Analytic Input to Societal Emergency Management - On the Design of Methods

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2009

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Doctoral thesis

Lund 2009

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Report 1043
ISSN 1402-3504
ISRN LUTVDG/TVBB--1043--SE
ISBN 978-91-628-7960-0

Number of pages: 75
Illustrations: Marcus Abrahamsson

Keywords: *emergency management, emergency preparedness, emergency response system, design, risk analysis, vulnerability analysis, values, preferences, evaluation.*

Abstract
Information from performed risk and vulnerability analyses, evaluation of responses in relation to actual emergencies etcetera can be very useful in efforts directed at preventing, mitigating and/or preparing for future emergencies. This thesis focuses on the development of methods for such analysis and evaluation. A general process for systematic design of methods is introduced and discussed and some of the main types of analytic input to societal emergency management are examined in terms of how methods for analysis should be constructed to fulfil their purpose. Furthermore, the importance of values and preferences in any design process is emphasised and two descriptive studies directed at investigating people's preferences regarding potential negative outcomes of unwanted events are presented.

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Summary

Societal emergency management includes a widespread variety of activities with various objectives ranging from preventive or mitigating efforts to activities undertaken to enhance the level of preparedness for different actors and systems to respond to and recover from unwanted events. Such activities can be informed by systematic investigation and analysis of for instance risks and vulnerabilities within the system of interest, e.g. a local municipality, by analysis and evaluation of the emergency response activities undertaken during actual emergencies etcetera. The present thesis is concerned with the design and development of methods for conducting such analyses and evaluations.

A process for development of methods is introduced, requiring a logic and transparent line of reasoning from the stated purpose of the method through the formulation of design criteria derived from the purpose to the actual construction of the method and subsequent evaluation. By use of this process, three methods have been constructed aiming at 1) generating input to preparedness activities in a local municipality, 2) generating information regarding how the emergency response system performed during an emergency, and 3) evaluating documented risk and vulnerability analyses in terms of fulfilment of their purpose. Design criteria pertaining to the respective methods have been developed and are argued for in relation to their respective purpose, and arguments regarding why the developed methods fulfil their respective criteria are put forward. The methods have all been applied in the respective context they are supposed to be used and an initial evaluation has been carried out, suggesting that they worked well even though some further developments are called for in future research activities. It is concluded that by explicitly describing how a suggested method fulfils its purpose, by use of the process referred to above, and exposing it to evaluation exercises, a strong basis for judging its effectives is provided.

Furthermore, one very important aspect of any design process is highlighted in the thesis, that of values and preferences. It is argued that the underlying values should always be made explicit when engaging in emergency management efforts, something that is reflected in the design criteria for the methods developed in the work behind the thesis. In addition, two descriptive studies directed at investigating people's preferences regarding negative outcomes of potential unwanted events are presented, whose results could serve as input to discussions regarding for instance the formulation of tolerability criteria regarding societal risk, and in situations where tradeoff considerations between various kinds of consequences are necessary, for instance when evaluating alternative emergency management measures aiming at reducing different types of consequences following an unwanted event.

Sammanfattning

Samhällelig olycks- och krishantering innefattar en mängd aktiviteter med olika syften, från rent förebyggande åtgärder till aktiviteter som syftar till att öka beredskapen hos olika aktörer och system att kunna akut hantera och återhämta sig från oönskade händelser. Underlag till sådana aktiviteter kan bestå av exempelvis information från analyser av risker och sårbarheter inom det system man är intresserad av, exempelvis en kommun, samt analyser och utvärderingar av hanteringen av tidigare inträffade nödlägen. Denna avhandling behandlar utveckling och design av metoder för att genomföra sådana analyser och utvärderingar.

En process för utveckling av metoder introduceras, vilken kräver ett logiskt och transparent resonemang utgående från metodens syfte, via formulering av designkriterier kopplade till syftet, till den faktiska utformningen av metoden och efterföljande utvärdering av den. Med utgångspunkt i denna process har tre metoder utvecklats med målsättning att 1) ta fram information att användas som underlag till beredskapsplanering i en kommun, 2) ta fram information avseende hur responssystemet fungerade och presterade under ett faktiskt nödläge, samt 3) utvärdera dokumenterade risk- och sårbarhetsanalyser avseende huruvida de uppfyller sitt syfte. Designkriterier för de olika metoderna har tagits fram och argumenteras för och en beskrivning ges avseende hur de utvecklade metoderna uppfyller kriterierna. Metoderna har alla använts och testats i den kontext de är avsedda att användas och en första utvärdering har genomförts som visar att de fungerar väl även om visst vidare utvecklingsarbete föreslås. En slutsats av detta arbete är att genom att tydligt beskriva hur en föreslagen metod uppfyller sitt syfte, med utgångspunkt i processen ovan, och genom att utvärdera den baserat på användning i den kontext den är avsedd att användas så skapar man en god grund för att kunna uttala sig om dess användbarhet och nytta.

En mycket viktig aspekt av alla designprocesser, till exempel utformning av metoder eller riskreducerande åtgärder, är de värderingar och preferenser som ligger till grund för arbetet. Dessa bör alltid lyftas fram och göras tydliga, något som avspeglas i de designkriterier som tagits fram för metoderna ovan. Dessutom presenteras i avhandlingen två studier avsedda att undersöka människors preferenser avseende oönskade händelsers potentiella negativa konsekvenser. Resultaten från dessa studier kan användas exempelvis som underlag till diskussioner kring formulering av kriterier för tolerabel samhällsrisk och i situationer där avvägningar måste göras mellan olika riskreducerande åtgärder som syftar till att reducera olika typer av konsekvenser av oönskade händelser.

Acknowledgements

This thesis would not have been possible without the substantial support and assistance that I have received during the last few years, and I would like to take the opportunity to express my sincere gratitude to a number of people and organisations.

First, I am grateful to the Swedish Civil Contingencies Agency and its predecessors the Swedish Emergency Management Agency and the Swedish Rescue Services Agency, for funding the research upon which the thesis is based.

A very special thank you goes to my present supervisors, Kurt Petersen and Henrik Tehler. Kurt, I really appreciate how you always make time to sit down and discuss whenever I feel the need to sort my mind out. Better yet, these discussions always help me see things clearer and you've been a great help in focusing the work behind the thesis. Henrik, your creativity, clarity of thought and extraordinary work capacity have helped me through some seemingly impossible situations and I sometimes feel you've quite literally pulled me through this process. It is a pleasure and a privilege to work with both of you.

I would also like to thank my former supervisor, Sven Erik Magnusson, for introducing me to the fascinating world of risk and emergency management a number of years ago. Furthermore, a warm thank you to Robert Jönsson, head of the Department of Fire Safety Engineering and Systems Safety, for creating a working environment which makes it a pleasure to come to work every day. Thank you also to the staff at the department who all contribute to making it the inspiring and challenging work place it is. I would especially like to thank Henrik Hassel for interesting discussions and extensive cooperation in research projects and Lars Fredholm for inspiring me to think about how knowledge from the area of risk analysis could come to better use in all phases of emergency management.

A special thanks to Olof Samuelsson at the Department of Industrial Electrical Engineering and Automation for constructive feedback on an earlier draft of the thesis.

I would also like to express my sincere gratitude to my parents, Ulla and Harald, and to relatives and friends who have offered tremendous support to me and my family over the years and especially during the process of finalising the thesis.

To my dearest friend and beloved wife Sofie, your everlasting love and support continues to amaze me. Nothing I write here could do you justice and I can only hope that you know how much I love you and appreciate all you have done. I am really looking forward to making it up to you…

Finally, to the greatest sources of inspiration I can imagine, Gabriel and Elmer; I love you more than anything and this book is entirely dedicated to you. You make it all worth while.

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1 Introduction

In large parts of the world, there has been an increased focus in recent years on emergency and crisis management to deal with potential future emergencies and crises in all sectors of society. In Sweden, this development has for instance led to new legislation, requiring public authorities on all levels to perform risk and vulnerability analysis within their respective sector or area of responsibility, and furthermore to develop plans and make preparations for the management of potential forthcoming unwanted events (SFS, 2003;2006a;b).

In this thesis, the term *analytic input* is used when discussing explicit documented information generated through a deliberate process with a specific purpose. Examples of analytic input to emergency management would include the outcome of risk and vulnerability analyses and structured analysis of past emergencies. A contrast would be tacit or implicit knowledge which is difficult to transfer to others by means of writing down or verbalising it, which still may influence activities in emergency management. The use of analytic input to the process of emergency management can be directed towards many different objectives. For instance, such input is frequently being used as basis for tolerability judgements, i.e. whether the level of risk in a certain system can be tolerated, for evaluating risk reduction measures and guiding decisions on investments in such measures and/or as input to emergency preparedness activities.

In this thesis, the issue of designing methods for such analytic input is highlighted, the guiding question at the most general level being whether the development of such methods could be conducted in a scientific manner. A general process for systematic design of methods is introduced, discussed and used to guide the development of a number of methods with various purposes. Furthermore, the importance of values and preferences in any design process is emphasised and two descriptive studies directed at investigating people's preferences regarding potential negative outcomes of unwanted events are presented.

The main work behind the present thesis has been performed in a research programme within this field, FRIVA (Framework Programme for Risk and Vulnerability Analysis), undertaken at Lund University Centre for Risk Assessment and Management, LUCRAM.

1.1 Outline of the thesis

In this section, an outline of the thesis is given to guide the reader regarding its content.

Background

The background describes the area of interest, terms and concepts of importance for the present thesis, the general motives behind the research, and provides the background to the research objectives and research questions that have guided the work.

Research objectives and research questions

This chapter introduces the main research objectives and the research questions formulated in order to work towards the objectives. Also the most important delimitations of the work are presented.

Research process and methods

The research process and methods chapter provides a short recapitulation of the process that has lead to this thesis and furthermore introduces the various methods and techniques used in the research conducted to address the research questions.

Research contributions

In this chapter a summary of the appended papers is given, alongside with a matrix describing the main perspective, types of research activity, methods used, study objects involved and the main results of each of the papers. This is followed by a section addressing and providing answers to the research questions and one summarising the results pertaining to the main research objectives.

Discussion

In this chapter implications of the results of the research behind the thesis are discussed alongside with implications of the delimitations of the work. In addition a discussion is held regarding relevant further research within this field.

Conclusions

In this chapter the main points of this thesis are summarised.

1.2 Publications

In this section the publications relevant for the present thesis, to which I have contributed, are listed.

1.2.1 Appended papers

The papers that form the basis for this thesis are listed below. The focus of papers I and II is on preferences regarding negative consequences following potential unwanted events, and the main focus of papers III-V is on the development of methods for various types of analytic input to societal emergency management. Within each focus area, the papers are listed chronologically.

Paper I Abrahamsson M. & Johansson, H. (2006) Risk preferences regarding multiple fatalities and some implications it has for societal risk decision making – an empirical study. *Journal of Risk Research,* Vol. 9, issue 7, pp. 703-715.

Paper II Hassel H., Tehler, H. & Abrahamsson, M. (2009) Evaluating the seriousness of disasters: an empirical study of preferences. *International Journal of Emergency Management,* Vol. 6, no. 1, pp. 33-54.

Paper III Abrahamsson M. et al (2007) Analytical input to emergency preparedness planning at the municipal level – a case study. In Jones, A. (Ed.) *Proceedings of Disaster Recovery and Relief: Current and Future Approaches (TIEMS 2007),* Trogir, Croatia, pp. 423-432.

Paper IV Abrahamsson, M., Tehler, H. & Hassel, H. Towards a system-oriented framework for analysing and evaluating emergency response. Accepted for publication in *Journal of Contingencies and Crisis Management*. To be published in Vol. 18, No. 1, 2010.

Paper V Abrahamsson, M. & Tehler, H. The role of risk and vulnerability analyses in emergency management systems – evaluating regional RVAs in the Swedish emergency management system. Paper for publication, submitted to an international journal.

Since all of the papers have been written in cooperation with one or more co-authors, an account of my contributions to each paper is given in section 5.1.

