. Because of the country's isolation, outside resources will be very far away or only in vicinity by chance, so for swift reaction the Icelandic system must provide some basic resources. As soon as people or equipment is brought to land, the local police chief takes over the project.
Realizing the importance of diverse actors' awareness of each other's missions, structures and styles of operation (Lindell 2003) the Icelandic government established in 2004 a highly efficient situation room, called SST, in the Rescue center located in Skogarhlid near the center of Reykjavik. All the major actors in rescue service and planning have representatives there. (See Figure B.3 Appendix B) Those are: National Commissioner of the Icelandic Police, the Capital District Fire and Rescue Service (SHS), the Civil Protection Agency, Icelandic Coast Guard, Ice-Sar: regional managers of voluntary rescue squads and the Red Cross. Representatives from the Icelandic Civil Aviation Administration, Landspitali University Hospital and The Icelandic Road Administration are called in when needed but do not have a fixed place there since they have their own stations in the Rescue centre. The National Police Department's Communications Centre and the Emergency Call Centre 112 are situated in close vicinity. Furthermore, The Icelandic National Broadcasting Service, RUV, has a studio adjacent to the SST room. During the day it only takes a few minutes to respond to an alert and get the center fully manned. Effective co-ordination between administrative units is very important because almost all emergencies cross administrative boundaries and require multiple response actors. (Buckle, 1999) The SST is in control of all coordination between provinces and different actors. (ICPD)

3.1.1 Monitoring

The Icelandic Meteorological Office actively monitors weather conditions and weather stations are situated all over the island giving good indication of what's to come. However, the fact that Iceland is an island, and a quite isolated one at that, makes

[14] There are 15 jurisdictions in total.

predicting the weather a bit more problematic. As mainland weather forecasters have a wider net of stations, Icelanders are limited to the edges of the country and the odd stations in the middle of the ocean. Those stations are difficult to maintain and expensive to run. Therefore our professionals have to analyze the weather reported where they can and project those situations on to Iceland and its surrounding territorial waters.

Shipping traffic is monitored by ICG's Maritime Rescue Co-ordination Centre, MRCC, in Reykjavik. All registered Icelandic commercial ships, that are over 6 m in length are installed with an auto-report mechanism, called STK which sends information on location, direction and speed every ten seconds to the centre. (MBL 2002) If a ship hasn't sent information for eight minutes an alarm goes off. If no contact is made during the next half an hour, rescue ships are sent out and all other ships and boats in vicinity to the lost ship are asked to partake in the search. The range of the auto-report mechanism is dependent on the height of the antenna on board the ship and the height of the transmission points at land, but generally the range is around 30-40 nm out to sea. Ships over 24 m are authorized to send reports through a satellite system, which allows unlimited range, with one hour intervals wherever they are in the world. The reason it's only every hour is that each report is charged for.

At the moment the land transmitters are being updated to international AIS transmitters and the ship owners will have to meet this by renewing their equipment by the end of 2010. This update is mainly done for economic purposes, as the AIS transmitters are more financially favorable than the old transmitters. For the decade or so that the auto-report mechanism has been running, the ICG has constantly been trying to cover so called shadow areas, areas where signals are not sent and received. Most of these areas have been eliminated with optimization, which involved the relocation of masts and antennas as well as adding new ones. The goal has been to get the equipment up to higher altitudes, such as mountaintops, in parallel to progress in electricity and other technologies. Trouble regions can however still be found in the North and North-West of Iceland because of antenna icing over the coldest winter months.

According to international agreements foreign ships have to report their whereabouts 24 hours in advance to the ICG if they intend to enter the 12 nm territorial waters. Icelandic law however states that reports ought to be given if ships enter the 200 nm economic zone. A lot of time and effort at ICG is spent on trying to get foreign ships within the economic zone to report and acknowledge Icelandic law. A good level of co-operation has been reached with neighboring countries on this matter and they give the ICG information on traffic that is likely to enter the economic zone. Those ships are contacted and a report demanded. Recently the International Maritime Organization, IMO, passed a regulation on a system called Long Identification and Tracking, LRIT, where most shipping traffic is obliged to send location information every six hours through satellites. The ICG receives this information in a 300 nm radius out of the coast of Iceland and since the system was activated in the fall of 2009 it has revealed that traffic through the economic zone is much greater than what was previously anticipated. This radius covers a big portion of the search and rescue region and if there were to be an accident outside it, the ICG could request real time information in extended areas.

The ICG has three surveillance and rescue vessels, Aegir, Tyr and Thor. Aegir and Tyr were bought in the 60's and 70's and are approximately 1200 tons. At the time of their purchase that was four times larger than the average size of ships sailing through the Icelandic economic zone but now there is a regular traffic of ships around 20.000 tons and Thor was bought as a reaction to that. (LHG 2009) Aegir and Tyr are not outfitted to deal with pollution, but Thor, which will not be delivered until 2010, will have a built in pollution control equipment as well as tank compartments to receive polluted waters. It will also have fire extinguishing devices, a state of the art surveillance system, large towing abilities and be able to transfer fuel to aerial helicopters. (LHG2 2009) The presence of Thor will be revolutionary in Icelandic search and rescue work at sea.

Further monitoring is done by a Dash 8 Q300 airplane called TF-SIF, acquired by ICG in July 2009, which is especially equipped for surveillance. TF-SIF tolerates strong winds, can fly in most conditions and has a flight range of 2100 nautical miles. It can monitor dynamic sea ice, fisheries, pollution, as well as carry out search and rescue. The ICG also monitors air traffic and is in contact with other communications centers in neighboring countries. When there's an emergency at sea, alarms go either straight to ICG's MRCC or to the 112 call center and from there get sent to the ICG. When an alarm is received it's immediately analyzed, in order to summon the appropriate groups but the most important actors are ICG, Ice-Sar and for co-ordination support, The Civil Protection Agency. Those groups then have their representatives in a co-ordination meeting within minutes. It's dependent on the nature of the threat, which additional units are called to the centre but in the case of a major disaster, all units are called.

3.1.2 International co-operation

Iceland is a part of many international agreements under which mutual emergency assistance and co-operation falls. First of all, there is a cooperation agreement between the Nordic countries; Iceland, Norway, Denmark, Sweden and Finland called Nordred. This agreement symbolizes a collective commitment by these countries to assist whenever any one of them is in a state of emergency. The partnership focuses on prevention and mitigation of various kinds of hazards and damages the general public might be subjected to. Subcontracts have been made in connection with the agreement where cross border cooperation is dealt with in more detail. Delegations from all participating countries normally meet twice a year and every three years a conference is held to discuss development of the deal and current issues. (ICPD 2009)

Iceland is also one of the founding members of the North Atlantic Treaty Organization, which was established in 1949. From the beginning NATO has been one of the main pillars when it comes to Iceland's security and defense issues. (NATO 2009) In emergency situations ICG has access to NATO's powerful communication and information systems as well as it naval stations. (Bjarnason 2007)

Other important organizations Iceland is a part of are: NAFO; North Atlantic Fisheries Organizations and The United Nations. The government also has access to assistance both from the European Union and the U.S. Coast Guard as well as a co-operation deal with the Danish navy and a close bond with Norwegian emergency response crews. More extensive agreements are currently being worked out. The Environment Agency of Iceland has multiple international agreements on response cooperation in case of pollution in the sea. A source of concern at the moment is that as a part of serious cost reductions for all government institutions in Iceland, funding for international cooperation has been greatly decreased which has caused the absence of Icelandic delegates in meetings and conferences. This development not only hinders Iceland's say in important issues, but it also quickly leads to a lack of personal contact, which in turn will cause the decay of relationships.

3.2 Scenarios

In reality, there is of course an infinite number of disruptive scenarios that can materialize and cause an emergency. The number of emergencies a response system is supposed to mitigate is also limitless. Risk managers therefore have the difficult task of including as much variety as possible in their representation and at the same time give a focused and useful analysis. For any analysis to take place there must be a departure from the continuous to the discrete, where certain scenarios are chosen as representation of possible events. The scenarios chosen in this project were decided upon based on the concerns the experts communicated in the interviews. There are two main scenarios, one has to do with search and rescue of humans and the other has to do with prevention and sanitation of pollution in sea. Reactions to these emergencies of course stem from the same response system, but there might be different aspects of it activated based on the nature of events. There is also the possibility of a simultaneous hazard to human lives and the marine ecosystem and even though such an instance will not be discussed, the total analysis does not exclude it. The scenarios are presented below. (See Figure 4, Case Study Summary Matrix, at the end of chapter three)

3.2.1 Scenario 1: Hazard to human lives

For a more detailed assessment, the case of hazards to human lives will be divided into two levels of risk. On the one hand there’s the case of fewer people, almost exclusively crew members of fishing and cargo ships, oil tanker or oil platform workers, and so on. In these instances the number of people at risk is estimated around 15-20 at average. It’s worth to note that these people are above average in mental and physical abilities. On the other hand there are events involving passenger ships, where people on board are hundreds and even thousands, with regular traffic in the Icelandic search and rescue region of cruise ships carrying 5000 passengers. Those passengers can be of all ages and physical health, often times senior citizens and even children. Events where single crews are in danger are more likely to occur farther from land than events involving a larger number of people, since cruise ships are generally closer to land, but crews on various kinds of vessels can be anywhere within the search and rescue region.

3.2.1.1 Design criteria

Time. When looking towards the design criteria, the first aspect to pay attention to is time. Time is especially important when it comes to human lives in the sea around Iceland where conditions are not viable for survival. People overboard only have a span of few minutes for rescue and no coordinated effort by actors that are not on site at the time can respond to that situation. Planning is therefore directed towards saving people that are still on board or in lifeboats. Considering that people in these scenarios will be in extreme conditions of darkness and cold, even hard winds and without access to food or water the survival time in lifeboats or seriously harmed ships is only a few hours. Considering the criterion of appropriate equipment, each level will be analyzed further below.

