Grasping complexity: analysing risk for sustainable development

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Abstract: Sustainable development relies on our ability to make decisions today that will determine our tomorrow. Given that uncertainty is explicitly allowed to influence our view of what the future holds for us, most ex ante analyses of challenges for sustainable development can be viewed as analysing risk. Many frameworks for analysing risk exist today, but analysing risk for sustainable development entails different requirements. By applying a combination of traditional science and design science, this thesis presents six such requirements, informed by available theory and new empirical studies. The thesis also presents six criteria for scientifically developing frameworks for analysing risk for sustainable development.

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Summary

Sustainable development relies on our ability to make decisions today that will determine our tomorrow. Given that uncertainty is explicitly allowed to influence our view of what the future holds for us, most ex ante analyses of challenges for sustainable development can be viewed as analysing risk. Many frameworks for analysing risk exist today, but analysing risk for sustainable development entails different requirements.

By applying a combination of traditional science and design science, this thesis presents justifications for six key requirements, informed by available theory and new empirical studies. Although the empirical base for this thesis is facilitating capacity development for managing risk, it may hold broader implications for analysing risk for sustainable development in general. The identified key requirements comprise the ability to: (1) integrate phenomena on various spatial and temporal scales, as well as structural and functional complexity (systemic); (2) accommodate different stakeholder values (multi-value); (3) incorporate a wide range of initiating events that may impact on what stakeholders value (multi-hazard); (4) integrate a multitude of factors and processes that contribute to the susceptibility of what stakeholders' value to the impact of the events (multi-susceptive); (5) involve various stakeholders across functional, administrative and geographical borders (multi-stakeholder); and (6) integrate several risk analyses performed by different groups of stakeholders (multi-analysis).

The thesis also presents six criteria for scientifically developing frameworks for analysing risk for sustainable development, namely a systematic and transparent design process in which: (a) the empirical and normative statements behind the framework's purpose and required functions are explicitly justified and stated; (b) the actual form of the developed framework makes it possible to utilise in practice; (c) the connections between purpose, functions and form of the framework are clear; (d) the framework is utilised in its intended contexts; (e) the utility of the framework is measured in how well its form fulfils the required functions to meet its purpose; and (f) the outcome of evaluating the framework guides further development.

Sammanfattning

Hållbar utveckling bygger på vår förmåga att fatta beslut i dag som avgör vår morgondag. Givet att osäkerhet tillåts påverka vår syn på vad framtiden har i sitt sköte, kan de flesta framåtblickande analyser av utmaningar för hållbar utveckling anses vara riskanalyser. Det existerar många ramverk för riskanalys idag, men att analysera risk för hållbar utveckling innebär särskilda krav.

Genom att tillämpa traditionell vetenskap och designvetenskap, presenteras i denna avhandling motiveringar för sex krav på riskanalyser för hållbar utveckling, baserade på tillgänglig teori och nya empiriska studier. Även om den empiriska grunden för denna avhandling är att underlätta utveckling av kapacitet för att hantera risk, kan dess resultat ha betydelse för att analysera risk för hållbar utveckling i allmänhet. Kraven är förmåga att: (1) integrera fenomen på olika skalor i rum och tid, samt strukturell och funktionell komplexitet (systemisk), (2) tillgodose olika värden (multi-värde), (3) innehålla många inledande händelser som kan påverka dessa värden (multi-hot), (4) integrera en mängd faktorer och processer som bidrar till sårbarheten hos dessa värden (multi-sårbarhet), (5) involvera olika intressenter över funktionella, administrativa och geografiska gränser (multi-intressent) och (6) integrera flera riskanalyser som utförs av olika grupper av intressenter (multi-analys).

Avhandlingen presenterar också sex kriterier för att vetenskapligt utveckla ramverk för att analysera risk för hållbar utveckling, nämligen en systematisk och öppen designprocess där: (a) de empiriska och normativa antaganden bakom syfte och funktion uttryckligen motiveras, (b) den konkreta utformningen av det utvecklade ramverket gör det möjligt att använda det i praktiken, (c) sambanden mellan syfte, funktion och form är tydligt, (d) ramverket används i dess avsedda kontext, (e) användbarheten av ramverket mäts i hur väl dess form uppfyller de funktioner som krävs för att uppfylla sitt syfte, och (f) resultatet av utvärdering efter användning vägleder ytterligare utveckling.