1.2.2 Related publications

In addition to the appended papers, I have contributed to a number of publications with relevance to the thesis. These publications are listed in reverse chronological order below.

Abrahamsson, M., Jönsson, H. & Johansson, H. (2008) Analyzing emergency response using a systems perspective. *Proceedings of PSAM9, Hong Kong, China.*

Eriksson, K., Abrahamsson, M. & Fredholm, L. (2007) An analysis of assistance needs during the storm Gudrun. In Jones, A. (Ed.) *Proceedings of Disaster Recovery and Relief: Current and Future Approaches (TIEMS 2007)*, Trogir, Croatia, pp. 65-72.

Jönsson, H., Abrahamsson, M. & Johansson, H. (2007) An operational definition of emergency response capabilities. In Jones, A. (Ed.) *Proceedings of Disaster Recovery and Relief: Current and Future Approaches (TIEMS 2007)*, Trogir, Croatia, pp.350-359.

Abrahamsson, M. & Johansson, H. (2007) *En studie av risker och sårbarheter i Stenungsunds kommun.* Report 1009, Lund University Centre for Risk Analysis and Management, Lund, Sweden. (Swedish)

Abrahamsson, M., Magnusson, S.E., & Petersen, K. (2004) Risk and vulnerability analyses in crisis management of extreme events – a pilot study. *Proceedings from Probabilistic Safety Assessment and Management PSAM7 - ESREL'04*, Berlin, Germany.

Abrahamsson, M. & Magnusson, S.E. (2004) *Användning av risk- och sårbarhetsanalyser i samhällets krishantering – delar av en bakgrundsstudie.* Report 1007, Lund University Centre for Risk Analysis and Management, Lund, Sweden. (Swedish)

Abrahamsson, M. & Magnusson, S.E. (2004) *Risk- och sårbarhetsanalyser: Utgångspunkter för fortsatt arbete.* KBM:s forskningsserie nr. 2, Krisberedskapsmyndigheten, Stockholm, Sweden. (Swedish)

Lundin, J., Abrahamsson, M. & Nilsson, J., (2003) *Översiktlig genomgång av "Länsprojekt Riskhantering" i Dalarnas län*. Report 7017, LTH Brandteknik, Lund, Sweden. (Swedish)

Abrahamsson (2002) *Uncertainty in Quantitative Risk Analysis – Characterisation and Methods of Treatment.* Licentiate thesis, Report 1024, Department of Fire Safety Engineering, Lund University, Sweden.

Abrahamsson, M., Johansson, H. & Magnusson, S.E. (2001) Methods for Treatment of Uncertainty in Quantitative Risk Analysis. *Proceedings of Safety, Risk and Reliability - Trends in Engineering (IABSE 2001)*, Valetta, Malta, pp 907-912.

Abrahamsson M. & Magnusson, S.E. (2000) Treatment of uncertainties in quantitative risk analysis. *Proceedings of ESREL 2000, SARS and SRA-Europe annual conference Foresight and Precaution*, Edinburg, Scotland, UK, pp. 1259-1266.

Abrahamsson, M. (2000) *Treatment of Uncertainty in Risk Based Regulations and Standards for Risk Analysis.* Report 3116, Department of Fire Safety Engineering, Lund University, Sweden.

2 Background

There are many forms of analytic input to society's efforts to deal with potential future emergencies, for instance risk and vulnerability assessments, analysis of past events and analysis of emergency response capabilities. All of these can serve as an important part of the foundation for a variety of different emergency management activities, ranging from decisions on preventive, mitigating or risk reducing measures to preparedness and emergency response capability enhancing activities. In this section, a brief introduction to the field is made alongside with a discussion on a design science perspective that has influenced much of the work and on some terms and concepts that are of importance in the thesis.

2.1 Analytic input to societal emergency management

The main topic of interest in this thesis is how different kinds of analytic input can be of use in societal emergency management. Before proceeding with a discussion on what might constitute emergency management, a couple of notes relevant for this concept should be made.

Firstly, there has been some debate regarding what could be considered an emergency and the relation to other terms such as disaster and crisis, e.g. (Quarantelli, 2000; Boin and t'Hart, 2006). It is not within the scope of the present thesis to contribute to this debate, rather a view in line with that adopted by Uhr (2009) will be taken in which emergencies, crises and disasters are all viewed as adverse situations where a series of events have given or can give rise to negative consequences in terms of people's lives and health, important societal functions and/or fundamental human values.

Secondly, over the last decades there has been a slight change of focus in risk and emergency management activities, from looking upon emergencies merely as the result of a realised hazard, to regarding emergencies and disasters to originate from the interactions between the triggering hazard agents and the vulnerability, i.e. susceptibility to a specific hazardous event, of the exposed system (McEntire, 2001). The former view was often leading to a strong focus on the hazard agents in risk and emergency management activities, while the contemporary dominant view puts an additional emphasis on for example the vulnerability of important societal functions to various kinds of stress, the social vulnerabilities of the affected populations and the capabilities of emergency response organisations (Weichselgartner, 2001; McEntire, 2005). This change has bearing on the present thesis in the respect

that the latter, more comprehensive, view should be reflected in any attempt to develop methods for analytic input to societal emergency management.

2.1.1 What is emergency management?

The term emergency management is here used in a wide sense comprising all activities taken by societal actors in order to reduce the risk of, prevent, mitigate, prepare for, respond to and recover from unwanted events of various scale. In figure 2.1, what is commonly referred to as the phases of emergency management (McLoughlin, 1985; McEntire, 2003) are shown. Even though the phases are closely related and sometimes hard to separate (Uhr, 2009, p.19), some even mean that the word "phase" can be misleading and could be substituted by for instance "functional activities" (McEntire, 2007, p.4), it is not uncommon that the actual work related to for instance prevention/mitigation and preparedness is carried out by different people in an organisation (Abrahamsson and Magnusson, 2004a) and it might be practical to use this categorisation when studying what is required of analytic input to the activities undertaken.

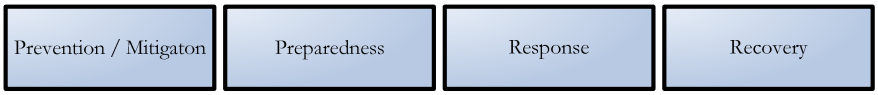

Figure 2.1 The phases, or functional activities, of emergency management

The first phase, or functional activity, is mainly directed towards risk and vulnerability reduction before an adverse event, such as taking actions to reduce the probability of hazardous events and to reduce inevitable consequences. This could for instance include structural measures such as improved design of process plant equipment, construction of seismic resistant buildings and installation of monitoring or detection systems, but also non-structural measures such as different regulatory measures, for instance regarding land use planning. In this phase, there has traditionally been a fairly strong focus on attempting to quantify the level of risk associated with a certain activity or system, then often based on a definition of risk given by Kaplan and Garrick in the early eighties (Kaplan and Garrick, 1981), where risk is seen as the answer to three questions: (i) what can happen?, (ii) how likely is it that it will happen?, and (iii) if it does happen, what are the consequences? The set of scenarios with their respective likelihood and consequences constitutes the risk in the system and can be used to construct various kinds of quantitative risk measures. This quantified

level of risk could then be used as input to acceptability/tolerability judgements (Ale, 2005), analysis and evaluation of risk reduction measures (Johansson, 2003) etcetera. A main challenge related to this approach has been (and still is) how to take appropriate account of the uncertainties related to the process of generating a quantitative measure of the level of risk in a system. This issue was the main topic of interest in the work behind my licentiate thesis (Abrahamsson, 2002) a number of years ago, which is briefly recaptured in section 4.1.1.

The preparedness phase involves all activities aiming at generating the prerequisites for effective emergency response, including for instance planning and production of plans, training and exercise and resource allocation. The challenges of emergency and crisis planning and preparedness have been debated in the emergency management literature for some decades. For instance, several suggestions have been put forward, presenting sets of guiding principles for good emergency and disaster planning and preparedness (Quarantelli, 1997; Boin and Lagadec, 2000; Alexander, 2003; Perry and Lindell, 2003; Alexander, 2005), while others have discussed why it is so difficult to put these "ideals of crisis preparedness" into practice in real life (McConnell and Drennan, 2006). A common principle in all of the guidelines referred to above is that planning should be based on thorough assessment of all hazards that are likely to occur in the geographical area of interest and the needs that would arise should any of these hazards manifest themselves. As of now, this is not necessarily the case, planning and preparedness activities traditionally having focused on an organisations own activities and functions in a system (Harrysson and Malmsten, 2004; Alexander, 2005; Fredholm, 2006). As Alexander (2005, p 163) puts it: "It is still common for emergency plans to be rich in details about command structures and resource availability but not to explain how these relate to the probable threats that would cause the plan to be activated." As stated above, emergency planning and preparedness is about much more than producing a plan in the form of a written document, but it seems reasonable that structured knowledge about the hazards one is facing, the potential needs that might arise should any of the hazards become realised (Buckle, 1998; Buckle, et al., 2000) and of current emergency response capabilities related to those events and needs (Jönsson, et al., 2007), is relevant to all aspects of preparedness such as responsibility and resource allocation issues, training etc. This is an area with large potential for development in terms of methods for analytic input.

What constitutes response has also been debated in literature, particularly the difference between response and recovery in terms of when the response phase ends and recovery starts (McEntire, 2007). In the present thesis, the

response phase will be considered involving all activities "undertaken to eliminate or reduce an emergency agent (also called a disaster agent), e.g. the fire, the flood, the disease, the conflict etcetera, and its immediate negative consequences" (Uhr, 2009, p.19). When an emergency or disaster situation arise, the typical situation is that a large number of actors such as governmental organisations, private companies and non-profit organisations, become involved in a cooperative effort to meet the needs and demands that arises in the affected part of society. Such a system of actors and their respective resources will here be referred to as an emergency response system (Uhr, et al., 2008). Traditionally in Sweden when analysing and evaluating the decisions and actions taken in a response to an emergency situation there has been a tendency to look at each actor (such as an organisation) separately, e.g. (SHK, 2001). However, in such situations no single actor acts independently of the context, for instance in terms of other actors, and there is a great need for development of methods aimed at enhancing the understanding of how the totality of such emergency response systems work taking into account interdependencies between actors, resources, infrastructures etc.

The recovery phase comprises all activities taken in the aftermath of the response phase of an emergency with the objective to bring things back to pre-disaster or a new desired (improved) state (McEntire, 2007). Emergencies and disasters, unwelcome as they are, are often said to generate "windows of opportunity" (Kingdon, 1995) for necessary change in order to reduce the risk of future ones. There is a strong linkage to the prevention/mitigation phase where concepts like "sustainable recovery" are linked to "sustainable development/sustainable hazards mitigation" (McEntire, 2003) and the phases referred to above are sometimes depicted in a circular manner in the "disaster cycle", e.g. (Tierney, et al., 2001; Alexander, 2002).

As indicated above, emergency management can consist of many different types of activities, all of which could possibly benefit from various kinds of analytic input. How and to what extent is explored further in this thesis.

2.1.2 The challenges and possibilities of anticipation

As stated above, the main topic of interest in this thesis is on how analytic input of various kinds, for instance risk and vulnerability analyses, can be of use as a foundation for emergency management work. This interest builds on a notion that it is possible to say something about what might happen in a system based on for instance observations of earlier events or other knowledge about the system, i.e. to use the concept of anticipation as a basis

for ones activities. The challenges of anticipation in complex systems have been debated in the literature over the last decades taking a starting point in Wildavsky's discussion on anticipation versus resilience in the late eighties (Wildavsky, 1988). Several authors have argued that, particularly when discussing the concept of emergency or crisis in a complex system like a human society where the inherent level of uncertainty is vast, the possibility of anticipation is limited (Boin and Lagadec, 2000; Boin, 2004; French and Niculae, 2005; Gundel, 2005) thus generating a need for strategies of resilience, which is often referred to as developing a capacity to absorb, respond to and recover from harmful events. However, others argue that anticipation can (and even should) be included in the concept of resilience (Kendra and Wachtendorf, 2003; Leveson, et al., 2006; Hollnagel, 2008). In fact, Hollnagel and Woods (2006) identify anticipation as one of three main qualities that a system must have to be able to be in control, and thus be resilient: "A resilient system must have the ability to anticipate, perceive and respond" (Hollnagel and Woods, 2006, p. 350). Kendra and Wachtendorf (2003) reason along the same line: "We argue, however, that resilience and anticipation are not polar opposites or mutually exclusive characteristics or states. /…/ Resilience is achieved by preparing, not for a particular event, but rather for a range of capabilities or functions that will be needed after any kind of event. /…/ anticipation is an integral dimension of resilience" (Kendra and Wachtendorf, 2003, p. 49). While acknowledging the difficulties related to "predict" what may occur in a system as complex as a human society, it is this latter view on anticipation and resilience that is adopted in this thesis.