Equipment: S1 a) – Number of people limited to a single crew. If the people at risk were limited to a single crew, the most efficient approach would be helicopter rescue. The ICG has three helicopters at its disposal. It owns one, an Aerospatiale Super Puma called TF-LIF, and rents two, TF-GNA and TF-EIR. TF-GNA is the same model as TF-LIF and TF-EIR is of a smaller type called Aerospatiale Dauphin II. The official goal of the ICG is to have two helicopter crews on call at all times. For safe emergency response, two helicopters must fly simultaneously to the emergency site. That goal is however not fulfilled at the moment and on average two crews are available only one third of the time. One helicopter was returned and three helicopter pilots were laid off in September 2009 as a part of drastic cost reductions that have been made throughout the whole public system in Iceland because of the financial collapse in the fall of 2008. This development is a blow to all seafarers and has a snowballing effect on safety levels at sea. The abilities of one helicopter for rescue work are greatly constrained. The flight range of a helicopter flying solo is based on pilot rules, which only allow a trip of 20 nautical miles[15] for the safety of the crew. That distance is miniscule compared to the vastness of the search and rescue region. The distance is greatly expanded when two helicopters are available, to a flight range of 240 nautical miles. In good conditions, two Super Puma helicopters could reach Jan Mayen, which is about 290 nm from Iceland and refuel there. The search and rescue region stretches well north of Jan Mayen, so that option might be of use. The maximum speed of the Super Pumas is 150 nm per hour but a viable speed is 125 nm/h. The Dauphin can go a little bit faster with viable speed ad 130 nm/h.

The poor financial situation of the country has stunted other projects at the ICG. Luckily both TF-SIF and Thor were well underway when the collapse occurred so their delivery was not cancelled. However, TF-SIF requires quite a lot of flight hours in its first year of operations for fault detection and currently the government cannot afford to fund all its flights. That might result in the airplane being utilized by other nations in some kind of a shared access deal.

Equipment: S1 b) – Passenger ships emergencies. The number of passenger ships entering the Icelandic search and rescue region has been gradually increasing and that is a cause of great concern to all actors involved with civil protection in Iceland. Those ships, carrying upwards of five thousand passengers are often sailing through hazardous areas in great isolation, because even though traffic is increasing, it is far more scattered in the Arctic than in other areas of the world. Passenger ships are generally not in the outer edges of the search and rescue region, since passengers are meant to see land, except for those that trace the east coast of Greenland visiting unmapped fjords. Greenland has a search and rescue region of 10 nm directly out from its shores, so not only is ICG responsible for search and rescue all the way up to that mark, but these areas of Greenland are so rural that most are just complete wilderness with no conditions to react to emergencies. Injured passengers could not be brought to shore there and would have to be moved to Iceland. The sea between Greenland and Iceland is furthermore an extremely turbulent area, frequently with dynamic ice coverage, shallows and strong ocean currents. Icelandic civil protection actors are more concerned with events in the sea between Iceland and Greenland, than they are with events in the sea North and East of the country because of the greater isolation to the west and more distance to European assistance. When examining the case of passenger ships with the number of people on board ranging anywhere from hundreds to thousands, it is clear that helicopter rescue would be of no use because of their limited carrying capacity. Response activity is therefore limited to ships.

Based on the extent of the emergency, the three search and rescue vessels of the ICG will be considered for response activities, but even more importantly, all nearby ships will be contacted and directed to the site of emergency. TF-SIF will be used for search and surveillance but the availability of proximate ships will probably affect the efficiency of rescue activities most. If an emergency happens closer to the shore, i.e.

[15] When helicopter flight range is given what is being referred to is a round trip with approximately 30 minutes on the site of emergency as well as a small amount of fuel store at the end of the project.

within 30-40 nm, Ice-Sar has fourteen 15 m ships on various locations around Iceland equipped for search and rescue at sea. The ships are British, of Arun type and were bought used from the U.K. Medical equipment is on board and trained paramedics are in some of the crews. Fire extinguishing equipment is also on board with the ability to put out fires in smaller ships and boats and provide cooling in case of bigger ships. The Ice-Sar rescue ships can be activated and on their way within 20 minutes, most of the time much quicker and just within minutes. Crew members are notified with text messaging so they know the nature of the emergency call right away. Ice-Sar crews go on over a hundred emergency calls per year and all crew members, who are volunteers, have quite extensive training. If there is need for more specific abilities, such as doctors or firefighters, they are also summoned.

The range limitations are because Ice-Sar ships are constricted to areas with VHF radio signals, which only go out to 30-40 nm. Another restraint is fuel, but refueling could be done at sea with fuel carried by the ICG's larger vessels. There can always be two to three Ice-Sar rescue ships on site at the same time and the travel speed is 15 nm/hour. Their passenger carrying capacity is normally 15 persons and but quite a lot more if the need is dire. Their role was originally only directed towards providing safety support to the Icelandic fleet and they are quite well equipped for such. Their ability is however very limited when it comes to large numbers of people in greater distance from land.

The coast guard ships Tyr and Aegir have a 5000 nm range and can therefore reach the outer edges of the search and rescue region and then some. The limiting factor in that instance is time and that of course depends on the situation each time. Their running speed in good conditions is approximately 20 nm/h and considering that the region extends 600 nm to the South-West and the coast guard ship was situated at dock in that part of the country, it would take about 48 hours to get to the emergency site. Tyr and Aegir can take a few hundred people on board in case of emergency but passengers would not be cared for adequately.

3.2.1.2 Design alternatives and evaluation

From this introduction, it's clear that a single operating helicopter does not fulfill either of the design criteria, unless the event is closer than 10 nm from land. Two helicopters have a much better coverage, even though they are nowhere near being able to provide quick assistance in the whole search and rescue region. With the introduction of new vessel Thor the flight range of helicopters is however greatly increased since it can refuel helicopters out at sea. Equipment for such an action has already been installed in TF-LIF but funding to put similar equipment in TF-GNA has not been acquired. The presence of Thor and two helicopters allows the second design criterion of appropriate equipment to be fulfilled, but the time criterion will not be secured. Since Thor has an approximate speed of 20 nm per hour and therefore takes about 10 hours to the edges of the economic zone and up to forty hours to the edges of the search and rescue area, it will be incidental if it is close enough to the event to be able to reach it within the time constraints on the design criterion. The suffering entity will be instructed to make an attempt to sail (if mobile) towards the closest ship or shore.

Another aspect of concern is that there are instances where helicopters cannot be used. Helicopter rescue is for example impossible in thick fog, which is quite common in the Arctic and can last for days. Then the only means of emergency search and rescue are ships. Ship based rescue is also at the forefront when it comes to passenger ship emergencies. Drills have been done to analyze the preparedness and response for such events, where aircrafts are not beneficial. Remote places with difficult access were chosen as the scenes of events. All available resources were called for help, including NATO, The United States Coast Guard, Nordred, and NAFO. Information on all ships in vicinity of the drill emergency that had any ability to assist in search and rescue was gathered and those ships were instructed to get on site to start response work. The results were shocking. The ICG considers it to only be a matter of time before a passenger ship will run into trouble in this area and as of now, the means to respond to such an event are inadequate to say the least. The time it took to direct response equipment to the site, whether it would be ordinary fishing ships or well equipped search and rescue ships was not promising for successful rescue work. The hours it takes for help to get to the site would surely prove deadly to a large number of passengers, who might be seriously injured, and the transfer time back to land or other medical assistance is another hurdle. Passengers will need basic food, resting space and sanitary facilities, and they might also be dependent on medications and other special care.

The deciding factor in a passenger ship emergency would be its position relative to land, search and rescue vessels and other ships capable of assistance. In the words of one of my interview subjects: “The most helpful rescue squad in that situation would be the Icelandic fishing fleet.” The Ice-Sar rescue ships would not be able to provide help beyond the 40 nm mark and it could take Thor dozens of hours to get to the most remote areas of the search and rescue region. There are therefore no viable design alternatives available in the current system.

3.2.1.3 Improvement suggestions

For the case of a single crew emergency, the by far most important system improvement would be to have two long range helicopters and crews on call at all times. Such measures would dramatically reduce time and greatly increase the possibility of appropriate equipment on site. That would mean that the system should preferably have three long range helicopters and crews at its disposal to buffer against any mechanical dysfunction or unavailability of human resources. Those helicopters should all be decked with equipment to refuel from the three larger search and rescue ships. Furthermore, those three helicopters should be owned by the state, since the current situation of owning one helicopter and renting two is not financially reasonable in the long run. The three helicopter goal was a part of the ICG’s plan, made in 2008, but the poor state of Iceland’s financial system has prevented it from being realized. The goal is therefore now to ensure the operation of this plan. Another part of the 2008 plan was to have three search and rescue vessels available, so that two ships could always be at sea at the same time. Analysis from the ICG’s MRCC would find the best locations for the ships with the goal of maximizing their response capacity.

When looking towards part b) with the passenger ship emergency, the approach most likely to yield success would be to never allow cruise ships sailing solo to enter the search and rescue region. Actors within the Icelandic system want laws to be passed that oblige maritime organizations to send passenger ships carrying a certain number of passengers two and two together. The ships would not have to travel side by side, but be within a certain distance of each other. This would eliminate the grueling fact proven in previous drills that the nearest ship with any carrying capacity to a solo passenger ship might be hundreds of nautical miles away. This was suggested in an agreement with Danish authorities in 1996 but the International Maritime Organization

and the private maritime organizations did not take well to the suggestion. Campaigning for this amendment might resume with increased traffic and would surely be beneficial both to passengers as well as emergency response organizations. Icelandic actors also compare this to Icelandic guidelines that mountain trucks must travel at least two and two together since it's impossible for response squads to have rescue trucks constantly up in the mountains.
It would also be very beneficial to the system if Ice-Sar's range could be increased. Both the crews and their ships are able to uphold activity farther from land than currently is allowed, as the constraining factor is the VHF radio signal. Ice-Sar must be in constant contact with ICG's MRCC to receive orders and information and if their current equipment would be replaced with short wave radio receivers they would be able to sail as far as to 100 nm. A project to fulfill this goal could not receive adequate funding. A bigger Ice-Sar ship at Isafjord port might also increase capacity since it's closest to events that happen in the sea between Iceland and Greenland. Finally, international recognition of maritime traffic notification obligations to ICG's MRCC would greatly enhance the situational awareness of its operators and make hazard analysis much more accurate.

3.2.2 Scenario 2: Case of environmental hazard

In the case of environmental hazard, the biggest threat is the transportation and possible harvesting of crude oil. Oil is the prevalent hazardous cargo being carried in the Arctic and further oil related risks come from oil spills of various kinds of leakage. There are certainly some very threatening instances of toxic or radioactive waste transportations, and those cases will get a brief mentioning, but for the sake of simplicity, oil spills will be in the focal point. Oil transportation is a much more risk laden endeavor in the Arctic than it is in Southern more common areas of oil activities. Oil also behaves differently under Arctic conditions as will be explained in more detail below. After that, the most common methods of oil cleanup efforts will be briefly presented, before further discussing aspects of design criteria for this scenario. Then an introduction of the system will follow, possible design alternatives given and evaluated. Finally improvement suggestions will be made.