Acknowledgements

Although I have spent my entire adult life dealing with risk or disaster-related issues in relation to sustainable development and pondering how to grasp their complexity, it was not until I started working at Lund University Centre for Risk Assessment and Management (LUCRAM) that I felt that I was getting somewhere. I am thus grateful to all my colleagues who have assisted me in this immense learning experience, both within Lund University and elsewhere. Especial thanks are due to my Head of Department, Robert Jönsson, for making it administratively possible to finalise a PhD while working as a Visiting Professor, and to my supervisor Professor Kurt Petersen for guiding me along the way. However, the biggest debt I owe is to Henrik Tehler, my co-supervisor and colleague, who through his great intellect and patience has supported the development of my understanding of risk, as well as my own intellectual development in general. Finally, I extend all my love to my wife, Anna, for always supporting me, and to my son, Noa, for inspiring me to continue to be as curious as he is.

Lund, October 18, 2010

Per Becker

Table of contents

1. Introduction

"Unless we change direction, we are likely to end up where we are going" - *Chinese proverb*

This thesis is an attempt to facilitate sustainable development by articulating an argument for the need to integrate the notion and management of risk in development policy and practice. And more specifically by outlining initial ideas for a framework for analysing risk in this context, including potential negative impacts of climate change.

1.1. Background

The world economy has been estimated to have increased around 50 times and the population almost six times from the industrial revolution to the end of our last century (Maddison 2001:28). This development continues to place increasing strains on the world's natural resources and environment (Kalas 2000; Grimble *et al.* 2002; Komatsuzaki & Ohta 2007; Syvitski 2008; Gadda & Gasparatos 2009; Fan & Qi 2010), while vast inequalities persist and even deepen both between and within states (Rist 2006:18; Bywaters 2009; Gorringe *et al.* 2009; O'Brien *et al.* 2009a). Although the last century saw a global increase in life expectancy (Riley 2001) and a decrease in child mortality (Ahmad *et al.* 2000:1175) and adult illiteracy (Parris & Kates 2003:8070-8071), the economic development was highly unequal rendering the same wealth in the final decade of the century to the richest one percent in the world as to the poorest 57 percent (Milanovic 2002:50). In order to reduce poverty while striving towards a more viable use of natural resources, it is vital to make future development more sustainable.

Regardless of whether one focuses on economic growth or on more human-centred parameters, such as increased literacy or reduced child mortality, most uses of the concept of development have one thing in common. This is the fact that they project some sort of scenario into the future, in which the variables of interest develop over time along a preferred expected course. This scenario is, in modern society, not believed to be predestined or predetermined in any way, but is dependent on a wide range of human activity, environmental processes, etc. The complexity and dynamic character of the world is, instead, continuously creating a multitude of possible futures (Japp & Kusche 2008:80), causing uncertainty as to what real development will materialise.

Being unable to see into the future, as well as being largely incapable of predicting it (Simon 1990:7-8; Taleb 2007/2008), modern individuals, organisations and societies resort to the notion of risk in order to make sense of their uncertain world (Zinn 2008:3-10). Risk is a contested concept, but to be able to talk about risk at all entails some kind of idea of uncertain futures as well as of their potential impacts on what human beings value (Renn 1998a:51). This use of risk also entails that risk must be defined in relation to some preferred expected outcome (Kaplan & Garrick 1981; Luhmann 1995:307-310; Kaplan 1997; Kaplan *et al.* 2001; Johansson & Jönsson 2007:12-14; Zinn 2008:4). If risk is related to potential deviations from a preferred expected future, stakeholders in development must endeavour to reduce such risk to safeguard their development objectives.

There are many courses of events and their underlying processes that may negatively impact development, in either the short or the long term. Abrupt changes in political leadership, global financial crises, algal bloom, epidemic outbreak, droughts, cyclones and outbreaks of communal violence are just a few examples of initiating events that may set off destructive courses of events. Behind these often dramatic courses of events lay processes of change which are less sensational, but may have far-reaching indirect impacts, such as globalisation (Beck 1999; Yusuf 2003; Murad & Mazumder 2009), demographic and socio-economic processes (Wisner *et al.* 2004:62-74; Satterthwaite *et al.* 2009:11-19), modernisation (Beck 1992), environmental degradation (Geist & Lambin 2004; Pimentel 2006; Lewis 2006), the increasing complexity of modern society (Perrow 1999b; Perrow 2008), the development of protracted low intensity armed conflicts (Kaldor 1999), and increased asymmetrical threats (Kegley 2003). In addition we have the mounting threats of climate change, not only potentially increasing the frequency and intensity of destructive extreme weather events (Webster *et al.* 2005; Nordhaus 2006; Syvitski 2008; von Storch & Woth 2008; Elsner *et al.*

2008; Gravelle & Mimura 2008; Kasei *et al.* 2010), but also changing everyday life for vast numbers of people.