2.1.3 Values and preferences

Before turning to a discussion on a design science perspective that have influenced much of the work behind this thesis, some brief comments should be made regarding one very important aspect of analytic input to emergency management, that of values and preferences. Values are paramount to any design process, and thus any attempt to prepare for or mitigate crises should seek to make the underlying values explicit, especially when there are several actors involved not necessarily sharing the same basic values. Regardless of the specific application of analytic input to emergency management, one must have a clear understanding of what is considered to be of value, for instance in terms of what we want to protect from harm. Without an apparent idea about this it will be problematic to decide what is to be considered as negative consequences following an unwanted event. Often one can find guidance regarding these issues by studying regulations and

policies etc. pertinent to emergency management, however expressed in fairly general terms. Another way of approaching this is to make explicit studies of people's preferences regarding for instance negative outcomes of potential unwanted events and of how these can be incorporated in decisions regarding various emergency management issues. The extent to which decisions related to risk and emergency management should be influenced by the general public or be left to "experts" has been quite heavily debated the last decades (Okrent and Pidgeon, 1998; Pidgeon, 1998), the general direction being that more inclusive strategies should be sought, especially in the face of vast uncertainty, see for instance (Stirling, et al., 1999; Renn, 2001). However, there is still a lot to learn regarding how people perceive the severity of potential negative consequences related to unwanted events, one of the dimensions of interest in such activities. Therefore, one of the research objectives behind the present thesis is related to the study of people's preferences regarding potential negative outcomes of unwanted events. This is further elaborated in chapter 3.

2.2 A design science perspective

The main focus of the work behind this thesis is the design of methods for analytic input to emergency management. This calls for a design or engineering approach to research that is forced to differ to some degree from traditional explanatory sciences. In this section, some brief comments will be made as to what might constitute a design science approach in this context and how that approach relates to explanatory sciences. Furthermore, a process for scientific development of methods will be introduced and discussed.

In explanatory sciences, such as the natural sciences and major sections of the social sciences, the main objective is to acquire knowledge and understanding about some part of the world by use of systematic and stringent methods of investigation (van Aken, 2004). In design and engineering, on the other hand, one is predominately concerned with the construction or design of various kinds of artefacts able to meet some predefined purpose in an efficient manner (Checkland, 1993; Cook and Ferris, 2007; Jönsson, 2007).

This viewpoint of design, of being "concerned with how things *ought* to be – how they ought to be in order to *attain goals* and to *function*" (Simon, 1996, p. 4) is generally applied to the design and construction of *physical* artefacts or systems. It could however be used also as a foundation for the development of methods since a method may be looked upon as a kind of designed abstract system of interrelated thoughts and concepts aimed at solving some specific problem (Checkland, 1993). To be able to discuss how the purposes and goals can be broken down into more tangible properties of a system, e.g. a method, it is useful to employ Rasmussen's (1985) representation of a technical system in several levels of functional abstraction. The highest level of abstraction is the functional purpose of the system and the lowest level of abstraction is the physical form of the system. Between these two levels of abstractions are various functions (physical, generalized, and abstract). In the present thesis it is enough to use a three part categorization in line with the one suggested by Brehmer (2008) who discuss the logic of designing artefacts in terms of the three levels: *purpose*, *function* and *form*. The purpose of an artefact answers the question *why* we need it, the function answers the question *what* functions need to be performed by the artefact so that the purpose can be fulfilled and finally the form answers the question *how* the physical design of the artefact performs the functions.

In explanatory sciences[1], the two main types of research activities are to *theorise* and to *justify* (March and Smith, 1995), where theorising concerns generating or proposing scientific claims (such as theories and laws) and justification involves activities for testing the validity of such claims. In design science, instead of posing theories and testing their validity, one strives to create models, methods and implementations that are innovative and valuable (March and Smith, 1995). The two main research activities in this process, parallel to theorising and justification in natural science, are to *build* and to *evaluate*, where "building is the process of constructing an artefact for a specific purpose and evaluation is the process of determining how well the artefact performs" (March and Smith, 1995, p 254). Consequently, it is these two research activities that form the basis for the process for scientific development of methods outlined in the following subsection.

[1] March and Smith (1995) use the term natural science when discussing what is referred to as explanatory sciences above and states that this includes traditional research in physical, biological and behavioural domains.

2.2.1 Scientific development of methods

In figure 2.2, a process for scientific development of methods is depicted. Even though this process could be regarded as one output of the research process behind the present thesis it is introduced here to facilitate the presentation in the following chapters.

In order to be able to *build* or develop an artefact, including a method, one needs to have an explicit notion of the *purpose* of that artefact. When it comes to methods for analytic input to societal emergency management the purpose may for instance be inferred from legislation or from an organisation's risk and/or emergency management policy. Given that the purpose has been stated, it is possible to start formulating the *criteria* to which the design of the method has to conform. These criteria are sometimes referred to as *constraints* (then often including the fulfilment of the purpose), see e.g. (Simon, 1996), but here the term design criteria is chosen to make it possible to differentiate between criteria that are directly connected to the purpose of the design, which often correspond to the functions that the artefact need to perform, and criteria that originates from other types of constraints not connected to the purpose, for instance related to costs and time consumption[2]. This part of the design process is of great importance and should be made transparent[3], since the design criteria will govern the actual construction of the method, as well as subsequent evaluation activities. When the design criteria have been established, the actual *construction* of the method can take place.

[2] It would of course be possible to formulate the purpose of a design in terms of such constraints as cost, making this distinction unnecessary.

[3] In relation to this it should be noted that the definition of purpose, the formulation of design criteria and the construction of the method all include or even require subjective judgement of the designer. If one does not agree with the stated purpose, that the proposed design criteria will lead to fulfilment of the purpose, or that the actual design satisfies the criteria, it is likely that one will not agree with the design of the method.

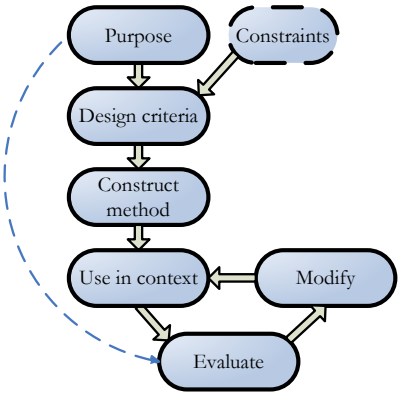

Figure 2.2 Process for designing methods, adapted from Jönsson (2007)

A common approach in systems engineering is to formulate the design criteria in terms of mathematical equations and then use for instance linear programming to find the optimal solution to the design problem (Hazelrigg, 1996). However, in complex problems, such as the design of a method for analytic input to emergency management where the number of possible design solutions is infinite, one usually has to settle for finding a solution that *satisfies* the criteria rather than finding optimal solution because one often lacks a practical method for finding the optimum (Simon, 1996). Even though the development of a method design that satisfies the design criteria usually takes as a starting point previous methods and approaches, in a similar manner as the activity theorising in explanatory sciences builds on previous research, the research contribution of the build activity, according to March and Smith, "lies in the novelty of the artefact and in the persuasiveness of the claims that it is effective" (March and Smith, 1995, p.260).

The next step of the process is to use the method in the context it is supposed to be used. As described by Jönsson (2007) this is analogue to conducting experiments or making observations in order to find evidence for or against a hypothesis in natural science. The subsequent evaluation in terms of whether the method satisfies the design criteria and more generally its purpose is in the same manner described by Jönsson as analogue to the interpretation of the experiments and observations and the subsequent falsification and corroboration of a hypothesis. The evaluation may give rise to modification of the method and the process then enters an iterative phase where the modified method is used again with subsequent evaluation and so on.

To summarise it is argued that scientific development of methods is possible by use of a systematic and transparent process where the designer presents a logic line of reasoning from the stated purpose of the method through the formulation of design criteria to the actual construction of the method. This is followed by evaluation of the method based on use in the context it is supposed to be used and, should it prove necessary, subsequent modification of the method.

3 Research objectives and research questions

The overall focus of the work behind this thesis is on methods for analytic input to societal emergency management. As discussed in section 2, such activities can have various purposes, ranging from generating input to decision making regarding for instance the location of facilities handling hazardous substances, to generating input to emergency preparedness activities.

In this section, the two main objectives of the research are presented, followed by the research questions related to each of the objectives. The objectives are formulated in fairly general terms while the research questions posed in relation to them by necessity are more specific.

3.1 Research objective 1

As stated in the background, one very important dimension of all analytic input to emergency management is the explicit account of the values and preferences underlying analysis and decision making, for instance in terms of what is considered to be negative consequences following an event. Since values and preferences are of such importance in this context, it is also the first focus area of the present thesis. Thus, the first objective of the research behind this thesis, which is of a descriptive nature, is *to investigate people's preferences regarding negative consequences of potential unwanted events*. This of course is a very broad objective and in order to be able to make a contribution to the knowledge regarding these issues the research has been focused on some areas within this objective[4].

As a first specific focus, the study of preferences regarding the consequence attribute *number of fatalities* was chosen. The main reason for this choice was that the number of fatalities has traditionally been of central importance in most risk based efforts to manage hazardous activities. One example is that

[4] At least two dimensions are of importance here. Firstly, one has to decide whether the research should focus on inter-comparison between different consequence attributes (such as loss of life, environmental effects, and economic effects) or on preferences "within" one consequence attribute. An example of the latter would be whether a situation leading to ten fatalities is judged to be ten times worse than one leading to one fatality. Secondly, one has to decide whether one should consider certain losses (i.e. deterministic consequences) or if uncertainty regarding the magnitude of the losses should be taken into account.

of quantitative risk assessments describing the societal risk associated with a particular activity as a function of the frequency of potential accidents and their consequences in terms of number of fatalities, so called F-N curves, see e.g. (CCPS, 2000). Such F-N curves are then often used as guidance for decisions on the tolerability of the level of risk a certain activity imposes on its surroundings. In most countries where criteria for tolerable societal risk are used, these are designed to reflect a significant aversion toward accidents involving many fatalities (Smeder, et al., 1996; Davidsson, et al., 1997; Ale, 2005), which, if these criteria reflect people's preferences, could be taken as to suggest that people are risk averse[5] considering the attribute number of fatalities. However, not find many studies either corroborating or falsifying this claim seems to have been performed, which led to the first research question:

RQ1. Are people risk averse regarding the consequence attribute number of fatalities in the range of 0 – 1000 fatalities?

The range of 0 -1000 fatalities was chosen since it is the range most often used when constructing tolerability criteria for societal risk (Davidsson, et al., 1997). The concept of risk aversion implies that in order to answer the research question one has to consider uncertainty regarding the number of fatalities a certain situation would give rise to.

Since the number of fatalities is only one, if ever so important, of many potential consequence attributes that might influence decisions related to emergency management, the second specific focus under this objective was directed towards the inter-comparison between a number of attributes. In addition, since many criteria for decision making concerning risk (based on for instance individual risk measures or F-N curves) do not consider the cause of a risk scenario, only its consequences (and frequency), it was of interest to study what kind of influence the apparent cause of emergency has on how people judge its seriousness. Although there is a wide variety of potential attributes that could be of interest when evaluating the seriousness of an emergency, the ones selected for study were *number of fatalities*, *number of*

[5] Risk aversion regarding negative consequences is the reluctance of a person to accept a situation with uncertain consequences (e.g. number of fatalities) rather than another situation with more certain, but possibly higher, expected number of fatalities.

serious injuries, *economic loss* and *cause of the disaster*[6]. Furthermore it was decided that, unlike the study with only one attribute described above, preferences regarding certain outcomes in terms of the selected attributes were to be elicited. This gave rise to the following two folded research question:

RQ2. a) Does the apparent cause of a disaster affect how people judge its seriousness?

b) How do people rank the seriousness of the following attributes given their ranges?