3.2.2.1 Typical arctic[16] conditions and potential impacts on spill response

There is relatively little knowledge and experience with oil spills in the Arctic, particularly when it comes to oil spills in areas with dynamic ice coverage or slush ice. Experiments have been conducted to some extent in laboratories and mimicked conditions but field experiments have been few and limited. (Brandvik 2009) What experts do know however is that Arctic conditions can have impact on the probability and consequences of a spill at the same time. Circumstances that increase the likelihood of a spill, such as reduced visibility, low temperature and dynamic ice also cause tremendous problems in the successful execution of response operation. A simultaneous occurrence of two or more of these factors also causes a synergy effect, for example the combination of low temperatures and wind might cause icing on equipment rendering it unsafe or even useless. (WWF 2007)
Most technology and experience with oil spills has been acquired from temperate

[16] The term "arctic" is used to refer to areas where arctic conditions exist for part or all of the year. (WWF 2007)

oceans but apart from outside factors, Arctic sea is quite different in nature from those regions, for example having lower temperatures and salinity. Spilled oil therefore behaves differently under Arctic conditions; it evaporates more slowly and can get trapped under ice caps. Presently technology does not allow for adequate remote detection and tracking of spilt oil trapped under, on or among ice. (Dickins 2004) The transportation of oil waste mixed with ice in Arctic weather condition is also a major challenge which is troublesome considering that one of the most important aspects of recovery is to contain the oil as closely to the source of the leak as swiftly as possible and safely removed it from the environment. In these difficult surroundings the prospect of response mechanisms reaching its operating limits is higher than in temperate waters. (WWF 2007)

In some limited instances, however, Arctic conditions prove to be propitious to emergency response. Several properties of oil in water behavior are favorable in low temperatures, such as slower spreading, reduced water uptake and more viscosity. (Brandvik 2009) Sea ice might even act as a containment barrier extending the time window of successful response and solid ice caps could possibly be used as platforms for recovery equipment. (WWF 2007) This is however all dependent on safe access to the site, which is often one of the biggest challenges posed by remote Arctic areas.

3.2.2.2 Oil Spill Recovery Mechanism

There are three major techniques available for oil spill recovery. They are usually combined in recovery efforts and in many cases these techniques require the support of aircrafts, vessels and trained personnel to reach the highest level of efficiency. All three require real time monitoring of natural conditions and tracking of the spilt oil to identify the location so that the appropriate safety measures are honored as well as a suitable distribution of equipment and personnel. (WWF 2007) Flexible response regulations, where all possible response tools can be considered at the occurrence of an emergency are also an important factor. (Dickins 2004)

Mechanical recovery: booms or natural confinements are used to contain the oil, which is then removed by using skimmers with suction or weirs. The waste is transferred to temporary storage using pumps or hoses until it can be properly discarded. Problems with using mechanical recovery in Arctic conditions include the interruption and limitation of boom operation in areas with dynamic ice. (Dickins 2004)

Dispersant application involves applying a combination of chemicals to oils slicks by driving the oil into a dissolved phase. Dispersants are only effective for a limited amount of time and it’s application is constrained by suitable oil type and oil characteristics at the time of it’s use.

In-situ burning entails controlled ignition and burning of spilled oil on the water’s surface. It requires an appropriate thickness of the oil and used promptly after the spill it removes the oil quickly and efficiently. (WWF 2007) Burning does not require large amounts of equipment but expelling ignition devices from helicopters or vessels induces combustion. In situations involving ice water oil spills, in-situ burning is considered the most effective recovery strategy. (Dickins 2004)

3.2.2.3 Design Criteria

Time. The time frame is not as stringent in oil spills as when it comes to human lives and hours will not make or break response activities. An alarming aspect is however the lack of knowledge on the effects of oil spills in the Arctic, since the conditions are so greatly different from those where oil harvesting practices have been developed. Response actors might have days to get to the site without dramatic effect on clean up, but the equipment is complicated and not suited to Arctic conditions, so the same situations that might cause a spill in the first place might prevent the appropriate cleaning equipment from being able to reach the site of emergency. At present, available technologies do not allow for safe mitigation of oil spills in the most extreme conditions.

Iceland is currently not involved in oil and gas harvesting even though there are possible oil reserves in the Dreki area, which lies in the outer North-East edges of the economic zone. The financial collapse in Iceland has prevented those options to be explored at this time. The country's response actors therefore do not currently possess advanced oil clean up equipment. Most response work will have the goal to minimize damage until international actors can take over. The design criteria are therefore more focused on how quickly appropriate first aid equipment can get to the site of emergency to begin clean up.

Equipment. Any serious contamination of the sea surrounding Iceland would be a catastrophe for the whole nation and any disturbance in the delicate ecosystem around the country is considered one of the biggest threats it's faced with. The Environment Agency of Iceland, EAI, is responsible for all pollution issues within the economic zone in close cooperation with the ICG and is accountable for the existence and renewal of appropriate equipment on board the ICG's ships. (Sigurdardottir 2007) Iceland's responsibility outside of that is not specified. The invisible line separating the economic zone and the search and rescue region does of course not present any protection barrier and in the case of pollution in the extended area, Iceland would still be the response actor closest to the event and actions would be assessed in accordance with the extent of contamination and the risk it would have of affecting the ecosystem. This is very grave considering the oil tanker traffic from Murmansk and Norway that is entering the waters around the country. According to Icelandic law on protection against pollution of sea and shore, all emission or pollution from seafarers within the economic zone must be immediately reported to the ICG's MRCC. Ships with hazardous goods are also obliged to give regular reports. The aim of these reports is first and foremost so the ICG can advise and respond more quickly if something goes wrong. (Sigurdardottir 2007) A large portion of this traffic is however not reported and how close to the shore of Iceland it gets is greatly dependent on winds and other weather conditions. The part of the traffic that presents the biggest distress to response actors is the one going the Denmark Strait, the turbulent and constricted sea between Iceland and Greenland. In the Denmark Strait, there is always risk of dynamic ice, it is relatively shallow and the streams are very forceful. Inexperienced captains and crews do not have the skills to manage the most extreme conditions in the area and since Greenland's resources are slight, Iceland's response system would be the closest for a considerable amount of time in the area where other traffic is scarce. The traffic to the North and East of the country does not worry Icelandic response actors as much since the waters are not as narrow and restricted and dynamic ice does not present a problem. Assistance from Europe is also closer by and there is a fair amount of towing ships available in reasonable distances.

Accordingly, when foreign oil tankers or other vessels with hazardous goods enter the economic zone, the ICG's MRCC will have to monitor and alert the EAI if anything unusual is detected. The EAI has pollution response equipment in thirteen ports around the country, including oil skimmers and fences, pumps and protective clothing. This equipment is intended for localized use in ports and is not suitable for long distance mobilization. The ICG's search and rescue vessel Thor will be equipped with oil clean up mechanism to deal with minor leakages in the form of a 300 m marine weir and Lamor suction skimmer. Additionally there will be about 700 cubic meters of tank space for contaminated sea. The Icelandic systems does not have any other sanitation resources at it disposal when it comes to pollution out at sea. According to Ice-Sar, the EAI has some minor weirs, applicable in good weather, to distribute to their ships in case of oil pollution, but there is no official agreement between the two institutions. When a pollution event is considered to be out of Thor's scope, international help will be summoned immediately. An important aspect in all marine pollution prevention and mitigation within the Icelandic system is the Copenhagen Agreement on Nordic cooperation for the marine environment. Iceland, along with Denmark, Finland, Norway and Sweden entered into an agreement, which entails that all these countries will cooperate on protecting the marine environment in case of pollution events, regardless of which country is threatened by the contamination. (Copenhagen Agreement 2006) The ICG also has an agreement with the United States Coast Guard where they will send a Mobile Strike Team as soon as a pollution alert is sent out.

3.2.2.4 Design alternatives and improvement suggestion

When Thor will be delivered to the ICG in the spring of 2010 the system will have a reasonable response alternative when it comes to oil pollution. Thor can sail in some very hard conditions and reach all the outer borders of the search and rescue region. More sophisticated or diverse equipment cannot be expected from the Icelandic system at this time, since it is very expensive and Iceland is not profiting from oil activities. The system relies on international responses when it comes to major oil spills and it's built to activate international agreements as soon as a disruption is evaluated to be out of the Icelandic scope. It is of course important to nurture the relationships with our international partners and active participation in international drills, conferences and meetings is crucial for successful relationships. This must be considered when budget cuts are being determined, as lines of communication can quickly deteriorate. Since the threat of oil pollution is only increasing, now is not the time to neglect our responsibilities on the international forum.

When looking back towards the system's local ability it's estimated that Thor can deal with moderate level oil leak emergencies and be on site within a couple of days. An important aspect in minimizing that time is stricter enforcement of required status reports and international acknowledgement of this obligation. All ships within the search and rescue region, whether domestic or international, should give location and direction information to the MRCC, so that the ICG can analyze traffic, offer recommendations and situate their response equipment accordingly. The Norwegian coast guard has controlled traffic by positioning their coast guard vessels so that they push hazardous traffic away from shore so that it is at least 30 nm from land but this approach is not considered suitable for Icelandic conditions. Ships with hazardous cargo have simply been instructed to keep a certain distance, but in fact when natural conditions have not been favorable, the ICG has had positive experience with directing ships with hazardous goods to sail up towards the coast of Iceland where they can get shelter from streams and winds. This has especially been done with ships carrying radioactive cargo, since it is stored in containers on deck.

3.3 Conclusion

Looking back at the research question (chapter 1.3) it was maintained that the goal of the case study was twofold. The first part was to display the applicability of the chosen approach and therefore assess its value. The chosen approach was to apply decision analysis to the system, building on the fact that emergency response systems fall under the realm of design science. Accordingly certain design criteria was established with the condition that all design alternatives the system had to offer that could fulfill those criteria would be considered acceptable. Looking at they system from that point of view gives the researcher clear instruction on how to approach such a complicated system. Decision analysis is a dynamic method and therefore especially well suited for dynamic systems. It includes a clear point of departure and easily translatable results. It steers its user to find the best available solutions to multilayered problems and therefore spontaneously draws attention to areas that need improvement and measures to take to acquire that improvement. Unlike index methods, where the results are given as numbers that vaguely represent the condition of the system, decision analysis offers results one can take across administrative boundaries and present in understandable terms, regardless of the audience's background. It is therefore concluded that this method has good applicability and can be of much value to researchers.