These courses of events and their underlying processes rarely exist in isolation, neither from each other nor from the development activities and processes that they impact. It is thus not only vital to ensure that development gains are durable in the face of destructive courses of events and their underlying processes, but also that the means to reach the development gains do not augment, or create new, risks that hinder development for future generations (WCED 1987). Analysing risk is thus a requisite for sustainable development (Haimes 2004:101-106). There are many frameworks for analysing risk that have been developed over the last four decades or so (e.g. Haimes 1998; Aven 2003). However, analysing risk in a sustainability science context entails additional, and sometimes different, requirements.

The world is increasingly complex (OECD 2003:33-50; Calvano & John 2004:25-26; Renn 2008:5). Facilitating sustainable development requires the ability to integrate phenomena on a wide range of spatial and temporal scales, from local to global and from delayed to immediate (Kates *et al.* 2001:641). It also demands the ability to grasp structural and functional complexity (*ibid.*), which means not focusing on individual elements of the world in isolation but on how they are connected, interact with and depend on each other (Haimes 1998:104; Turner *et al.* 2003a:8077). This causes the consequences of an initiating event to propagate through the system (Rinaldi *et al.* 2001; Hollenstein *et al.* 2002:56-61; OECD 2003:44-45; Jiang & Haimes 2004:1215-1229; Dobson *et al.* 2007). To facilitate sustainable development, societies must have the capacity to manage a wide range of risks (Haimes 1992:415; Haimes 2004:101-106) to a complex set of elements that human beings value. It is vital to include a multitude of initiating events in the analysis and an even larger set of interdependent factors and processes, both social and biophysical (Kasperson & Kasperson 1996:96; Turner *et al.* 2003a), contributing to the susceptibility of these elements to the direct or indirect impact of the events. It is also vital to include a wide range of stakeholders (Renn *et al.* 1997:218-219; Haimes 1998:104; Renn & Schweizer 2009) representing legal, institutional, social, political and economical contexts (Renn 2008:8-9), as well as experts, policymakers and the public at large (Renn 2001).

2. Research demarcation

"The most beautiful part of every picture is the frame" - Gilbert Keith Chesterton (1909/2008:105)

2.1. Presenting the context of the research

Sustainable development is, as will be presented later in this thesis, both conceptually and practically a broad and multifaceted issue (WCED 1987; Kates *et al.* 2001). It is an issue of paramount importance for the continued existence of the world as we know it. At its core lies the idea that in planning for the future, we must think about what to do and not to do today, in order to bring about that future (Simon 1990:11). An important part of sustainable development is, in other words, forward-looking. However, there may be many ways to envisage the future. A major distinction among these approaches is the extent to which uncertainty is explicitly allowed to influence the resulting view of what the future holds for us. This thesis is limited to concerning itself with frameworks for ex ante analyses of challenges for sustainable development that explicitly include uncertainty (Figure 1), i.e. frameworks for analysing risk for sustainable development.

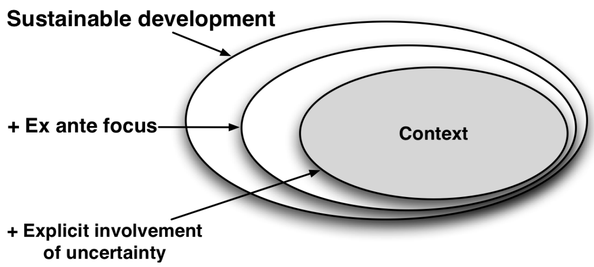

Figure 1. Demarcation of research context.

Analysing risk for sustainable development entails a broad societal focus, which limits this thesis to excluding analysing risk in more monomorphous contexts, e.g. restricted to one stakeholder (a company), one particular site (a chemical plant), one functional sector (power distribution), etc. The frameworks for analysing risk for sustainable development envisioned in this thesis are, in other words, for stakeholders with interest of society as a whole, e.g. national, provincial or local governing bodies, public-private partnerships for regional development, civil-society organisations with broad social responsibility, etc.

2.2. *Purpose, research question and process*

The purpose of this thesis is to outline a framework for analysing risk for sustainable development, including negative impacts of climate change. To meet this purpose, the thesis intends to answer the following overall research question:

<u>What criteria should guide the design of a framework for analysing risk for sustainable development, and how should such a framework be developed scientifically?</u>

The scientific design of a framework necessitates a somewhat different approach than traditional science (March & Smith 1995; Abrahamsson 2009:20). Instead of being mainly concerned with the pursuit of knowledge (Weber 1949; Ravetz 1996; Checkland 1999:50), the focus must be placed on designing a framework that must meet some predefined purpose (Simon 1996:4-5, 114; Poser 1998:85-87; Cook & Ferris 2007:173; Abrahamsson 2009:20; Hassel 2010:14-15).