- Number of fatalities (0 – 1000)
- Number of serious injuries (0 – 4000)
- Economic loss (SEK 0 – 40 billion)
- Cause of the disaster (natural, accidental, terrorism)

As stated above, the research questions under the first main research objective are of a descriptive nature, calling for empirical studies with a descriptive objective which could be categorised as the research activity *justification* as described in 2.2.

3.2 Research objective 2

The second objective, which is of a prescriptive nature, has to do with the actual development and design of methods for analytic input to societal emergency management. Several studies have indicated a need for such development for example regarding risk and vulnerability analyses in order to make them suitable for their purpose (Harrysson and Malmsten, 2004; Hamrin and Strömgren, 2008; Nordström and Tonegran, 2008; Riksrevisionen, 2008). While making no claim to cover all possible applications of analytic input to emergency management, the second research objective is *to develop methods for analytic input to societal emergency management.* Within this mainly normative objective, the focus has been directed towards a number of specific types or applications of such analytic input, each with

[6] The selected attributes correspond to those collected in the EM-DAT database of disaster events maintained by the Centre for Research on the Epidemiology of Disasters (CRED), located at the Catholic University of Leuven.

specific purposes and aims. Three research questions have been formulated under this objective and, recollecting the main research activities related to design as described in section 2.2, to *build* and to *evaluate*, questions 3 and 4 are mainly directed towards building and question 5 mainly towards evaluating. The process of generating research questions within this objective has been exploratory. For each type of analytic input a "guiding" question has been formulated in fairly general terms in order to be able to start the process. As important aspects of the problem, e.g. design criteria, have been formulated the research question has been reformulated in order to narrow its focus. Before turning to the respective research questions a general point regarding questions 3 and 4 should be noted. The normative formulation "*how should…*" that recurs in these questions means in this context that a design solution satisfying the design criteria is sought, not the "optimal" solution, see 2.2.1.

The first specific use of analytic input studied is related to preparedness activities such as planning, training, resource allocation etc. Preparedness activities are commonly looked upon as a predominately local affair, where higher levels offer assistance (Boin, et al., 2003; Perry and Lindell, 2003; Alexander, 2005; McEntire, 2006) and the focus of this work has therefore been on the local, municipal level. The guiding question for this work has been: *how should a method for generating analytic input to preparedness activities in a local municipality be constructed?* This question has of course many possible answers and needs to be narrowed. This is done by use of the design criteria defined related to the purpose of this specific type of analytic input. The arguments for the choice of design criteria are presented in section 5.2.1 as part of the research contributions. This leads to the following research question:

RQ3. How should a method for generating analytic input to preparedness activities in a local municipality be constructed, considering in particular:

- the values one wants to protect from harm,
- the wide spectrum of potential hazards facing the community,
- the potential needs that may arise among the affected population should any of the hazards manifest themselves, and
- the capabilities of the emergency response system to meet these needs.

The second specific focus under this objective has to do with the possibility of generating knowledge (to be used in the risk and emergency management work) from the analysis and evaluation of performed emergency responses, where the typical situation is that a vast number and variety of actors (authorities, organisations, private companies etc.) have been involved. The guiding question for this work has been: *how should a method for analysing and evaluating emergency response in a multi-actor setting be constructed*? This question has also been narrowed during the design process to reflect the design criteria which are elaborated in section 5.2.1. The resulting research question is:

RQ4. How should a method for analysing and evaluating emergency response in a multi-actor setting be constructed, considering in particular:

- the values governing the evaluation,
- the complexity of the systems involved,
- the validity of the information on which the analysis and evaluation is based, and
- the limiting conditions under which the emergency response system operated?

The third specific focus under this objective has to do with the evaluation of performed risk and vulnerability analyses (RVAs). In Sweden, a new system for the use of RVA as input to emergency management activities on all administrative levels (local, regional and national) has been implemented during the last years[7]. This system has lead to increased activity in this field and RVAs are being conducted on a regular basis. It would be of interest to study whether this system has been successful so far and if the RVAs that are being produced fulfil their respective purpose within this system. This led to the general guiding question within this focus area: *Does the system for risk and vulnerability analysis in Sweden fulfil its purposes?* To provide an answer to this question would be a task of monumental proportions and thus it had to be narrowed. A choice was made to focus on one part of this system, the analyses conducted by the regional County Administrative Boards. By linking the purpose of the analyses performed on the regional level to the purpose of the total system for RVA through the study of relevant legislation, and by

[7] Related to this, new legislation has been issued strengthening the requirements for RVA to be performed by public authorities at all levels, e.g. (SFS, 2006a;b).

focusing on a chosen set of analyses, those performed in 2008, a somewhat more specific guiding question was formulated: *do the risk and vulnerability analyses performed by the Swedish County Administrative Boards in 2008 fulfil their purposes related to the purposes of the overall system for RVA?* Also this question has been narrowed during the process focusing on one specific purpose, as interpreted through the study of pertinent legislation, of generating input to a national overview of risks, vulnerabilities and emergency management capabilities. This leads to the following research question:

RQ5. Do the risk and vulnerability analyses performed by the Swedish County Administrative Boards in 2008 fulfil the purpose of generating input to a national overview of risks, vulnerabilities and emergency management capabilities?

All in all, five research questions have been posed and these are all addressed in chapter 5, research contributions.

3.3 Delimitations

As indicated above, there are some delimitations to the research behind this thesis related to the possibility of reaching the objectives of the research. Here, some of the most important delimitations will be briefly elaborated.

Regarding the study of preferences two main delimitations should be mentioned. Firstly, one could argue that the two research questions related to this objective has a fairly "narrow" focus, one considering a single attribute involving uncertainty regarding the outcomes and the other encompassing four attributes under the assumption of certain outcomes. Other attributes could be investigated in order to get a more comprehensive understanding of peoples' preferences regarding negative consequences of unwanted events, something that is emphasised in the discussion on further research in 6.1.2. Secondly, even though the research questions were formulated in terms of *people's* preferences, the actual study groups were not chosen with the objective to get a good representation of the general public, which, if such a representation is indeed possible, would have required additional efforts regarding the composition of the study groups. The studies performed in relation to this objective were limited in this sense, the generalisability of the results thus being restricted. This has some consequences regarding the conclusions that can be drawn from the studies related to this objective,

something that is further addressed in relation to the description of results in 5.2 and in the discussion in 6.1.1.

Regarding the development of methods there are at least three delimitations that should be mentioned. Firstly, related to this objective three different types or applications of analytic input have been addressed in the research questions. There may of course be other types that could be of interest to study in terms of method development, for instance methods for risk and vulnerability analysis to be used by national governmental agencies in their emergency management related work. Secondly, this research objective is principally explored in a Swedish context. It is not necessarily the case that the dimensions and design aspects that are considered relevant in this context would be the same in another setting, for instance in a developing part of the world. Thirdly, the developed methods have been "tested" and evaluated principally through participatory observation. The final aim is that the methods should be possible to use by the relevant actors themselves, not necessarily involving researchers (the *instantiation* activity of design as described by March and Smith (1995)). This has not yet been carried out.

4 Research process and methods

In this chapter, the research process behind the present thesis is briefly described, alongside with a short introduction to the methods and techniques used in the process.

4.1 The research process

In this section, a short description of the research process leading up to the present thesis is given. Some related work that is not included as appended papers is briefly recaptured.

4.1.1 The licentiate dissertation

In this section, a short recapitulation of the main points of the work behind the licentiate dissertation, based on (Abrahamsson, 2000; Abrahamsson and Magnusson, 2000; Abrahamsson, et al., 2001; Abrahamsson, 2002) is given. The main focus of this work was on the use of quantitative risk analysis (QRA) as input mainly to the prevention/mitigation phase of emergency management.

It is possible to discern a considerable increase in the use of QRA in Sweden as part of the foundation for decision making regarding safety-related issues in various areas, for instance land use planning, licensing procedures for hazardous activities, infrastructure projects, and as an integrated part of environmental impact assessments. The QRA methodology has proven to be of substantial use regarding the determination of major contributions to risk, and for the evaluation of different decision options, e.g. different design alternatives. However, due to a lack of consensus concerning which methods, models and inputs should be used in an analysis, and how the, sometimes considerable, uncertainties that will inevitably be introduced during the process should be handled, questions arise regarding the credibility and usability of the absolute results from QRA. Without a description of and discussion on the uncertainties involved in such an analysis, the practical use of the results in absolute terms will be severely limited. For instance, comparison of the results with established risk targets, or tolerability criteria, something that is becoming increasingly common, becomes a fairly arbitrary exercise.

Somewhat simplified, comprehensive uncertainty analysis can be regarded as having three major objectives. Firstly, it is a question of making clear to the

decision-maker that we do not know everything, but decisions must be based on what we do know. Secondly, the task is to define how uncertain we are. Is the uncertainty involved acceptable in meeting the decision-making situations we face, or is it necessary to try to reduce the uncertainty in order to be able to place enough trust in the information? Consequently, the third step is to try to reduce the uncertainty involved to an acceptable level.

At an elementary level, two major groups of uncertainty can be discerned, i.e. aleatory (or stochastic) and epistemic (or knowledge-based) uncertainty. The most important distinction between these two types of uncertainty, at a practical level, is that the knowledge-based uncertainty can be reduced by further study, should a reduction in the overall uncertainty in the results from an analysis prove necessary. The aleatory uncertainty, on the other hand, is by definition irreducible. Inherent in the QRA process is the need to use expert judgement to estimate the values of unknown parameters (knowledge-based uncertainty). In the dissertation a discussion is presented on various methods of eliciting information from experts in a structured manner, together with a presentation of known pitfalls of such exercises. Knowledge about such procedures, and about the problems associated with them, is a key issue in keeping knowledge-based uncertainty to a minimum.

The core of the dissertation, however, is a structured survey of methods of propagating and analysing parameter uncertainty. The basic features of a number of different approaches and methods of uncertainty treatment are presented, followed by a discussion of the arguments for and against the different approaches, and on different levels of treatment based on the problem under consideration. To further exemplify the different features of the methods surveyed, a case study is presented, in which a simplified facility for ammonia storage is analysed with respect to the risk it poses to its surroundings. Emphasis is placed on the kind of information required for use of the different methods, and on the kind of results they produce.

It is concluded that methods are available for the explicit treatment of uncertainty in risk analysis with sufficient sophistication for most problems, although some types of uncertainty, mainly those related to completeness and general quality issues, are inherently problematic to quantify.

Recommendations for future research and standardisation efforts in the area are given in the dissertation (Abrahamsson, 2002).

4.1.2 The Pilot project preceding FRIVA

In this section, a short recapitulation of the main points resulting from the pilot project preceding FRIVA, the Framework Programme for Risk and Vulnerability Analysis, is given. FRIVA forms the basis for most of the work behind the present thesis. The presentation is based on Abrahamsson and Magnusson (2004a;b) and Abrahamsson et al (2004).

At the time of the study, new regulations (SFS, 2002)[8] regarding government actions for crisis management of extreme events had been issued, requiring government agencies to identify and analyse risks and vulnerabilities within their sector of responsibility of such magnitude that the functionality of that sector may be severely impaired. Reviews are to be submitted yearly to the Ministry of Defence.

The pilot study consisted of two tightly interconnected parts; an interview study with the objective to generate a preliminary overview of methods and procedures used by relevant Swedish governmental agencies in their risk- and crisis management work, and a generic overview of existing risk- and crisis management strategies, risk- and vulnerability analysis methods etc., covering a wide range of government agency areas/sectors (based on literature studies). Below some conclusions from the interview study are presented. For information on the second part, see any of the references above pertaining to the project.