The latter goal was to bring useful information out in order to contribute to the system's improvement. It's also concluded that this was successful. According to the analysis it cannot be said that the Icelandic response system has suitable capacity when it comes to saving lives and protecting nature in the search and rescue region. Considerable improvement, possibly raising the capacity up to a suitable level, does however not require extreme costs or dramatic changes of the system.

For the case of hazard to human lives – fewer people, the only viable design alternative is to have two helicopter crews on call at all times. This alternative is only partially available, so to obtain it at all times requires additional funding for a fully manned second crew. With these relatively minor changes the response time can be reduced from days to hours. Further improvement would be accomplished by trading TF-EIR in for a long range helicopter and buying equipment instead of renting it promises future cost benefits. Possible refueling from the rescue vessels would also provide an important step in the better coverage of the search and rescue region, so the installation of aerial refueling equipment in TF-GNA would be valuable. There will of course always be instances of weather conditions causing reduced visibility, but current, attainable technology does not provide a solution to that problem.

In the instance of passenger ships, there are no suitable design alternatives. Appropriate equipment is not available and the equipment available will only meet the time constraints by chance. All mitigation will be heavily relied on voluntary help of proximate vessels and international help. There is however a simple solution to this dilemma: obliging all passenger ships of a certain size to travel two and two together. This would fulfill both design criteria in swiftly providing suitable equipment on site and reducing response time from dozens of hours or days down to a couple of hours. Specialized response equipment, such as helicopters, could in that case focus on those who are worst off as the other passengers could be provided with acceptable accommodations in the other ship. The obligation of coupling of passenger ships in the search and rescue region would not cause increased cost for the Icelandic system but it would require some re-organization of the companies behind passenger travel.

With the arrival of Thor, there will be a significant increase in marine pollution mitigation capacity of the system. At present, the EAI only has oil cleanup equipment in ports around the country but no mobile apparatus. Establishing co-operation with

Ice-Sar and upgrading the clean up equipment on board their vessels might be very valuable at limited cost. Increasing Ice-Sar's vessels range is also very beneficial for all response work. It is also really important that the ICG and EAI keep up dynamic co-operation with international actors and not underestimating the significance of active participation in development work. Finally, and maybe most importantly, international recognition of maritime traffic notification obligations to ICG's MRCC would be a great advantage in the progression of prevention efforts.
In the end it must be considered that emergencies come at a high price in many ways; loss of lives, destruction of invaluable nature, damaged equipment and costly reconstruction are only a few aspects. It is therefore critical to invest in emergency response capacity and that way take steps towards both preventing them from happening and reducing their consequences. These results are further summarized in the following table.

Case Study Summary

Scenario	Statistics	Design Alternative (i)	Design Alternative (ii)	Design Alternative (iii)	Consequences*	Improvement suggestion
Number of people limited to a single crew	Thousands of ships.	2/3 of the time: One helicopter, with flight range 20 nm. Should be on site within half an hour if event is max 10 nm from land. --Note: Helicopters are inoperable in natural conditions which entail reduced visibility	Ice-Sar rescue ships: reach max 40 nm. Should be on site within 3 hours.	1/3 of the time: Two helicopters, with flight range 240 nm. Possibility of refueling with the assistance of Thor. Without refueling: Should be on site within 2 hours if event is max 120 nm from land. With refueling: Reach the whole search and rescue region but time would depend on Thor's situation. Can take up to a couple of days if it's poorly situated.	i) Not acceptable for any instances farther than 10 nm from land. ii) Not acceptable for any instances farther than 40 nm from land. iii) Acceptable, as best possible service is provided with available technology.	Fairly good coverage and swift response is obtained with two helicopter crews on call at all times. Another crew should therefore be available. Long term cost reduction would furthermore be acquired by buying the two hired helicopters.
Passenger ships emerg-encies	In 2007, more than 250 passenger ships were registered in the Arctic.	Call all ships in certain vicinity to the event and ask for help. Number of available ships unknown. Timeframe: hours to days. International help. Timeframe: dozens of hours to days.	Ice-Sar rescue ships: reach max 40 nm. Should be on site within 3 hours.	Thor, Tyr and Aegir can reach the whole region but depending on their situation could take dozens of hours to get on site and only have combined carrying capacity to take dozens to a few hundred of passengers.	All design alternatives are deemed not acceptable since none fulfills the design criteria.	An acceptable option, both providing suitable equipment and greatly reducing the timeframe would be to oblige all passenger ships of certain size to travel two and two together.
Environ-mental hazard at sea	In 2008, the ICG registered 39 oil- and gas tankers within the search and rescue region. Most of those ships carry between 40 and 80 thousand tons.	TF-SIF has state of the art surveillance system for oil pollution detection. Thor can reach the whole region and will be equipped to provide first aid.	International help. International agreements are active and ensure swift response of all members.	Iceland Environment Agency has oil pollution cleansing equipment in all of the larger ports around Iceland. This equipment is not suitable for mobilization.	As Iceland is not taking part in any oil activities as of now, alternatives (i) and (ii) are deemed suitable. (iii) Is acceptable for ports but the IEA should have access to more mobile equipment.	The most important improvement for this scenario would be in prevention. Giving the ICG more authorization to monitor traffic would improve their ability to offer assistance and coordinate response.

*A combination of design alternatives is certainly possible and accounted for in evaluation.

Figure 4: Case Study Summary

3.4 Statistics and calculations

Usually, it is difficult to acquire data for low frequency events like some of those discussed here. It can however be very beneficial to give numeric representations of points that are being presented, as it is easily understood in most levels of administration and can therefore make results more powerful. Fortunately, serious environmental accidents have been very uncommon in the search and rescue region and large passenger ships have not had grave problems as of yet. There's therefore no workable statistical data to be had on those incidents. That does not reduce the seriousness of the threat and it must be kept in mind that the risk of such events is steadily increasing. Events involving fishing and cargo ships as well as smaller passenger ships have however occurred enough times to generate some consistent data over the years.

After contacting the ICG, Ice-Sar and the Icelandic Marine Accident Investigation Board with a request to get access to information on those events, it became apparent that data on the nature and extent of incidents that have happened in the search and rescue region is not readily available. Even though great amounts of information are gathered and used to some extent by all organizations, it is not collected into a general database and therefore it is not easily accessible for researchers. Better cross-institutional cooperation on data gathering would definitely make a great difference in all analytical risk management efforts.

Instead of trying to lift data from each institution's sporadically published reports the course taken was to examine the ICG's news bulletins (LHG3 2010), which have been issued online since March 2002. That way a consistent degree of detail was acquired, providing information to build an analysis. The news bulletin board reports on all major events concerning the ICG as well as giving information on other organization's part in response work. After going through all posts from March 2002 to March 2010, one hundred events were considered relevant. Each event was then categorized based on the location of the incident, weather conditions, number of crewmembers and so on. This information is inarguably superficial but despite that, it provides an idea of the system's settings. See detail of calculations in Appendix D.

3.4.1 Basic Information

The basic information gathered from the news bulletins is the following.

Location of incident was divided into four categories, Far West, Far East, Near West and Near East. An event was considered to be "Far" when it occurred more than 40 nm from land, in a distance where one helicopter would definitely not be allowed to take off on its own. All events closer to land than 40 nm are then considered "Near". Events taking place in directions South-West, West, North-West and North, were labeled West, and directions North-East, East, South-East and South were labeled East. With these simplifications in mind the probability of an event occurring in each category is:

Far West = 0.46
Near West = 0.33
Far East = 0.13
Near East = 0.08

As has been explained in the text there is only one helicopter crew available two thirds of the time, so the probability of each number of helicopter crews is:

Two Helicopter crews = 0.33
One Helicopter crew = 0.67

One hundred relevant events occurred during the nine years examined, so:

Frequency of Event = 11.1 per year

Of these 100 events, in 18 instances a fishing or rescue ship was the first responder on site, so there was no need for helicopters in those instances. Since the density of fishing and rescue ships decreases with distance from land, a ship rescue was much more likely in locations categorized as “Near”. So the probability of fishing or rescue ship saves is:

Near – 17 times out of 41 events = 0.41
Far – 1 time out of 59 events = 0.02

Number of crewmembers varied greatly but for simplicity they were divided into two categories. In the most common cases there were 1-3 individuals at risk, for example where smaller boats were sinking or individual crewmembers needed swift response because of acute illness or injuries. On the other hand there were bigger crews and smaller passenger ships in need of assistance, for example where larger boats were sinking or on fire. The number of individuals in those instances was anywhere from 15 to a couple of dozen. The representative numbers chosen, and their probability, are:

Fewer people, number set at 3 = 0.95
More people, number set at 18 = 0.05

In most of the bulletins, weather conditions were not reported. Not reported conditions were considered to represent “Good Weather”; situations where weather did not affect response activity. In a number of events it was specifically mentioned that weather was bad and the probability of each of the two conditions is:

Good = 0.83
Bad = 0.17

To estimate response time, i.e. the time it took helicopters to reach the site of emergency the average of reported response time in each location was derived. The time to reach location in hours is:

Far West = 4.7 h (average of reported time in 46 cases)
Near West = 1.5 h (average of reported time in 33 cases)
Far East = 6.2 h (average of reported time in 13 cases)
Near East = 2.5 h (average of reported time in 8 cases)

3.4.2 Evaluative Information

The following information was not extracted from news bulletins but is purely evaluative.