The normative focus of this endeavour poses a different challenge than for traditional descriptive research, as normative statements are inferred from value preference and not from empirical observation, a philosophical assumption presented in detail in Section *3.1.3 Axiological assumptions*. This challenge opens up the way for an infinite number of possible frameworks that could be considered to meet the stated purpose (Figure 2) (Simon 1996:119-120; Poser 1998:86). Just as it is unfeasible to identify all possible frameworks, it is also unfeasible to design the optimal framework (Simon 1996:119-120; Poser 1998:86; Hevner *et al.* 2004:88-89). The aim must instead be to design a framework that satisfies some predetermined design criteria (Simon 1996:119-121; Abrahamsson 2009:23; Hassel 2010:40).

To scientifically develop the framework, we must ensure transparency of both what underlies decisions about design criteria and of the design process itself, so that they are open to scientific scrutiny (Abrahamsson 2009:22-24; Hassel 2010:42-47). Each decision about a specific design criterion may or may not have implications for other criteria, but the process to establish them can be seen as additive in the sense that each decision determines the path to take through this part of the design process (Figure 2). The set of design criteria is then what the framework is evaluated against.

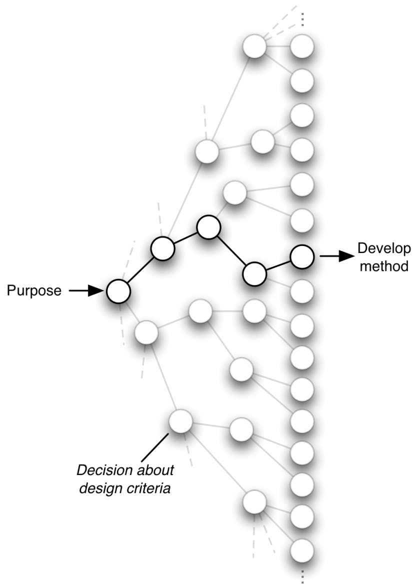

Figure 2. The additive process of establishing design criteria.

The research process of this thesis is to establish design criteria, to develop the framework, apply it in context and evaluate it against the established design criteria. This may seem like a rather linear process, but it is inherently iterative (Hevner *et al.* 2004:88). The design process is presented in full in Chapter *4.2 The design process*.

The framework for analysing risk for sustainable development that is outlined in this thesis is only applied and evaluated in one context. This may seem to limit the effectiveness and usability of the framework itself, as more applications most certainly are necessary to guide further development. However, the overall research question of this thesis is not focused directly on the outcome of the design process, which is the first embryo of a framework. Rather, it focuses instead on making a transparent argument for design criteria that should guide the design of such a framework, as well for how such framework can be designed scientifically. Such a focus is less limited by the few applications of the framework itself.

2.3. Appended papers

This thesis is based on a synthesis of six peer-reviewed journal articles. The first five (I-V) are descriptive in nature and are intended to empirically inform the normative argumentation behind the establishment of key design criteria. This connection between the descriptive and the normative is elaborated on in Section *3.1.3 Axiological assumptions*. The argumentation behind such criteria is also informed by available theory. The last paper (VI) is used to present initial ideas for a framework for analysing risk for sustainable development and to discern if the used design process can be scientifically rigorous. The setting for the studies described in the appended papers is international and their focus is on facilitating capacity development for managing risk or actual destructive courses of events. This represents one of many possible settings within the context of this research, but still, it forms the empirical basis for indicating potential generalisations in the final chapter of this thesis. The research contribution and implications of the papers are summarised in the table below (Table 1).

2.4. Outline of the thesis

This thesis consists of six chapters, a bibliography and six appended papers. Here follows a brief synopsis of the four remaining chapters:

Chapter 3. Philosophical and theoretical framework: This chapter starts by presenting vital assumptions about ontology, epistemology, axiology and complexity. The chapter continues by presenting a theoretical framework for informing the argumentation for key design criteria.

Chapter 4. Methodological issues: This chapter presents traditional science and design science as complementary, and equally essential, elements for the purpose of this thesis. It also presents the design process and similarities and differences between research methodologies and methods used during the thesis research.

Chapter 5. Research contribution: The first part of this chapter presents empirical studies which together with established theory are used to inform the argumentation for key design criteria that should guide the design of the target framework. The second part outlines initial ideas for a framework for analysing risk for sustainable development, and presents how it is tested and evaluated against the design criteria. The chapter ends by elaborating on, and answering, the overall research question.