A series of interviews were performed with representatives from nine Swedish governmental agencies, all serving important functions within the Swedish emergency management system. The interviews were structured in accordance with the four phases of emergency management: prevention/mitigation, preparedness, response and recovery. Risks and vulnerabilities originating partly from sources within each agency's respective sector of responsibility, and partly from "external" sources, such as dependence of various technical infrastructures (electrical power, water supply etc.) were considered. Questions related to for instance methods for identifying, assessing and evaluating risks, and regarding how management systems designed to deal with these issues are constructed and revised, were discussed in order to generate an understanding of the approaches adopted by the different agencies. Some of the main results from this study, which influenced the focus of some activities in the following research programme, are briefly recaptured below.

[8] Provision SFS 2002:472 has since then been replaced by provision SFS 2006:942 (SFS, 2006b).

The key question revolved around links and interdependencies between sectors and different administrative levels. A multitude of problems related to such issues were discussed during the interviews and it was concluded that there was an evident need to develop, apply and evaluate various tools in the process of analysing and managing risks and vulnerabilities across different sectors with various actors and agencies involved. This was one of the reasons for adopting a systems perspective in much of the work behind the present thesis. Another main result was that all of the agencies in the study had developed or acquired methods for identifying "every day" or "normal" risks within their respective sector of responsibility. In general, however, no structured methods for identifying the mechanisms for potential escalation to more serious events were in effective use and this was an area in need of development. An additional interesting result was that many of the agencies in the study regarded the RVAs as one of the main cornerstones in the resource allocation process for peacetime emergency preparedness.

As mentioned above, insights from this study influenced the design of the research programme FRIVA introduced below.

4.1.3 The FRIVA programme

The Framework Programme for Risk and Vulnerability Analysis, FRIVA, undertaken at Lund University Centre for Risk Assessment and Management, LUCRAM, is a multi-disciplinary research programme involving some 25 researchers from various disciplines. The topics covered include studies of social vulnerability, safety culture, organisational learning, robustness of large scale infrastructures and various types of use of risk and vulnerability analyses in societal emergency management. The work behind the present thesis has been conducted within this framework programme, mainly within the theme related to development of methods for risk and vulnerability analyses. Since the large part of this work is to be presented in chapter 5 it will not be further elaborated here.

4.2 Methods and techniques

In this section, a brief introduction to the types of methods and techniques used in the research behind the thesis is given. A more detailed presentation of specific methods and techniques is given in the respective papers, except regarding interviews which has only been used in the project preceding FRIVA described above which is not reported in the appended papers.

4.2.1 Literature studies

Continuous systematic study of literature has been conducted during the whole process in order to get a comprehensive understanding of the research areas relevant to this thesis. In order to be able to address the research questions literature relating to for instance emergency/crisis/disaster management, risk management, risk and vulnerability analysis, risk perception, systems theory, decision theory, accident investigation and programme evaluation have been searched for mainly in electronic databases such as ELIN (Electronic Library Information Navigator) at Lund University, and search engines such as Google Scholar. Other sources for literature search have been reference libraries and electronic libraries of various Swedish and international authorities.

4.2.2 Interviews

In relation to the pilot project preceding FRIVA briefly recaptured above a series of nine interviews were performed with representatives from Swedish governmental agencies at the national level. The main objective of this study was to get an understanding of the kinds of methods and approaches the various agencies used in their risk and emergency management work, and furthermore what they perceived as challenging aspects of that work. In order to be able to get an as comprehensive picture as possible, a semi-structured interview protocol with thematic questions was used to guide the interviews. The reason for this choice was that semi-structured interviews offer more flexibility in terms of following up on particularly interesting topics and using probing and clarifying questions than more strictly structured interviews (Smith, 1995). All interviews were recorded and transcribed in order to facilitate subsequent analysis and categorisation of the received information.

4.2.3 Surveys

In relation to the studies concerning people's preferences regarding potential negative outcomes of unwanted events, the elicitation techniques chosen for the respective studies were implemented in software developed by the researchers specifically for this purpose. These computer programs were used in the surveys set up in order to answer research questions 1 and 2. The specific elicitation techniques used in the studies are explicitly described and discussed in papers 1 and 2, for instance regarding the effects of various

biases, which are inherent in all available techniques, on the reliability and validity of the results. In both of the studies two complementing eliciting procedures were used in order to provide insight into the uncertainty of the results.

As for the study of people's preferences regarding the consequence attribute number of fatalities pertaining to research question 1, two main settings were used for the study. One that of a "face-to-face" survey, where subjects completed the tasks involved in the presence of a facilitator after receiving oral instructions, the other that of a "web-based" survey in which the subjects completed the tasks without the physical presence of a facilitator[9], where the subjects logged into a website in which both written instructions and the survey were presented. In both settings, tasks pertaining to the actual elicitation of preferences were carried out, followed by a subsequent questionnaire (or discussion with the facilitator in the face-to-face setting), where the subjects were requested to provide qualitative comments related to the elicitation procedure.

In the study of preferences regarding various attributes pertaining to research question 2, a "web-based" survey, however conducted in a lecture hall, was used, where subjects completed the tasks involved in the presence of two facilitators who could assist during the process, after receiving oral instructions. As in the study referred to above, tasks pertaining to the actual elicitation of preferences were carried out, followed by a subsequent questionnaire, where the subjects were requested to provide free text comments related to the elicitation procedure.

4.2.4 Process for method development

As for the work pertaining to the development of methods, which is of a prescriptive nature calling for a design science perspective, the process for method development outlined in section 2.2.1 has been employed.

4.2.5 Content analysis

In the study pertaining to research question 5 regarding the evaluation of documented risk and vulnerability analyses, content analysis (Weber, 1990; Neuendorf, 2002) of relevant documents has been employed. Content

[9] Two facilitators were however available by phone and e-mail.

analysis provides a systematic means of classifying textual material, reducing it to more relevant, manageable bits of data (Weber, 1990) and was used both to infer the purposes of the Swedish system for risk and vulnerability analysis from relevant legislation and to analyse all of the risk and vulnerability analyses performed by the regional County Administrative Boards in 2008 regarding the kind of information these provided to the system.

4.2.6 Participatory observation

Participatory observation originates from cultural anthropology, where it involves getting close to people and making them feel comfortable enough with your presence so that you can observe and record information about their lives, and is usually undertaken over an extended period of time (Bernard, 1995). In the present context, however, participatory observation refers to the situation where a developed method is put to use in its intended context where the designer both takes active part in applying it and performs an evaluation of its performance based on reactions from the participants, the outcome of the exercise etcetera. This has been done for the two methods developed in order to address research questions 3 and 4, in connection with a series of workshops held in Swedish municipalities in order to apply the methods in their intended context and perform an initial evaluation. This activity should be seen in contrast to actual instantiation (March and Smith, 1995) of the methods, where the intended users of the methods apply them in their normal work.

In the following chapter, the research contributions resulting from the work conducted by use of the abovementioned methods and techniques are presented.

5 Research contributions

In this chapter, the results of the research contributing to answering the respective research questions are presented.

5.1 Summary of appended papers

In this section, a table with an overview of the appended papers is presented followed by a brief summary of each of the appended papers.

5.1.1 Overview

In table 5.1, an overview summarising the main perspective, the main research activities, the methods used, the study objects and the main results related to each paper is presented. Regarding the main types of research activity, the categorisation described by March and Smith (1995) is used, see section 2.2. Regarding the results, these are further elaborated on in relation to answering the research questions in section 5.2.1 and in the discussion in chapter 6.

Table 5.1 Overview of appended papers.

	Paper I	**Paper II**	**Paper III**	**Paper IV**	**Paper V**
Main Perspective	*Descriptive	*Descriptive	*Prescriptive	*Prescriptive	*Descriptive/ *Prescriptive
Research activity	*Justify	*Justify	*Build *Evaluate	*Build *Evaluate	*Build *Evaluate *Justify
Methods	*Literature studies *Web-based survey *"Face-to-face" survey	*Literature studies *Web-based survey	*Literature studies *Process for method development *Participatory observation	*Literature studies *Process for method development *Participatory observation	*Literature studies *Process for method development *Document study, content analysis
Study object	*87 persons with professional or educational knowledge of risk and emergency management.	*81 students with educational knowledge of risk and emergency management.	*Swedish municipality.	*Part of the emergency response system in a Swedish municipality active during the storm Per.	*Legislation pertaining to the Swedish system for RVA. *RVAs produced by the Swedish County Administrative Boards 2008.
Main result	*Not all people are risk averse (fatalities 0-1000). *Most people in this study display risk seeking behaviour.	*Cause matters in evaluation of harm. *Physical harm matters most (of these attributes with these ranges).	*Method for analytic input to emergency preparedness activities in a municipal setting. *Evaluation of method based on participatory observation.	*Method for analysing and evaluating emergency response in a multi-actor context. *Evaluation of method based on participatory observation.	*Method for evaluating documented RVAs. *Evaluation of regional RVAs in Sweden 2008.

In the following sections, summaries of the appended papers are given.

5.1.2 Paper I

Abrahamsson M. & Johansson, H. Risk preferences regarding multiple fatalities and some implications it has for societal risk decision making – an empirical study. *Journal of Risk Research,* Vol. 9, issue 7, pp. 703-715.

In this paper an empirical study of 87 persons' risk preferences related to emergency situations involving the possibility of multiple fatalities is presented and discussed in relation to societal risk decision making. A tradeoff method was used in order to obtain von Neuman-Morgernstern utility functions over the range of 0-1000 fatalities, describing each of the subjects' preferences regarding the attribute number of fatalities. Most of the utility curves were found to be convex, implying the majority of the subjects to display risk-seeking behaviour, i.e. that they were prepared to "gamble" and accept the risk of highly serious consequences in terms of number of fatalities in order to have the possibility of the consequences being much less serious. The authors argue that the results arrived at would be useful as input to decision making regarding activities having the potential of generating accidents involving multiple fatalities, for instance in discussions underlying the formulation of tolerability criteria for societal risk. It is however acknowledged and even emphasised that while the number of fatalities is an important attribute when evaluating the seriousness of the consequences of a major accident or emergency, there clearly are other matters that need to be taken into consideration and the authors highlight the importance on further research regarding the importance of other attributes of interest.

Author's contribution: Main author, responsible for the preparation of the study, performed the face-to-face surveys, performed the data analysis.

5.1.3 Paper II

Hassel H., Tehler, H. & Abrahamsson, M. (2009). Evaluating the seriousness of disasters: an empirical study of preferences. *International Journal of Emergency Management,* Vol. 6, no. 1, pp. 33-54.

In paper II, an empirical study of 81 persons' preferences regarding a number of attributes relevant for evaluating the seriousness of disasters is presented and discussed. The attributes and ranges used in the study were: *number of fatalities* (0-1000), *number of serious injuries* (0-4000), *economic loss* (SEK 0-40 billion) and *cause of the disaster* (natural, accidental, terrorism). Two separate methods were used to elicit weights for the different attributes, in order to provide insight into the uncertainty of the elicited weights and the different strengths and weaknesses of the methods used. The authors conclude that a majority of the participants regarded the attributes related to physical harm (especially the number of fatalities) to be most serious considering the ranges used, but also that the apparent cause of the disaster affected many of the participants' judgement of its seriousness. The authors further provide a thorough discussion on methodological considerations and different types of biases inherent in available techniques for formal elicitation of attribute weights, and they argue that despite potential biases and problems of formal elicitation techniques, their use is more appealing than using some kind of intuitive approach or implicitly assuming attribute weights. It is concluded that the types of preferences elicited in this study, where the aim has been to be generic rather than specific to a particular decision, are especially applicable in small to medium-sized projects where explicit value elicitations are rarely conducted due to budget constraints.

Author's contribution: Co-author, participated in the preparation of the study, participated in the data collection, participated in the data analysis.

5.1.4 Paper III

Abrahamsson M. et al (2007) Analytical input to emergency preparedness planning at the municipal level – a case study. *Proceedings of Disaster Recovery and Relief: Current and Future Approaches (TIEMS 2007),* Trogir, Croatia, pp. 423-432.