Difficult weather conditions are quite common in the search and rescue region and since weather is a big factor in response activity, an increased response time must be expected. Icelandic response actors are however very well trained and experienced in hard conditions. So extra time in bad weather is only considered to be one hour, which increases previously reported numbers to:

Far West = 5.7 h
Near West = 2.5 h
Far East = 7.2 h
Near East = 3.5 h

The survival time of people in hazardous incidents at sea is a number that is very difficult to evaluate. It was decided here to have two categories, representing good preparedness and poor preparedness. What good preparedness entails is the crew's knowledge of emergency plans and proper response, availability of emergency equipment; flares, rescue dress and lifeboats. Poor preparedness represents the lack of such knowledge and equipment. The survival time in hours for each instance was therefore estimated to be:

Good preparedness = 8 h
Poor preparedness = 1.5 h

Since good preparedness seems to be dominant in the reviewed cases the probability of each instance of crew's preparedness is estimated:

Good preparedness = 0.85
Poor preparedness = 0.15

3.4.3 Results

From the basic and evaluative information given in parts 3.4.1 and 3.4.2 the following tables were generated:

Weather		Preparedness		Probability of Scenario	Frequency of Scenario	Helicopter Rescue Frequency [1]	Other Equipment Rescue Frequency [2]	Equipment capacity failure frequency [3]	Time to Death	Time to Rescue	Time capacity **given two helicopters**
Good	0.83	Good	0.85	0.32	3.60	1.18	0.07	2.35	8.0	4.7	OK
Good	0.83	Bad	0.15	0.06	0.64	0.21	0.01	0.42	1.5	4.7	Not OK
Bad	0.17	Good	0.85	0.07	0.74	0.24	0.01	0.48	8.0	5.7	OK
Bad	0.17	Bad	0.15	0.01	0.13	0.04	>0.01	0.09	1.5	5.7	Not OK
Sum:					**5.11**	**Equip. Success: 1.76**		**Fail: 3.34**			

Table 7: Location Far West, Probability = 0.46. Two helicopter crews minimum. Expected fatalities = 13.5 per year

Table 7 Results
Equipment and time criteria met: 1.5 instances per year
Equipment and time criteria not met: 3.6 instances per year
This means that in seven out of every ten events in the Far West area, design criteria will NOT be met.
70 % expected failure.

1) Frequency of successful response with two helicopters per year
2) Frequency of successful response without helicopter per year
3) Frequency of equipment capacity failure per year, i.e. one helicopter

Weather		Preparedness		Probability of Scenario	Frequency of Scenario	Helicopter Rescue Frequency	Other Equipment Rescue Frequency	Equipment capacity failure frequency	Time to Death	Time to Rescue	Time capacity **given two helicopters**
Good	0.83	Good	0.85	0.09	1.02	0.33	0.02	0.67	8.0	6.2	OK
Good	0.83	Bad	0.15	0.02	0.18	0.06	>0.01	0.12	1.5	6.2	Not OK
Bad	0.17	Good	0.85	0.02	0.21	0.07	>0.01	0.14	8.0	7.2	OK
Bad	0.17	Bad	0.15	>0.01	0.04	0.01	>0.01	0.02	1.5	7.2	Not OK
Sum:					**1.45**	**Equip. Success: 0.49**		**Fail: 0.95**			

Table 8: Location Far East, Probability = 0.13. Two helicopter crews minimum. Expected fatalities = 3.8 per year.

Table 8 Results
Equipment and time criteria met: 0.42 instances per year
Equipment and time criteria not met: 1.02 instances per year
This means that in seven out of every ten events in the Far East area, design criteria will NOT be met.
70% expected failure.

Weather		Preparedness		Probability of Scenario	Frequency of Scenario	Helicopter Response Frequency	Other Equipment Response Frequency	Time to Death	Time to Rescue	Time capacity
Good	0.83	Good	0.85	0.23	2.58	1.52	1.06	8.0	1.5	OK
Good	0.83	Bad	0.15	0.04	0.46	0.27	0.19	1.5	1.5	OK
Bad	0.17	Good	0.85	0.05	0.53	0.31	0.22	8.0	2.5	OK
Bad	0.17	Bad	0.15	0.01	0.09	0.06	0.04	1.5	2.5	Not OK
Sum:					3.66	Equip. Success: 3.66				

Table 9: Location Near West, Probability = 0.33. One helicopter crew minimum. Expected fatality < 1 per year.

Table 9 Results
Equipment and time criteria met: 3.57 instances per year
Equipment and time criteria not met: 0.10 instances per year
This means that in three out of every hundred events in the Near West area, design criteria will NOT be met.
3% expected failure.

Weather		Preparedness		Probability of Scenario	Frequency of Scenario	Helicopter Response Frequency	Other Equipment Response Frequency	Time to Death	Time to Rescue	Time capacity
Good	0.83	Good	0.85	0.06	0.63	0.37	0.26	8.0	2.5	OK
Good	0.83	Bad	0.15	0.01	0.11	0.07	0.05	1.5	2.5	Not OK
Bad	0.17	Good	0.85	0.01	0.13	0.08	0.05	8.0	3.5	OK
Bad	0.17	Bad	0.15	>0.01	0.02	0.01	0.01	1.5	3.5	Not OK
Sum:					0.89	Equip. Success: 0.89				

Table 10: Location Near East, Probability = 0.08. One helicopter crew minimum. Expected fatality < 1 per year.

Table 10 Results
Equipment and time criteria met: 0.76 instances per year
Equipment and time criteria not met: 0.14 instances per year
This means that in sixteen out of every hundred events in the Near East area, design criteria will NOT be met.
16% expected failure.

3.4.4 Conclusion

The calculations presented in the tables above clearly show that in these kinds of emergencies, two helicopters are crucial. For the Far West and Far East cases failure will be reduced from 70% to 15% and 16% respectively by ensuring two helicopter crews year round. Furthermore, in all four tables it can be seen that if the appropriate equipment criterion is fulfilled and the crew has a good level of preparedness, the time constraints will be met. This is a very positive and important point to make as it indicates that with proper resources and best available technology, the system is successful.

The equipment criterion is met in all the “Near” cases, but it’s only met in one third of the “Far” cases. That means that equipment capacity failure will be a fact in 4.3 events of the average 11.1 events per year. The correction of this deficit is crucial. The time criterion is a collateral damage in instances of equipment capacity failure. Bearing this in mind there are two major factors harming the system’s capacity at this time.

If a second helicopter crew was established and therefore the equipment criterion would be met at all times, the number of cases of unsuccessful response would plummet down to 1.2 per year. Those failures would be solely related to the bad preparedness of the crew. The focus of the system could then shift towards eliminating unprepared crews. The goal of civil protection systems is not only to respond to emergencies, but also to inform and enlighten its public. So even though crew preparedness is considered to be good in great majority of instances, given the value of 85% here, there is still improvement to be made by raising the risk awareness of all companies and individuals having activities in the search and rescue region.

4. DISCUSSION

The goal of this final chapter of the project is to summarize and discuss the process and results of the study. The project was divided into two parts, the first part was a theoretical study on emergency capacity assessment and the second part was a case study where the findings of part one were applied to assess the Icelandic response system's capacity when it comes to emergencies in the Icelandic search and rescue region at sea. The discussion will therefore begin by reverting back to the research question:

How is emergency and disaster management capacity evaluated and does the Icelandic response system have an acceptable capacity when it comes to emergencies in its search and rescue region?

To answer the research question it will be divided into two parts:

Part One: How is emergency and disaster management capacity evaluated?

Part Two: Does the Icelandic response system have an acceptable capacity when it comes to emergencies in its search and rescue region?

Each part will be discussed individually below.

4.1 Part One

Risk managers are assessing capacity every day in all levels of society, in order to plan and prepare for mitigation of emergencies. This is an essential part of all of their work because without knowing the capacity of a system all response design will be a shot in the dark and improvement inadequately substantiated. Despite this, the first prominent realization one is faced with when researching emergency capacity assessment is that there's no generally accepted approach attached to it. In fact, literature on the subject is astoundingly scarce and disparate. Note that the search for a common approach should not be confused with the demand for a holistic assessment model for the whole field of emergency capacity, which in this project is argued to be quite a dangerous goal. (See Chapter two, 2.3 Summary) The goal of a common approach would more appropriately cast focus on analytic capacity assessment and therefore more likely yield the best approach at each time. It would raise the standard of capacity assessment work and give a foundation for intersystem comparison. As of now there is however no such dialogue and a general answer to the research question would therefore be: It is evaluated on a case-by-case basis without a common framework or general consensus on the approach.

Since that is not a particularly enlightening answer the next step is to see whether the actual approaches can be divided into different schools of thought or whether there are some strong trends followed. There are indeed. The literature study showed that available emergency capacity assessment methods and models can be divided into two categories: index methods and non-index methods. The index methods all have in common the procedure of giving numerical values to assigned indicators and from there derive a single number index to symbolize capacity. The grounds for rejecting this method are given in chapter two but its biggest downfall is its lack of regards for the fact that systems cannot be solely explained as sum of their parts. The three remaining non-index models also had common features in dividing capacity into levels or sets and then focusing on certain aspects within each set. This is a more open approach but it has very little operational value since it acts more as a memo to risk

managers on the complexity of the system rather than tell how to tackle that complexity.
The dissatisfaction with available methods led to a deeper examination of the concept of capacity and from there an adoption of decision analysis. That approach is based on the fact that emergency response systems fall under the realm of design science. It has three steps: to establish design criteria, find possible design alternatives that accomplish the goals of that criteria and finally evaluate the alternatives based upon how well they solve the problem. But before that can be done, one must know the system at hand and so emergency capacity was defined as the answer to three questions:

What can happen when an actor is performing a specific task given a specific context?

How likely is it?

What are the consequences for the performance measures defined for that particular task?

These questions were used in the expert interviews conducted for part two, to get a clear picture of the system.

4.2 Part Two

After choosing a setting for the case study, an introduction of the Icelandic system was given. Further narrowing the focus, one of the more sensitive areas of the system was chosen for examination, namely its emergency capability when it comes to response in the search and rescue region at sea. There are of course numerous things that can go wrong in that region and in trying to capture the most serious disturbances; two broadly inclusive umbrella scenarios were selected. Those scenarios were; hazard to human lives and environmental hazard. Because of the considerable difference in response depending on the amount of lives at risk, the case of hazard to human lives was moreover divided into two scenarios; up to a couple of dozen people and up to thousands. From there, the decision analysis approach was assumed and in complying with that, design criteria were established. Two factors were deemed the most relevant aspects of capacity in the scenarios chosen for the Icelandic system: time and equipment. Capacity is therefore represented by appropriate equipment and actions that reduce response time and the goal was to find design alternatives that required the shortest amount of time to get appropriate equipment on site.
An acceptable capacity is represented by every suitable design alternative but it was clear early on that there were not many alternatives to choose from when fulfilling this criteria. When it comes to hazard to human lives there is no available design alternative that can offer swift assistance in the entire search and rescue region in all weather conditions. Rescue vessels and nearby ships are slow responders and would only be close enough to reach the emergency site within hours by chance. Helicopters on the other hand have limited flight range and are not operable in fog and other extreme conditions with reduced visibility.
If the few areas out of helicopter flight range were excluded as well as the relatively rare weather conditions that render them inoperable, it can be said that in the instance of fewer people, the timeframe for response is unacceptable two thirds of the time. With only one helicopter crew available, resulting in miniscule flight range compared to the vastness of the area, options would be to either contact the closest ships or try to get a fully manned second crew. Both options are poor as luck would be the biggest factor determining the time. A suitable design alternative is obtained one third of the

time when there are two helicopter crews on call. Their flight range is much greater, covering big portions of the search and rescue region. The most important source of improvement would therefore be to ensure that two helicopter crews are on call at all times.

There are no such small system adjustments to be made in the instance of more people. Capability in that situation is completely unsatisfactory. That is however not because of the lack of planning or expertise of Icelandic response actors, nor even the lack of equipment, it primarily has to do with the almost unmanageable risk captains of passenger ships take by traveling solo to places of extreme isolation and difficult weather. Equipment needed to rescue thousands of people would only be in the form of rescue vessels and as was said above, they can take days to get on site. Apart from that, it is unreasonable to expect a nation of 300 thousand people to have rescue vessels with suitable space for thousands of suffering passengers.

Despite the seriousness of the situation, there is a solution. A suitable design alternative would be to oblige all passenger ships wishing to enter the search and rescue region to travel two and two together. Then there would always be lifeboats and facilities within a certain distance.

In the case of environmental hazard, the purpose of the system is not to be responsible for full cleanup. Such actions are part of international agreements and there are active contracts with both the Nordic countries, the EU and the United States. These contracts ensure access to vessels and other equipment for ocean cleanup. The Icelandic responsibility lies therefore within monitoring, quick activations of international actors, first aid and prevention, such as advising captains on natural conditions. TF-SIF presents a suitable design alternative for monitoring and with the arrival of Thor the same can be said of first aid cleanup. Improvement is however needed in international traffic report system to facilitate stronger information distribution and therefore better prevention.

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Experts

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APPENDIX A

A.1 Local Institutional Capacity Evaluation (Briscoe 2004)

– Minor adjustments have been made

<u>The capacity to access and manage resources</u>

1. Management practices: management of human, financial and technical resources, organizational learning, strategic planning.

Indicator	**Rationale**	**Operational Definition**
Employee Evaluations	Employee evaluations promote the quality of human resource management which in turn promotes proper use of financial resources leading to higher institutional capacity	Not Available (N/A)
Budgetary performance	Strong economic performance indicates high institutional capacity	N/A

2. Human resources: availability of skilled and knowledgeable labor force, effective recruitment and training procedure.

Indicator	**Rationale**	**Operational Definition**
Multilingualism	Multilingualism of workers indicates institutional capacity to respond to multi-cultural public and to access and share intra/international resources.	Percentage of bilingual individuals […]
Education	Level of education is an indicator of skills and knowledge. Specialized and professional education and training are recognized as indicators of institutional capacity	Percentage of individuals with a post-secondary education […]
Highly skilled workers	Indicates extent of highly skilled human resources available to institutions which, in turn, contributes to local institutional capacity	Percentage of workers employed in intellectual and managerial occupations […]
Self-Employment	Individuals who are self-employed are not working in institutions, thus negatively affecting local capacity	Percentage of workers who are self-employed […]

3. Financial resources: ability to secure and mobilize funding, adequacy of financial resources available.

Indicator	**Rationale**	**Operational Definition**
Provincial spending on education, health and social services	Indicates relative level of financial support and importance placed on institutional activity by provincial government	N/A
Provincial and municipal spending on labor and employment	Indicates relative level of financial support and importance placed on institutional activity by provincial and local levels ot government	N/A

4. Technical resources: application of technical knowledge, access to information, technology and research

Indicator	**Rationale**	**Operational Definition**
Computer access	Availability and use of computers indicates the speed and ease of access to information as well as the efficiency of inter- and intra-institutional communication practices which contributes to high local institutional capacity	N/A
Business high tech and	Availability and use of high-tech and computer applications indicates the speed and ease of access to	N/A

computer software applications	information, application of technical knowledge as well as the efficiency of inter- and intra-institutional communication practices which contributes to high local institutional development	
Institutional research and development spending	Indicates application of technical knowledge and investment in research for institutional development	N/A

The capacity to carry out key functions

5. Performance of key functions: provision of services, products, constituency empowerment, contribution to social progress and well-being

Indicator	Rationale	Operational definition
Education	Presence of employment in education sector indicates the local existence of key institutions to carry out valued functions as well as recruit, train and employ workers which contributes to high institutional capacity	Percentage of workers employed in education […]
Government	Presence of employment in government indicates the local existence of key institutions to carry out valued functions as well recruit, train and employ workers which contributes to high institutional capacity	Percentage of workers employed in government […]
Health and social services	Presence of employment in health and social service sector indicates the local existence of key institutions to carry out valued functions as well recruit, train and employ workers which contributes to high institutional capacity	Percentage of workers employed in helath and social services […]

The capacity to initiate structural changes and ensure sustainability

6. Governance: legal structure, impact of policies and laws affecting institutional governance and inter-/intra-institutional relations

Indicator	Rationale	Operational Definition
Institutional Internal Reforms	Indicates capacity to govern autonomously and that organizational learning is taking place which is a strong indicator of high institutional capacity	N/A

7. External relations: networks with other institutions and stakeholders, public relations

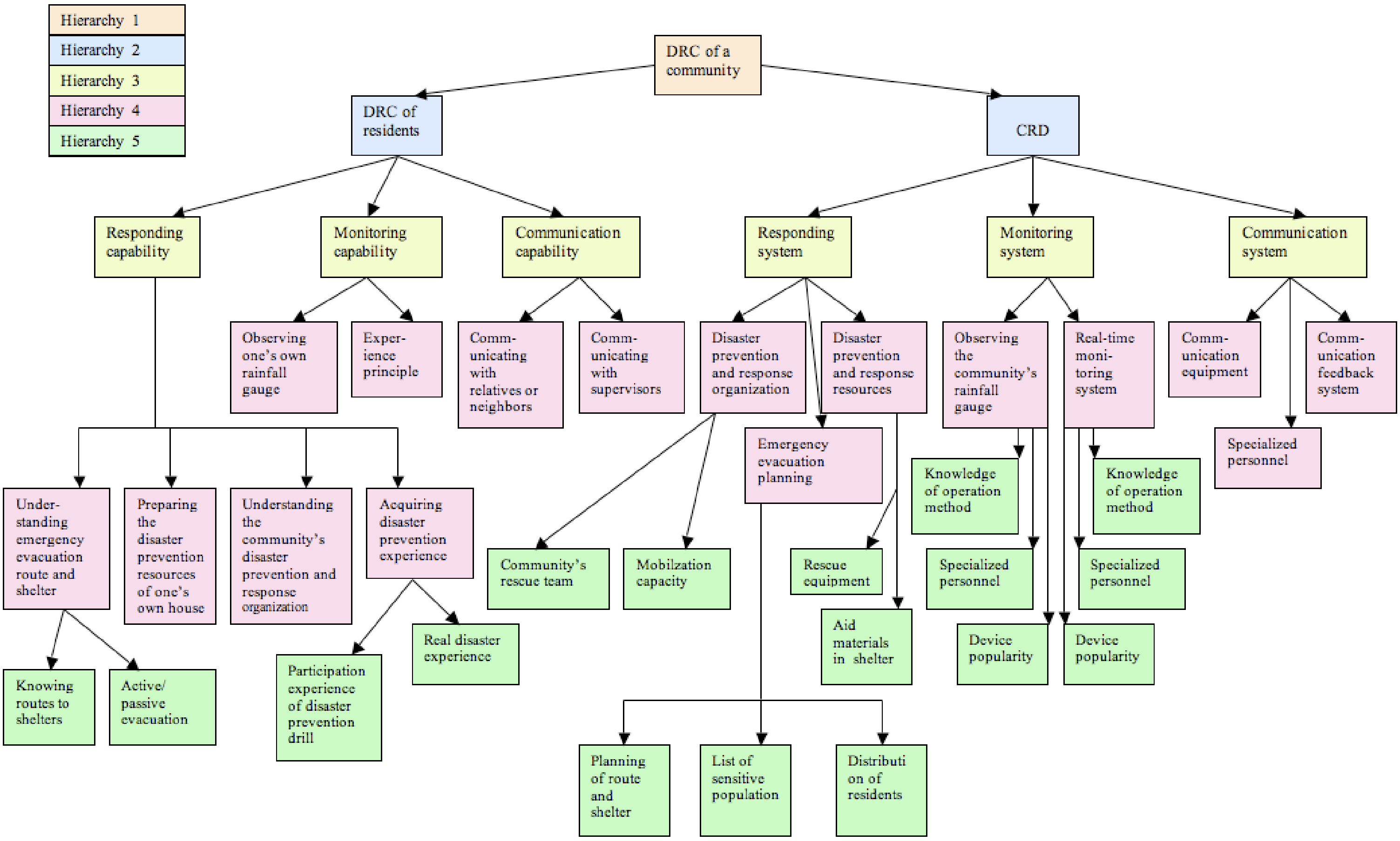
Indicator	Rationale	Operational Definition
Collaborative Initiatives and Valued Outcomes	Emphasis is given throughout the literature to the importance of networks between institutions and desired valued outcomes which are both strong indicators of local institutional capacity	N/A
Media representations of institutional effectiveness	Indicates how the public perceives (both positively and negatively) the performance of institutions which is also an indicator of local institutional capacity	N/A

8. Sustainability: leadership, institutional autonomy, organizational learning, security of revenue/funding sources, niche management

Indicator	Rationale	Operational Definition
Employee assessments of leadership quality	Interviews or surveys of institution’s employees about the quality of leadership and examples of organizational learning	N/A
Municipal and provincial funding	Amount of money municipalities and provinces direct towards institutions is an indicator of local institutional capacity	N/A

Local Institutional Capacity Index Formulation
Local Institutional Capacity (LIC) =
+ % of bilingual individuals (CSD level)
+ % with a post-secondary education (CSD)
+ % employed in intellectual and managerial occupations (CCS)
+ % self-employed workers (CSD)
+ % employed in education (CCS)
+ % employed in government (CCS)
+ % employed in health and social services (CCS)

A.2 Resilient Capacity Assessment Method (Chen 2009)



A.3 Disaster Risk Management Performance Index (Carreño 2007)

RI1	Systematic disaster and loss inventory	w_{RI1}
RI2	Hazard monitoring and forecasting	w_{RI2}
RI3	Hazard evaluation and mapping	w_{RI3}
RI4	Vulnerability and risk assessment	w_{RI4}
RI5	Public information and community participation	w_{RI5}
RI6	Training and education on risk management	w_{RI6}