In this paper an approach for employing analytic input as a foundation for emergency preparedness efforts at the local municipal level is presented. The development of the approach was guided by the notion that for analytic input emergency preparedness activities to be effective one must explicitly acknowledge the interaction between the hazards, the affected system (community) and the capabilities of the emergency response system. A case study in a Swedish municipality is used to exemplify the features of the approach, which consists of three interconnected parts; a broad scope hazard identification and analysis, an assessment of potential assistance needs among the affected population should any of the identified hazards manifest themselves, and finally a mapping of central actors in the emergency response system, their respective tasks in a given scenario and the dependence relationships within the response system. The authors argue that use of the approach will be useful in terms of creating a suitable foundation for emergency preparedness planning which is based on the spectrum of hazards relevant to the specific community in question, the range of specific needs that may arise in that municipality as a consequence of any of the hazards materialising and on current emergency response capabilities.

The work behind the paper has been more elaborately described (in Swedish) in (Abrahamsson and Johansson, 2007).

Author's contribution: Main author, responsible for the development of the method, conducted the workshops in the municipality under study, presented the paper at an international conference.

5.1.5 Paper IV

Abrahamsson, M., Tehler, H. & Hassel, H. Towards a system-oriented framework for analysing and evaluating emergency response. Accepted for publication in *Journal of Contingencies and Crisis Management*. To be published in Vol. 18, No. 1, 2010.

In this paper a framework for analysis and evaluation of performed emergency response in a multi-actor context is presented and discussed using a case study. As a basis for the development of the framework, the authors examine four major challenging aspects related to such analysis and evaluation 1) issues related to the values governing the evaluation, 2) issues related to the complexity of the systems involved, 3) issues related to the validity of the information on which the analysis and evaluation is based, and 4) issues related to the limiting conditions under which the emergency response system operated. An outline of the framework, which on the most general level consists of three parts; to define the conditions for the evaluation, to generate a system dynamics model and analyse scenarios, and to evaluate system performance and suggest ways of improvement, is presented alongside with an account of how the different parts of the approach relates to the four challenging aspects referred to above. The second part of the framework, i.e. the generation of a system dynamics model and analysis of scenarios, is the one given the most attention in the paper and in order to exemplify the steps and merits of this part some results from a case study involving the analysis of the response operation in a local municipality following the severe storm *Per*, that struck the southern part of Sweden on 14 January 2007 are presented. The authors conclude that the suggested framework has several desirable properties in relation to the identified challenging aspects of analysing and evaluating emergency response in a multi-actor setting in that it promotes explicit treatment of values and objectives and it provides a common ground for the analysis of a specific operation, i.e. it enables various actors to reach agreement on what they did during the operation, and how they affected each other. Furthermore, the collaborative generation of the system model used for analysis reduces potential biases due to distorted memories etc. In addition, this joint effort to develop the system model may foster knowledge-transfer and learning across organisational borders. Finally, the structured analysis of what is referred to as counterfactual scenarios broadens the scope of the conclusions that can be drawn from studying one event, thus enhancing the potential of the framework to serve as a tool to learn from past emergencies and prepare for future ones.

This paper is a revised and extended version of a presentation given at the Ninth International Conference on Probabilistic Safety and Management (PSAM9) (Abrahamsson, et al., 2008).

Author's contribution: Main Author, responsible for the development of the method, participated in the development of the software used during the workshops, conducted the workshops where the approach was tested.

5.1.6 Paper V

Abrahamsson, M. & Tehler, H. The role of risk and vulnerability analyses in emergency management systems – evaluating regional RVAs in the Swedish emergency management system. Paper for publication, submitted to an international journal.

Risk and vulnerability analyses (RVA) can form a very important part of a nation's or a region's emergency management system by conveying information on risks and vulnerabilities in the system of interest, information that can be used as input to various emergency management activities. In Sweden, like in many other countries, a system for RVA was established a number of years ago, requiring authorities on all administrative levels to perform RVA within their respective area of responsibility. In this paper, the issue of evaluating such a system in terms of fulfilment of its purpose is addressed. An approach to analysis and evaluation of systems for RVA is suggested and to exemplify the approach, a part of the Swedish system for RVA is analysed and evaluated. Firstly, an analysis of the purpose of the Swedish system for RVA is undertaken by examining the legislation, including the legislative history, requiring such analyses to be performed. This is done with use of information from the area of risk analysis as a point of departure and the result is a set of desirable functions that the system for RVA needs to perform in order to fulfil its purpose. Secondly, by focusing on one specific function, that of generating a national overview of risks, vulnerabilities and emergency management capabilities, and on one level of administration, the regional, a set of desirable properties an individual RVA should have in order to facilitate the fulfilment of the function is generated. Using these properties as a point of departure a content analysis of all documented RVAs conducted by the Swedish regional County administrative boards (there are 21) in 2008 is performed in order to establish whether the necessary properties can be found in these documents. It is concluded that some of the RVAs do not display the necessary properties in order to fulfil the purpose of providing input to a national overview of risks, vulnerabilities and emergency management capabilities. Implications of this finding for the system for RVA are discussed and recommendations regarding how these issues could be addressed are presented based on the evaluation.

Author's contribution: Main author, participated in the preparation of the study, participated in the content analysis of legislation, conducted the content analysis of the regional risk and vulnerability analyses.

5.2 Results

In this section, the main results of the respective research activities are presented, the respective research questions are addressed and a summary of the results pertaining to the two main research objectives is given.

5.2.1 Addressing the research questions

In this section the respective research questions are addressed and answers are provided. Each of the appended papers explicitly addresses one research question. Research questions (and thus papers) I and II are both directed towards the first research objective *to investigate people's preferences regarding negative outcomes of potential unwanted events*, while research questions (papers) III-V are more directed towards the second, mainly normative research objective *to develop methods for analytic input to societal emergency management*.

Research question 1

The first research question concerns people's risk preferences regarding the consequence attribute number of fatalities.

RQ1. Are people risk averse regarding the consequence attribute number of fatalities in the range of 0 – 1000 fatalities?

From the study in paper I, one can conclude that not all people are risk averse regarding the number of fatalities in the specified range. In fact, most of the subjects in this particular study group displayed risk seeking behaviour, implying that they are prepared to "gamble" and accept the risk of highly serious consequences occurring in order to retain the possibility of the consequences being much less serious. Potential implications of these findings are reflected upon in the discussion in 6.1.1.

Research question 2

The second research question relates to people's preferences regarding a number of attributes and to whether the apparent cause of a disaster affect how its seriousness is being judged. The question is thus two-folded.

RQ2. a) Does the apparent cause of a disaster affect how people judge its seriousness?

b) How do people rank the seriousness of the following attributes given their ranges?

- Number of fatalities (0 – 1000)
- Number of serious injuries (0 – 4000)
- Economic loss (SEK 0 – 40 billion)
- Cause of the disaster (natural, accidental, terrorism)

From the study in paper II, one can conclude that yes, the apparent cause of a disaster does affect how people (in this study group) judge the seriousness of the disaster. Furthermore, for this particular study group, the attributes related to physical harm, especially the number of fatalities, were regarded as the most serious (given the ranges of the attributes used in the study). The overall ranking was, from the most to the least serious: *number of fatalities*, *number of serious injuries*, *economic loss* and *cause of the disaster*. Potential implications of these findings are reflected upon in the discussion in 6.1.1.

Research question 3

The third question relates to the issue of generating input to preparedness activities in a local municipality.

RQ3. How should a method for generating analytic input to preparedness activities in a local municipality be constructed, considering in particular:

- the values one wants to protect from harm,
- the wide spectrum of potential hazards facing the community,
- the potential needs that may arise among the affected population should any of the hazards manifest themselves, and
- the capabilities of the emergency response system to meet these needs.

The structure of the presentation of results pertaining to this design oriented question will be as follows. First, the purpose of the method will be presented, followed by the arguments for the chosen design criteria in relation to the purpose and how the suggested method satisfy the design criteria.

The overall purpose of the abovementioned method is to provide input to preparedness activities in a local municipality. As mentioned in the background, such activities aim at generating prerequisites for effective emergency response and include planning processes and generation of plans, training and exercise, resource allocation etc. A number of important aspects of analytic input to such activities, underlying the design criteria for a method for such input, have been identified and below these aspects or design criteria will be elaborated in terms of why they are relevant in relation to the purpose of the method and what the effect would be of not applying them in the design process.

Firstly, it is of importance to be explicit about the underlying values, i.e. accounts of what we care about (Keeney, 1992), regarding what one wants to protect from harm, as these will form the basis for what kinds of consequences the analyses conducted by use of the method will consider and furthermore the evaluation of the seriousness of identified hazards and the potential risk scenarios in relation to them. This is especially important when several actors are involved since it can not be taken for granted that they all share the same values. In addition, virtually any kind of preparedness measure has some cost related to it and since in most (if not all) cases societal emergency preparedness activities are undertaken under resource constraints, priorities are called for which would be difficult to make without a clear understanding of the underlying values regarding what is to be protected from harm.

Secondly, influential research literature pertaining to emergency preparedness promotes an all hazards approach, where emergency planning and preparedness activities should be of a generic nature rather than focusing on separate contingencies (Quarantelli, 1992;1997; Perry and Lindell, 2003; Alexander, 2005), something that should be reflected in a method for analytic input to such activities. The main argument for such a comprehensive view on emergency management is that different emergency scenarios related to different hazards, sometimes referred to as "disaster agents", often have shown to generate similar agent-generated and response-generated demands, where the same emergency response functions can be effectively used to address different hazard agents (Quarantelli, 1992). Following this line of reasoning, a method for analytic input to emergency preparedness should

consider the wide spectrum of potential hazards facing the community in order to facilitate an understanding of which generic emergency response functions need to be in place in order to be able to effectively respond to a variety of potential future emergencies, and thus enhancing the resilience of the system (Kendra and Wachtendorf, 2003). A too narrow focus, for instance on detailed analysis of only one or a few types of hazard separately, may drive the planning process, that uses the analysis as input, away from the comprehensive all hazards approach.

Thirdly, the method should promote explicit consideration of the needs among the affected population should any of the hazards manifest themselves. As mentioned in the background, there has been a general change in focus in societal emergency management activities, from a strong focus on the hazard agents to a broader view including the interactions between the hazard agents, the susceptibility of the affected system and the capabilities of the emergency response system. However, the methods for analytic input that have been used in local municipalities do not necessarily reflect this change of focus. For instance, Harrysson and Malmsten (2004) demonstrated that it was uncommon for Swedish municipalities to use risk and vulnerability analyses as basis for planning and preparedness activities, partly because of the traditional strong hazard focus making the analyses ill suited for that purpose. For a method for analytic input to preparedness activities to be useful, and thus hopefully used, it needs to be capable of also taking the susceptibility of the affected system, for instance in terms of the generation of various needs among the affected population (Buckle, 1998; Fredholm, 2006) into consideration.

Fourthly, the method should promote and facilitate explicit consideration of the capabilities of the emergency response system[10] to meet the needs and demands generated during an emergency. The main argument for this being that a well founded understanding of current capabilities, as well as limitations to those capabilities, provides a foundation for structured reasoning regarding for instance which preparedness efforts that should be prioritised.

Based on the important aspects outlined above, a method for analytic input has been constructed and used in a Swedish municipality, as described in

[10] An *emergency response system* (Uhr, et al., 2008) is here a referred to as a system made up of various actors and resources, for example, official agencies such as the fire and rescue services, the police and the emergency medical services, as well as actors from the private sector and non-profit organisations, that becomes involved in response to an emergency.

appended paper III. The method satisfies the criteria in that the underlying values are explicitly addressed and translated into relevant consequence categories, it promotes and facilitates an all hazards approach to preparedness activities and furthermore an explicit assessment of the potential needs that may be generated in various emergency scenarios. Finally it explicitly addresses the capabilities of the emergency response system to meet these needs. In the discussion in section 6.1.1 some of the main insights from a first evaluation of the method that was conducted based on participatory observation when it was used for analysis in a Swedish municipality are briefly described.