RMI_{RI}

RR1	Risk consideration in land use and urban planning	w_{RR1}
RR2	Hydrographical basin intervention and environmental protection	w_{RR2}
RR3	Implementation of hazard-event control and protection techniques	w_{RR3}
RR4	Housing improvement and human settlement relocation from prone-areas	w_{RR4}
RR5	Updating and enforcement of safety standards and construction codes	w_{RR5}
RR6	Reinforcement and retrofitting of public and private assets	w_{RR6}

RMI_{RR}

DM1	Organization and coordination of emergency operations	w_{DM1}
DM2	Emergency response planning and implementation of warning systems	w_{DM2}
DM3	Endowment of equipments, tools and infrastructure	w_{DM3}
DM4	Simulation, updating and test of inter institutional response	w_{DM4}
DM5	Community preparedness and training	w_{DM5}
DM6	Rehabilitation and reconstruction planning	w_{DM6}

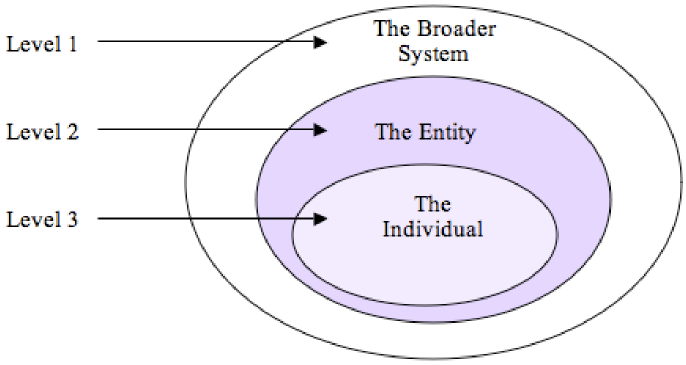
RMI_{DM}

FP1	Interinstitutional, multisectoral and decentralizing organization	w_{FP1}
FP2	Reserve funds for institutional strengthening	w_{FP2}
FP3	Budget allocation and mobilization	w_{FP3}
FP4	Implementation of social safety nets and funds response	w_{FP4}
FP5	Insurance coverage and loss transfer strategies of public assets	w_{FP5}
FP6	Housing and private sector insurance and reinsurance coverage	w_{FP6}

RMI_{FP}

RMI

A.4 Public Health Emergency Response Capacity (Hu 2005)



1. **The systems level:**

a. *Policy*: systems have a purpose; they exist to meet certain needs of society or a group of entities. Also included are value systems, which govern the entities within the system
b. *Legal/regulatory*: includes the rules, laws, norms, or standards that govern the system and within which a capacity initiative is to function
c. *Management or accountability*: defines who manages the system and what entities or stakeholders function within the system. From a capacity development perspective, this would identify who is responsible for potential design, management and implementation, coordination, monitoring and evaluation, and all other related capacities at the systems level
d. *Resources:* (human, financial, information) that may be available within the system to develop and implement the program and/or the capacities
e. *Process*: the interrelationships, interdependencies, and interactions among the entities, including the fact that these may comprise subsystems within the overall system.

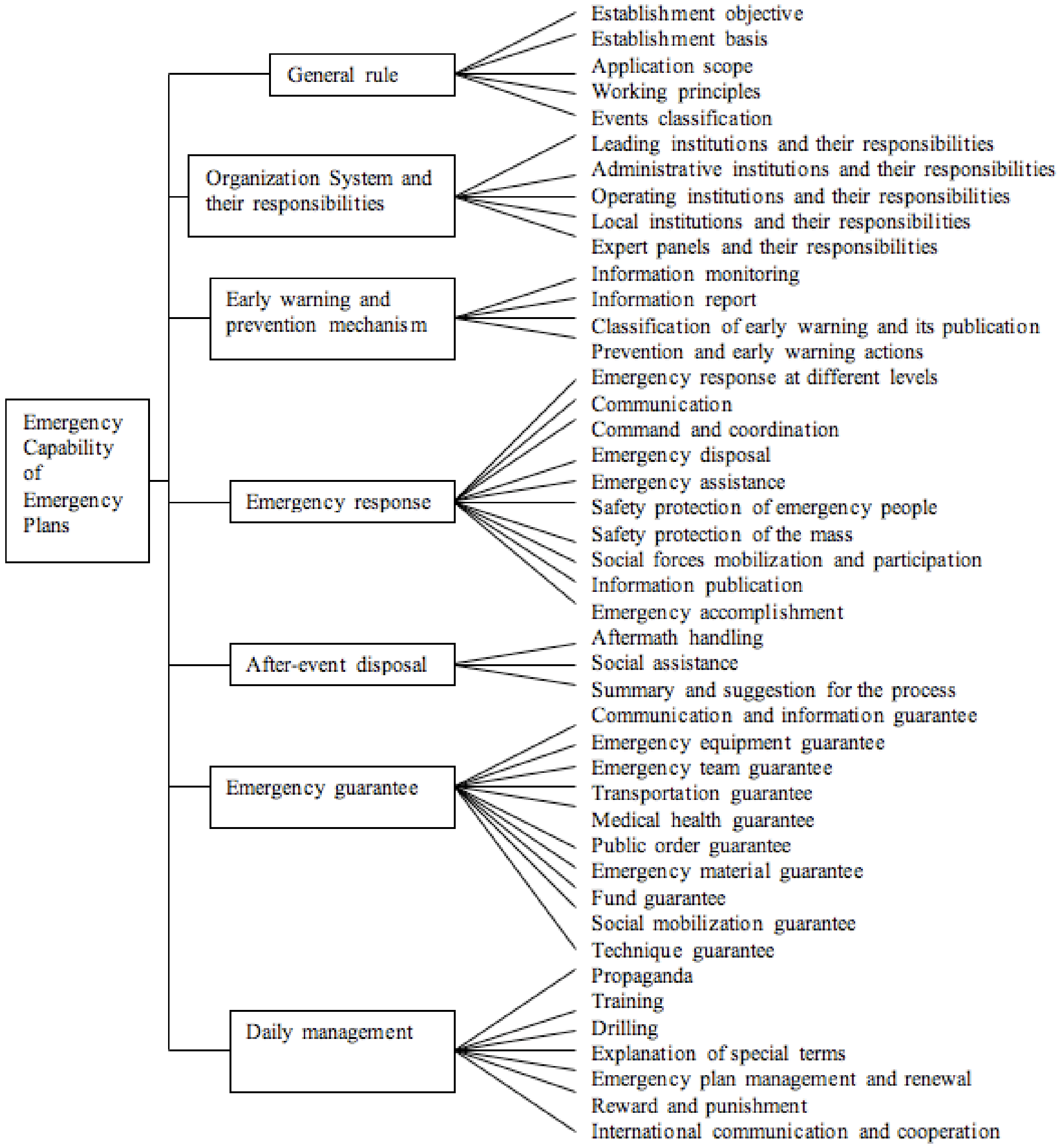
2. **The entity or organization level:**

a. *Mission and strategy*: include the role, mandate, and definition of products/services; clients/customers served; interactions within the broader system and “stakeholders;” the measures of performance and success; and the presence of core strategic management capacities
b. *Culture/structure and competencies*: organizational and management values, management style, and standards, organizational structures and designs, core competencies
c. *Processes*: supporting such functions as planning, client management, relationships with other entities, research/policy development, monitoring and evaluation, performance/quality management, financial and human resources management, etc.
d. *Human resources*: the most valuable of the entity’s resources and upon which change, capacity, and development primarily depend
e. *Financial resources*: both operating and capital, required for the efficient and effective functioning of the entity
f. *Information resources:* of increasing importance, and how these resources (all media, electronic and paper) are managed to support the mission and strategies of the entity
g. *Infrastructure:* physical assets (property, buildings, and movable assets), computer systems and telecommunications infrastructures, productive work environments.

3. The individual level:

a. Job requirements
b. Training/retraining
c. Career progression
d. Access to information
e. Performance/conduct incentives/security
f. Values and attitudes
g. Interrelationships and teamwork interdependencies
h. Work redeployment
i. Professional integrity

A.5 Evaluation Index System (Yang [2] 2008)



A.6 Synthetic Evaluation Indicators System (Xiong 2007)

The synthetic evaluation indicators system of city public department emergency management		
	First-level indicators	Second-level indicators
Foundation safeguard	Legal construction	Emergency law Emergency rescue management rules Government law and standard
	Emergency information system construction	Construction level of City emergency platform
	Emergency safeguard capability	Training and education of professional contingent Donation management of social belongings Establishment of local relief materials storehouse Purchase and R&D situation of rescue equipment Setting up of emergency reserve
Organization system	Organization command capability	Management structure Emergency center Professional contingent
	Society control capability	Designing of city disaster prevention plan Training condition of publicity, education, […] public's emergency knowledge Design and implementation of government's emergency management policy
Operation of emergency	Monitoring and early warning capability	Emergency information system […] Investigating capability of […] risk and hidden danger Construction […] of early warning […] Monitoring network system […]
	Rescue handling capability	Condition of construction […] of disaster rescue system […] Training condition of specialized rescue team […] Resource allocation in the process of disaster rescue Scale and training condition of the volunteer disaster relief organization Condition of construction […] of disaster emergency management organization system
	Restore reconstruction capability	Reconstruction capability […] Construction of after disaster reconstruction center Emergency refuge and the construction of urgent evacuation exit
	Predetermined plan establishment	

APPENDIX B

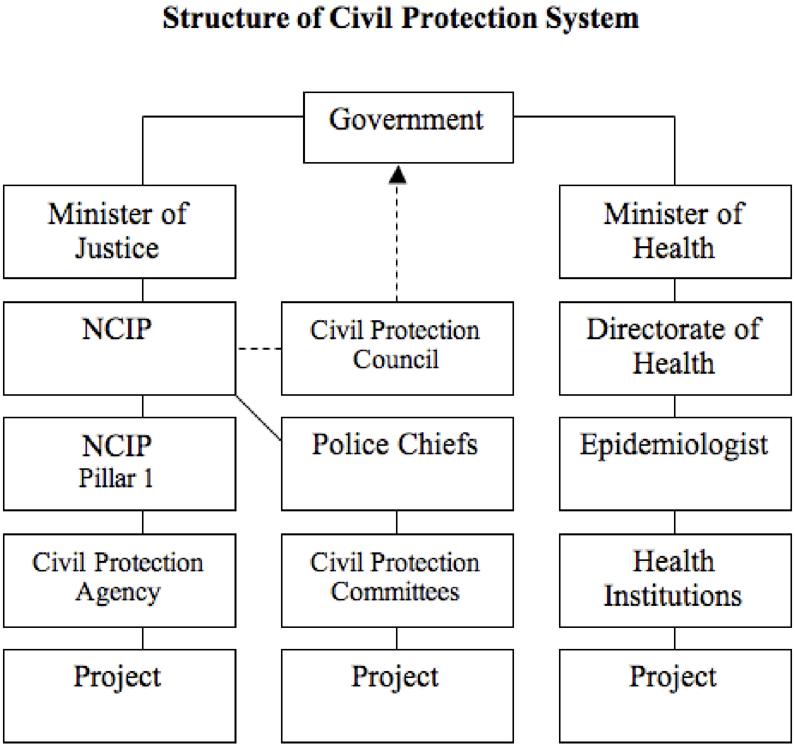


Figure B.1: Public Administration Structure of Civil Protection in Iceland


Figure B.2: The Icelandic search and rescue region.