To summarise it is argued that in using the suggested approach one creates a suitable foundation for emergency preparedness planning which is based on the spectrum of hazards relevant to the specific municipality in question and on the range of specific needs that may arise in that municipality as a consequence of any of the hazards materialising.

Research question 4

The fourth question relates to the analysis and evaluation of emergency response.

RQ4. How should a method for analysing and evaluating emergency response in a multi-actor setting be constructed, considering in particular:

- the values governing the evaluation,
- the complexity of the systems involved,
- the validity of the information on which the analysis and evaluation is based, and
- the limiting conditions under which the emergency response system operated?

The structure of the presentation of results pertaining to this design oriented question will be in line with that of question 3. First, the purpose of the method will be presented, followed by the arguments for the chosen design criteria in relation to the purpose and how the suggested method satisfy the design criteria.

The main purpose of the abovementioned method for analysis and evaluation is to generate information regarding how the emergency response system performed during an emergency. This encompasses descriptive information to be used in generating an understanding of what happened and why, but also information to be used when addressing the question whether the response was successful, which requires subjective values judgements. This information is to be of use in efforts directed at preventing, mitigating and/or preparing for future emergencies. A number of important aspects or challenges related to such analysis and evaluation, underlying the design criteria for a method for such input, have been identified and below these aspects or design criteria will be elaborated in terms of why they are relevant in relation to the purpose of the method and what the effect would be of not applying them in the design process.

Firstly, the method for analysing and evaluating emergency response should facilitate explicit treatment of values and preferences. Any evaluation will by necessity be based on value judgements, i.e. accounts of what one cares about (Keeney, 1992). Value judgements will guide the focal point of the evaluation process, as well as the conclusions drawn based on the observations, for instance in terms of recommendations for future improvements. Value judgements are highly related to the question of how successful a specific response operation is considered to be. Without values with which to assess the operation, one cannot know whether it was successful or not. Such value judgements must be made explicit, especially since in a system comprised of many different actors it is not necessarily the case that everyone shares the same underlying values governing the evaluation.

Secondly, the method for analysis and evaluation of emergency response should consider the emergency response system as a whole, and employ models capable of dealing with the level of complexity involved and which facilitate a common understanding of the situation being evaluated. The fact that many actors participate in a cooperative effort to manage an unwanted event and its effects in society, with strong dependencies between the different actors and various resources (i.e. a complex system), is posing some serious challenges to the analysis and evaluation of such operations. In order to understand not only what happened during the emergency, but also *why* the system behaved as it did and the outcome was what it was, an effort must be made to understand the relationships and dependencies between the actors involved, as well as the context in which they were operating. To only focus on the respective actors' performance, in isolation of the rest of the emergency response system, would significantly reduce the value of the information obtained as input to emergency management efforts.

Thirdly, the method should explicitly consider the validity of the information upon which the analysis and evaluation is based. Often the main source of information regarding the course of events during an emergency situation is interviews with the people who were actually involved with the event, leading to problems related to for instance biases of human memory and people's potential reluctance to give a full account of their perception of the events, especially when they feel threatened by criticism or vulnerable to blame assignment (Heath, 1998; Killian, 2002; Stallings, 2006). It is important to assure careful design of the interview situation in the data acquisition phase of an analysis and evaluation, to clearly articulate the purpose of the analysis and evaluation to those contributing to the process, and to explicitly address the effects of hindsight and other biases.

Fourthly, the method should facilitate making the limiting conditions under which the emergency response system operated visible. Were there other ways of affecting the objectives of the system in a positive way that were not exploited, or were the actions taken the only ones or the best possible? One must differentiate between the analysis and evaluation of the actual performance and that of what might have happened if the circumstances had been different, e.g. if an actor had had greater resources. Therefore, it is important to make the limiting conditions under which the emergency response system operated visible when analysing and evaluating its performance.

Based on the important aspects outlined above, a method for analysis and evaluation of emergency response in a multi-actor setting has been constructed and used to study the response in relation to the storm Per in a Swedish municipality, as described in appended paper IV. The method satisfies the criteria in that it promotes explicit treatment of values and objectives on which the evaluation of the emergency response operation is based. Secondly, it provides a common ground for the analysis of a specific operation, i.e. it enables various actors to reach agreement on what they did during the operation, and how they affected each other. Thirdly, since the various actors that participate in analysing the emergency response operation develop the system model of the operation together, the biases that might otherwise have occurred for instance due to people having distorted memories of the event will be reduced. Furthermore, this joint effort to develop the system model may foster knowledge-transfer and learning across organisational borders. Fourthly, dealing explicitly with the constraints of the operation and analysing counterfactual scenarios aids the evaluation of the emergency response system's performance as well as the individual actor's performance. More specifically, the structured analysis of counterfactual scenarios broadens the scope of the conclusions that can be drawn from

studying one event, thus enhancing the frameworks potential to serve as a tool to learn from past emergencies and prepare for future ones. In the discussion in section 6.1.1 some of the main insights from a first evaluation of the method that was conducted based on participatory observation when it was used to study the response in relation to the storm Per in a Swedish municipality are briefly described.

Research question 5

The fifth research question relates to the evaluation of documented risk and vulnerability analyses (RVA). A part of the Swedish system for the use of RVA as input to various emergency management activities have been studied based on the following question:

RQ5. Do the risk and vulnerability analyses performed by the Swedish County Administrative Boards in 2008 fulfil the purpose of generating input to a national overview of risks, vulnerabilities and emergency management capabilities?

The question indicates that the RVAs conducted by the regional County Administrative Boards are part of a larger system for RVA, where they serve as important input. In order to be able to address the question, a method for evaluation of systems for RVA and, as a part of that, of individual RVAs has been constructed, as described in paper V. The main considerations in developing this method was 1) that it should make it possible to state whether the intended purposes of the system for RVA as well as those of the individual analyses were fulfilled, 2) it should do so by establishing testable propositions describing the link between the purpose of the system and the observable properties of an individual RVA, and 3) it should be based on study of documented RVAs since these constitutes the main way of conveying information in the system for RVA.

The activity of evaluation assumes that there exist well defined purposes or goals for the artefact of interest. In paper V, it is demonstrated how this can be inferred from studying pertinent legislation, including the legislative history. The approach starts with an analysis of the purpose of the system for RVA, then proceeds with establishing what this means for the purpose of an individual RVA. Based on this, and on information from the area of risk analysis and risk assessment, a set of desirable properties for the individual

RVAs are established. It is these properties that form the basis for the analysis and evaluation necessary to address research question 5 above. Based on the study presented in paper V, it is concluded that a number of the studied RVAs do not display the necessary properties in order to fulfil their purpose of generating input to a national overview of risks, vulnerabilities and emergency management capabilities. Implications of these findings are addressed in paper V and are further discussed in section 6.1.1.

Research questions 1-5 were all related to two main research objectives. In the following section the results pertaining to the respective research objective are summarised.

5.2.2 Summary of results related to the research objectives

In this section, a short summary of the results pertaining to the respective research objectives is given. Related to the first objective, *to investigate people's preferences regarding negative consequences of potential unwanted events*, two studies have been presented. The first focused on the consequence attribute number of fatalities and concluded that not all people are risk averse regarding this attribute in the range of 0 – 1000 fatalities and that majority of the subjects in this particular study group displayed a risk seeking behaviour. The second study focused on inter-comparison between a number of attributes and concluded that the attributes related to physical harm matters most in the evaluation of consequence seriousness (given the ranges of the attributes used in the study) for this particular study group. It was also shown that the apparent cause of a disaster affect how people (in this study group) judge its seriousness.

The extent to which these results contribute to reaching this research objective and what is missing in order to do that is reflected upon in the discussion in chapter 6.

Related to the second research objective, *to develop methods for analytic input to societal emergency management*, three studies have been presented. The first two were mainly focused on the building part of the design process, resulting in a method for analytic input to preparedness activities in a local municipality and a method for analysing and evaluating emergency response in a multi-actor setting. The third study mainly focused on the evaluation part of the design process and resulted in the evaluation of a part of the Swedish system for risk and vulnerability analysis, and as part of that system the risk and

vulnerability analyses produced by the regional County Administrative Boards in 2008.

The extent to which these results contribute to reaching this research objective and what is missing in order to do that is reflected upon in the discussion in chapter 6.

6 Discussion

In this chapter, the findings of the research presented in this thesis are discussed in terms of potential implications of the results to societal emergency management activities. In addition, some implications of the delimitations of the research, in relation to reaching the stated research objectives, are addressed and some ideas and thoughts on future research activities are discussed.

6.1.1 Perspectives

The main focus of this thesis is on the design of methods for analytic input to societal emergency management. One very important aspect of such input is that of values and preferences, since they will govern what is to be considered as negative consequences following an unwanted event when conducting risk and vulnerability analysis, and influence the focus of evaluation efforts after an emergency etcetera. It is argued here that any attempt to engage in emergency management activities, whether it is in terms of trying to prevent, mitigate or prepare for effective response to and recovery from unwanted events, should strive to make the underlying values explicit. This is for instance reflected in the design criteria related to each of the developed methods in the present thesis. It is not within the scope of the present thesis to discuss at length *whose* values and preferences should influence emergency management activities, such matters have been addressed elsewhere, e.g. (Fischhoff, et al., 1992; Pidgeon, 1998; Stirling, et al., 1999; Renn, 2001; Sjöberg, 2001). Here the discussion is limited to establishing the necessity of making them explicit when engaging in emergency management activities and that there are many sources of information one could use as input in such efforts, ranging from the study of relevant legislation and policy documents expressing underlying values to making explicit studies of people's preferences. The work behind the present thesis included two studies of the latter sort and in the following subsections these are discussed in terms of implications for societal emergency management activities and fulfilment of research objectives.

The results from the studies behind papers I and II can be used by societal actors as input to discussions for instance regarding the formulation of tolerable levels of societal risk and in situations where tradeoff considerations have to be made between different attributes. More specifically, the results from the study of preferences regarding the consequence attribute number of fatalities presented in paper I suggest that, insofar as the preferences of the

participants of that study can be generalised, the common practice of letting tolerability criteria for societal risk reflect a significant aversion toward events involving many fatalities, by use of a steep negative gradient for the criterion F-N line (see for instance (Smeder, et al., 1996; Davidsson, et al., 1997; Ale, 2005)), may not be called for over the entire range of fatalities used in the experiments (0 – 1000 fatalities). There may of course be other reasons for "punishing" low-frequency/high-consequence events when designing tolerability criteria for societal risk, for instance related to society's capability of managing the effects of events of various scale (Ball and Floyd, 1998). In any case, the results from paper I would provide important input to discussions on the establishment of tolerability criteria for societal risk. As for the comparative study of various attributes presented in paper II, the kind of relative weights for different attributes resulting from that study would, insofar they could be generalised, be of use in situations where tradeoff considerations between various attributes are necessary, which is almost always the case in practical decision situations where priorities have to be made between for instance alternative emergency management measures aiming at reducing different types of potential consequences following an unwanted event. Furthermore, from the study in paper II, it could be concluded that the apparent cause of a disaster did affect how people (in this particular study group) judged the seriousness of the disaster. It should be noted, however, that this does not necessarily imply that the apparent cause of a risk scenario should be taken into consideration when involved in decision making concerning risk management of potential future risk scenarios. It is beyond the scope of the present thesis to discuss this issue at length but certainly knowledge about how people's judging of scenario seriousness is affected by its apparent cause could serve as valuable input to such discussions.

Regarding the fulfilment of the research objective *to investigate people's preferences regarding negative consequences of potential unwanted events*, the studies behind papers I and II were both limited in terms of the composition of study groups, one consisting of people with professional or educational knowledge of risk and emergency management issues, and the other of people with educational knowledge of such matters. This leads to limited possibility of generalisation of the results in the respect that they cannot be said to represent "people's" preferences. There were also limitations in scope in terms of which attributes were included in the studies. To gain a more adequate understanding of the values and preferences of the general public in such matters and increase the generalisability of the results, studies with other composition of study groups, involving other relevant attributes and ranges of attribute values are called for. Again, it is beyond the scope of the present thesis to discuss at length

whose preferences should influence emergency management activities, and in some situations it may not be necessary to strive for a representation of the general public, for instance in specific projects affecting only limited parts of society. In relation to this it should be noted that one aim of the studies regarding people's preferences was to test the methods for elicitation of preferences in terms of their strengths and weaknesses, something that is discussed in more detail in papers I and II. Software has been produced to facilitate the eliciting procedures and the methods used in paper I and II could be used in order to elicit the preferences of those involved in emergency management activities in a specific context, for instance related to a specific project or in a specific municipality.

Regarding the second research objective, *to develop methods for analytic input to societal emergency management*, one main contribution of the work behind the present thesis is the actual process for method development described in section 2.2.1 and put to use in papers III-V. The reason that it is introduced in the background, when it really could be regarded a part of the result of the research process, is that it had to be placed early in the thesis in order to facilitate the presentation of the subsequent chapters. Obviously, this process bears a strong resemblance to general design processes discussed in the literature, but the adoption of a structured process for the development of methods, something that was lacking in the beginning of the research behind the present thesis, will be of great value in future efforts to develop methods for analytic input to societal emergency management.

Two of the studies under this research objective were mainly focused on constructing new methods, i.e. the *build* activity as described by March and Smith (1995), for addressing two different problem areas; generating input to preparedness activities and evaluating emergency response. March and Smith (1995) describes the research contribution resulting from the build activity in design science as being determined by the novelty of the artefact and the persuasiveness in the claims that it is effective. As for the effectiveness of the methods presented in paper III and IV, the arguments for the design criteria in relation to the purpose and the way that the developed methods satisfy the criteria has were presented in the results section and will not be repeated here. However, some insights from a first evaluation of these methods based on participatory observation are discussed below, alongside with a discussion regarding the novelty of the two methods.

Starting with the method for analytic input to emergency preparedness activities in a local municipality, the main argument for adopting a broad scope in terms of hazards and risk scenarios considered in an analysis is that it provides the municipality with a platform for comprehensive preparedness

planning activities. One could argue that there are two sides to that coin, in that it is a time and resource (in terms of personnel) consuming activity to address a vast number of hazards and risk scenarios in an analysis. The response from the municipality under study indicates however, that the advantages were considered to be worth the extra effort, in that the participants gained a better knowledge of the total spectrum of risks facing the municipality, and that they were able to identify and discuss potential unwanted events that they had no experience of beforehand. The all hazards approach alongside with the explicit, structured identification and description of potential assistance needs that may arise given a specific risk scenario were considered to be of use to municipality officials, planners and politicians as one input to reasoning about for instance the distribution of responsibility to meet identified needs, identification of areas in need of improvement, identification of education and training needs, resource allocation issues etc. In relation to this it should be mentioned that the term "assistance needs" that was used in this study was considered by some participants to possibly "give the wrong signal" in the respect that it indicates that people are looked upon merely as victims and not as resources in emergency management. This was not the intended signal and in forthcoming studies the more general term needs will be used in stead. It may also be a point that the kind of inter-organisational workshops that were conducted during the study, with representatives from many different administrative units within the municipality, could assist in building professional networks. Such networks have proved to be of importance in the management of emergencies and crises, see for instance Uhr and Johansson (2007). As for the novelty of this approach, at the time of method development, there seemed not to be any approaches with such a broad scope available, at least not in use in a Swedish context or described in the studied literature, which addressed all of the design criteria stipulated for this method.

Regarding the method for analysing and evaluating emergency response in a multi-actor setting presented in paper IV, some insights from a first evaluation based on participatory observation are discussed below, alongside with some notes on novelty. Firstly, the method facilitated structured discussions on dependencies among the participating actors. In discussions with the participants of the workshops it became evident that the construction and use of an explicit model of the emergency response system increased their understanding of how they affected each other and the system as a total. However, in this first use of the approach there was no possibility of generating the system dynamics model in real time during the data collection, since it had to be drawn manually and it was not practically feasible to do that while collecting the data. In stead, the data collection took

place during one workshop and the discussion based on the system dynamics model during another. In order to facilitate the generation of the system dynamics model and make this process more transparent, an effort should be made to investigate the possibility of producing software where the system dynamics model could be generated in real time during the data collection process. In relation to this it should be mentioned that several authors have argued strongly in favour of data collection regarding emergencies taking place during the actual emergency, see for instance (Quarantelli, 2002; Stallings, 2006), in order to get more accurate accounts of what actually happens, reduce the effects of hindsight biases etcetera. Even though such an approach would bring about other methodological and practical concerns having to do with timing, access to the "right" people during the emergency (Stallings, 2006) and the fact that the emergency response system usually is geographically distributed etcetera, it would be of great interest to investigate the possibilities of conducting at least a part of the data collection underlying analysis and evaluation in real time during an emergency. As for the novelty of the method presented in paper IV, the approach to collaboratively generate a systems dynamics model representing the emergency response system during the studied period, with the subsequent study of counterfactual scenarios to broaden the scope of conclusions that can be drawn from the study is something that has not been found elsewhere.

The third study under this research objective was more directed towards the evaluation part of design. The evaluation of a part of the Swedish system for risk and vulnerability analysis, focusing on the analyses performed by the regional County Administrative Boards in 2008, presented in paper V, concluded that this system do not fulfil its purpose related to the generation of a national overview of risks, vulnerabilities and emergency management capabilities. This is because a number of the individual risk and vulnerability analyses did not provide the information necessary for such an overview to be produced. The study in paper V, however, focused only on one part of the system, the regional, and furthermore only on one of several purposes for that system. In order to get a fuller understanding of the performance of the system as a whole, evaluation of other parts of the system, i.e. local and national, and regarding other purposes of the system is called for. Also, it should be noted that even though one purpose of the system is not fulfilled, this does not mean that the system is not producing valuable information to be used as input to various emergency management activities. However, the approach to evaluation generates an explicit account of the properties lacking from the individual RVAs related to the fulfilment of the purpose, information that can be used as input to efforts in terms of modification and further development of the analyses.

6.1.2 Further research

During the research process leading to the present thesis a number of new and related questions have been identified, which would be of relevance for future studies. In this section, some the most important ones are highlighted.

In relation to the study of people's preferences regarding negative consequences of potential unwanted events, it would be interest to perform studies that are more "open" in terms of what kinds of attributes affect the judgement of scenario seriousness. The studies performed here used fixed attributes, i.e. there was no room for the participants to explore other types of attributes. One way to address this would be to use open questions requesting of the participants to describe themselves what types of consequences they would see as most serious following an emergency scenario. Information provided through studies of this sort could for instance be used as input to discussion on what kinds of consequences one should explicitly consider when performing, or developing methods for, risk and vulnerability analyses. However, if one aims at eliciting attribute weights, as in appended paper II, the introduction of more attributes will always be at the expense of more comprehensive eliciting procedures and the extra effort this requires from everybody involved must be balanced against the extra value one sees in studying more attributes.

In order to increase the possibility to generalise the results of the studies in papers I and II, it would be of interest to repeat the studies with other constellations of study groups.

Regarding the development of methods; at a general level it would be of interest to further study the process of scientific development of methods. The work behind this thesis has contributed to some part but more studies are needed, particularly on the evaluation part of the process. One way of proceeding would be to work towards "instantiation" (March and Smith, 1995) of the methods developed during the work behind this thesis, that is to make use of them in real life. The final aim is that they should be of use to the relevant actors involved in emergency management activities, and then not necessarily involving researchers. The researchers' role and contribution would then be to develop metrics and procedures to evaluate their performance in order to facilitate further development.

Looking more specifically at the method for analytic input to emergency preparedness in a municipal setting described in paper III, it would be of interest to further develop primarily the third part of the method, concerning assessment of the capabilities of the emergency response system to meet

generated needs in an emergency. One way forward with promising potential would be to use the approach proposed in paper IV regarding analysis and evaluation of actual emergency response as input to such development work.

Furthermore, the method for analysis and evaluation of emergency response proposed in paper IV, which was demonstrated by brief empirical examples, should be applied in more extensive case studies with following evaluation. It would be of interest to employ the method in a variety of settings, such as emergencies of different types and scales, in order to identify strengths and weaknesses for further development. In addition, the possibilities of conducting at least part of the data collection in real time during an emergency should be investigated, then preferably with the possibility of generating the system dynamics model in real time. Furthermore, as indicated above, it would be of great interest to further explore the possibilities of using this approach to modelling and analysis in a forward-looking setting, i.e. while performing risk and vulnerability analyses based on potential future scenarios.

Finally, the approach to evaluation of systems for risk and vulnerability analysis presented in paper V has only been applied to one part of the Swedish system, the regional level, and then focusing merely on one out of several purposes for that system. It would be of interest to apply the proposed line of investigation also to other purposes and other levels, local municipal authorities and central authorities, to study the risk and vulnerability analyses produced on these levels in terms of fulfilment of their purpose and their relation to the fulfilment of the purpose for the overall system.

7 Conclusions

In the introduction chapter a very general question was asked concerning whether the development of methods for analytic input to societal emergency management could be conducted in a scientific manner. In order to be able to address this issue a design science perspective was adopted and during the research process behind this thesis a systematic process for such method development evolved, requiring a logic and transparent line of reasoning from the stated purpose of the method through the formulation of design criteria to the actual construction of the method. This should then be followed by evaluation of the method based on use in the context it is supposed to be used and, should it prove necessary, subsequent modification of the method. By use of this process, some main types of analytic input to societal emergency management have been examined in terms of how methods should be constructed in order to fulfil their respective purpose. In addition, the importance of values and preferences to any design process has been highlighted and it is argued that any attempt to engage in emergency management activities should strive to make the underlying values explicit, which is reflected in the design criteria formulated for the developed methods. Furthermore, two explicit studies of people's preferences regarding negative outcomes of unwanted events have been conducted. Below, the main points of the present thesis are summarised:

- A process for scientific development of methods, based on a design science perspective, has been introduced, used and discussed. By explicitly describing how a suggested method fulfils its purpose, by use of the process referred to above, and exposing it to evaluation exercises, a strong basis for judging its effectiveness is provided.
- A method for analytic input to emergency preparedness activities in a municipal setting has been developed and evaluated based on participatory observation. The method satisfies the design criteria derived from its purpose in the respect that it promotes explicit treatment of underlying values and these are translated into relevant consequence categories, it promotes and facilitates an all hazards approach to preparedness activities and furthermore an explicit assessment of the potential needs that may be generated in various emergency scenarios, and it explicitly addresses the capabilities of the emergency response system to meet these needs.
- A method for analysing and evaluating emergency response in a multi-actor context has been developed and evaluated based on participatory observation. The method satisfies the design criteria

derived from its purpose in the respect that it promotes explicit treatment of underlying values, it addresses the complexity of the systems involved and the validity of the information used as input to analysis and evaluation, and it facilitates making the limiting conditions under which the emergency response system operated visible.

- A part of the Swedish system for risk and vulnerability analysis, in particular the risk and vulnerability analyses produced by the Swedish County Administrative Boards in 2008, has been evaluated by use of a method developed specifically for this purpose. It is concluded that the system does not fulfil its purpose related to generating a national overview of risks, vulnerabilities and emergency management capabilities. This is because a number of the individual risk and vulnerability analyses do not provide the information necessary for such an overview to be generated.
- It is of importance to make the underlying values and preferences visible when engaged in emergency management activities. This is because they will govern many aspects of such activities, for instance what is to be considered as negative consequences following an event and it is not necessarily the case that all actors involved share the same values.
- Not all people are risk averse regarding the consequence attribute number of fatalities (given the range 0-1000 fatalities). In fact most of the participants in the study undertaken here display risk seeking behaviour regarding this attribute. These results could serve as input to discussions regarding the formulation of tolerability criteria for societal risk.
- Most of the participants in the study regarding evaluation of disaster seriousness were affected by the apparent cause of a disaster when judging its seriousness.
- Attributes related to physical harm, especially the number of fatalities, mattered most to the participants of the abovementioned study when evaluating disaster seriousness (given the ranges of the attributes used in the study). The overall ranking of the attributes was, from the most to the least serious: number of fatalities, number of serious injuries, economic loss and cause of the disaster.

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