Members of Rescue Centre under NCIP Pillar 1

Actor	Description	Objectives
NCIP	In charge of Rescue centre and director of operations on land.	Manpower and equipment for: all general police work.
Civil Protection Agency	Organizes and implements measures to protect the wellbeing and safety of the public, environment and property.	Prevention, preparedness and reductions of hazards and recovery from disasters, caused by natural or manmade hazards, pandemics, military action or other types of disasters.
Icelandic Coast Guard	Director of operations at sea and general policing of the ocean around Iceland.	General policing, search and rescue, surveillance and assistance in the execution of civil defense.
SHS	The Capital District Fire and Rescue Service works on fire prevention and provides first response in protecting people's lives, health, environment and property.	Manpower and equipment for: fire fighting, emergency medical transport, fire safety and protection, environmental accident response and civil defense.
Ice-Sar	Volunteers in search and rescue on land and at sea.	Manpower, search and rescue equipment for land and sea.
Red Cross	Provide care to those affected by emergencies.	Mass relief and social assistance, including the management of relief centers and provision of temporary housing.

Figure B.3: Permanent actors in the Rescue Centre. All located in the same building in Reykjavik.

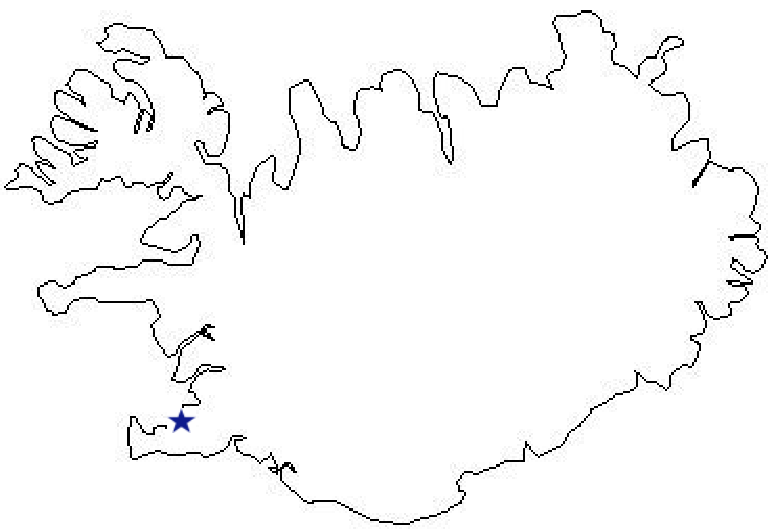


Figure B.4: Blue star shows Reykjavik on a map of Iceland

APPENDIX C

From Interviews to Design Alternatives

When applying the decision analysis method to the case study, I first of all requested interviews with all the main actors in the Icelandic response system. Fortunately I had the opportunity to meet with most of them for in depth discussions. I started the interviews by asking the three questions corresponding to the capacity triplet:
*What can happen when an actor is performing a specific task given a specific context?
*How likely is it?
*What are the consequences for the performance measures defined for that particular task?
The context being referred to is what has been described as the setting of the case study, i.e. emergencies in the Icelandic Search and Rescue Region and the “task” has quite a broad reference, having to do with activities that include risk to both human lives and nature.
These are quite broad questions, as they must be since I was dealing with such a dynamic system, so for support and clarification, I asked some more direct support questions, such as:
What is the purpose of the system?
What kinds of events are within your scope?
How far, geographically speaking, does your responsibility reach?
What are the effects of weather conditions on response work?
What is appropriate equipment?
How long does it take you to get to accidents within the search and rescue region? And so on.
From there, the interviews took on the form of more general discussions, where smaller nuances of the system’s structure were given attention. After finishing and reviewing all the interviews I considered myself to have obtained a holistic view of the system and could start constructing design alternatives. This was quite a creative process, not relying on systematic procedures but more contemplating all alternatives in accordance with the experts’ views. Along the way, some additional information was needed and it was obtained either by contacting the interview subjects again or through reports and legislation texts.

APPENDIX D

A formula view of the Excel worksheet used to give results displayed in Tables 7, 8, 9 and 10

	A	B	C	D	E	F	G	H	I	J	K	L
3	**Location Far West**			**probability**		**0.46**						
4	**weather**			**preparedness**	**probability of scenario**	**frequency of scenario per year**	**frequency of successful response without helicopter per year**	**frequency of equipment capacity failure per year, i.e. one helicopter**	**frequency of appropriate equipment capacity per year**	**Time to Death**	**Time to Rescue**	**Time capacity OK or not OK given two helicpters**
5	Good	0.83	Good	0.85	=$F$3*B5*D5	=$E$38*E5	=$E$40*F5	=(F5-G5)*$B$44	=(F5-G5)*$B$43	8	4.7	=IF(J5<K5, "Not OK", "OK")
6	Good	0.83	Bad	0.15	=$F$3*B6*D6	=$E$38*E6	=$E$40*F6	=(F6-G6)*$B$44	=(F6-G6)*$B$43	1.25	4.7	=IF(J6<K6, "Not OK", "OK")
7	Bad	0.17	Good	0.85	=$F$3*B7*D7	=$E$38*E7	=$E$40*F7	=(F7-G7)*$B$44	=(F7-G7)*$B$43	8	5.7	=IF(J7<K7, "Not OK", "OK")
8	Bad	0.17	Bad	0.15	=$F$3*B8*D8	=$E$38*E8	=$E$40*F8	=(F8-G8)*$B$44	=(F8-G8)*$B$43	1.25	5.7	=IF(J8<K8, "Not OK", "OK")
10												
11	**Location Far East**			**probability**		**0.13**						
13	**weather**			**preparedness**	**probability of scenario**	**frequency of scenario per year**	**frequency of successful response without helicopter per year**	**frequency of equipment capacity failure per year, i.e. one helicopter**	**frequency of appropriate equipment capacity per year**	**Time to Death**	**Time to Rescue**	**Time capacity OK or not OK given two helicpters**
14	Good	0.83	Good	0.85	=$F$11*B14*D14	=$E$38*E14	=$E$40*F14	=(F14-G14)*$B$44	=(F14-G14)*$B$48	8	6.2	=IF(J14<K14, "Not OK", "OK")
15	Good	0.83	Bad	0.15	=$F$11*B15*D15	=$E$38*E15	=$E$40*F15	=(F15-G15)*$B$44	=(F15-G15)*$B$4	1.25	6.2	=IF(J15<K15, "Not OK", "OK")
16	Bad	0.17	Good	0.85	=$F$11*B16*D16	=$E$38*E16	=$E$40*F16	=(F16-G16)*$B$44	=(F16-G16)*$B$48	8	7.2	=IF(J16<K16, "Not OK", "OK")
17	Bad	0.17	Bad	0.15	=$F$11*B17*D17	=$E$38*E17	=$E$40*F17	=(F17-G17)*$B$44	=(F17-G17)*$B$4	1.25	7.2	=IF(J17<K17, "Not OK", "OK")
19												
20	**Location Near West**			**probability**		**0.33**	one helicopter	enough				
22	**weather**			**preparedness**	**probability of scenario**	**frequency of scenario per year**	**frequency of successful response without helicopter per year**	**frequency of helicopter response**	**Time to Death**	**Time to Rescue**	**Time capacity**	
23	Good	0.83	Good	0.85	=$F$20*B23*D23	=$E$38*E23	=$E$41*F23	=F23-G23	8	1.5	=IF(I23<J23, "Not OK", "OK")	
24	Good	0.83	Bad	0.15	=$F$20*B24*D24	=$E$38*E24	=$E$41*F24	=F24-G24	1.25	1.5	=IF(I24<J24, "Not OK", "OK")	
25	Bad	0.17	Good	0.85	=$F$20*B25*D25	=$E$38*E25	=$E$41*F25	=F25-G25	8	2.5	=IF(I25<J25, "Not OK", "OK")	
26	Bad	0.17	Bad	0.15	=$F$20*B26*D26	=$E$38*E26	=$E$41*F26	=F26-G26	1.25	2.5	=IF(I26<J26, "Not OK", "OK")	
27												
28	**Location Near East**			**probability**		**0.08**	one helicopter	enough				
30	**weather**			**preparedness**	**probability of scenario**	**frequency of scenario per year**	**frequency of successful response without helicopter per year**	**frequency of helicopter response**	**Time to Death**	**Time to Rescue**	**Time capacity**	
31	Good	0.83	Good	0.85	=$F$28*B31*D31	=$E$38*E31	=$E$41*F31	=F31-G31	8	2.5	=IF(I31<J31, "Not OK", "OK")	
32	Good	0.83	Bad	0.15	=$F$28*B32*D32	=$E$38*E32	=$E$41*F32	=F32-G32	1.25	2.5	=IF(I32<J32, "Not OK", "OK")	
33	Bad	0.17	Good	0.85	=$F$28*B33*D33	=$E$38*E33	=$E$41*F33	=F33-G33	8	3.5	=IF(I33<J33, "Not OK", "OK")	
34	Bad	0.17	Bad	0.15	=$F$28*B34*D34	=$E$38*E34	=$E$41*F34	=F34-G34	1.25	3.5	=IF(I34<J34, "Not OK", "OK")	
35												
36												
37	**Data:**											
38	frequency of events:				11.1	per year						
39	Likelihood of ship rescue:											
40	Far				0.02							
41	Near				0.41							
42	Number of helicopters	probability										
43	two	=1/3										
44	one	=2/3										
45												