Chapter 6. Final remarks: The last chapter of the thesis includes a final discussion of implications for analysing risk for sustainable development in general, and presents ideas for future research.

Paper I	**Research question** What general results may come from focusing international development cooperation on specific factors influencing disaster risk without acknowledging interdependencies with other factors?	**Research methods** Observation Interviews **Research object** 4 projects in Tajikistan and Sri Lanka	**Research results** Ignoring interdependencies between factors relevant for meeting project purposes results in sub-optimisation problems and in reduced chances for monitoring and evaluation in all four studied projects. **Implications** As it is likely that these problems are general, it is vital to take into consideration interdependencies between factors when planning and implementing projects.
Paper II	**Research question** What do stakeholders in disaster risk reduction in Fiji express as valuable and important to protect?	**Research methods** Semi-structured interviews **Research object** 11 stakeholders selected from all levels of state and traditional leadership, important market sectors, and from civil society in Fiji.	**Research results** There is great variation in what the 11 included stakeholders express as valuable and important to protect. **Implications** As it is likely that there is variation in what stakeholders express as valuable in general, explicit discussions of what is valuable are vital for risk management initiatives, since the lack of such discussions may result in stakeholders pursuing irreconcilable goals.
Paper III	**Research question** What do groups of municipal and county council civil servants express as valuable and important to protect and what underlies these expressions?	**Research methods** Focus groups **Research object** 4 focus groups of 7-21 civil-servants each (3 with municipal and 1 with county-council employees) in Sweden.	**Research results** There is variation in what the four groups of civil-servants express together as valuable in their context, indicating a range of social, cognitive and contextual factors influencing the result. **Implications** Although it is likely that such variation in what groups express together as valuable is a general factor, the picture supplied is likely to be richer than the sum of individual accounts and could also provide a mutual framework for acting together towards common goals.

Paper IV	**Research question** How do women and men of from three municipalities in El Salvador rank hazards in their communities?	**Research methods** Structured interviews **Research object** 69 randomly selected respondents from 3 randomly selected municipalities in El Salvador.	**Research results** Although there are no statistically significant differences in the ranking of hazards between women and men in the study, variation in livelihood, level of education, locations of dwellings, age, etc, provide statistically significant differences. **Implications** As it is likely that demographic factors may influence how hazards are prioritised in general, a wide inclusion of people is vital for broad public commitment to specific risk management measures.
Paper V	**Research question** What are the similarities and differences in expressed flows of information and assistance regarding risk and disasters between different administrative levels involved in managing risks and disaster situations in Fiji?	**Research methods** Semi-structured interviews **Research object** 5 related stakeholders from all administrative levels potentially involved in risk and disaster-related activities in Fiji.	**Research results** There are substantial discrepancies between what the 5 respondents on different administrative levels express regarding most aspects of the flow of information and assistance between them. **Implications** As there may be considerable differences between what stakeholders express when describing their system for managing risk and disaster situations, it is vital to integrate information from different administrative levels when constructing one comprehensive view of that system.
Paper VI	**Purpose** To present justifications for key requirements for analysing risk for sustainable development, and to outline, test and evaluate initial ideas for a framework for analysing risk that meets these requirements.	**Research methods** Focus groups Transect walk **Research object** 3 focus groups of 7-10 civil-servants and a full day of transect walk.	**Research results** The paper presents justifications for six key requirements for analysing risk in the context of developing capacities for managing risk for sustainable development (systemic, multi-value, multi-hazard, multi-susceptive, multi-stakeholder, and multi-analysis). It also presents, tests and evaluates, based on ten questions, an initial framework for building human-environment systems and structuring risk scenarios, in terms of their different strengths and weaknesses. **Implications** Although the initial framework seems to meet the six stated requirements to a certain extent, there are still modifications that have to be made and additional applications are necessary. Representing the world as an explicit human-environment system, while involving a multitude of stakeholders, seems central to analysing risk in the complex context of sustainable development.

Table 1. Summary of research contribution.

3. Philosophical and theoretical framework

"Thoughts without content are empty, ideas without concepts are blind[1]" - Immanuel Kant

3.1. Philosophical assumptions

3.1.1. Ontological assumption

The world is dynamic and complex (Dewey 1922). Although parts of the world are determined by processes over which human action has little influence, e.g. tidal cycles or the movement of tectonic plates, human activity has increasingly become the most important determining factor of our future (Simon 1996:2-3). However, regardless of what our world is determined by, this thesis rests on the assumption that the world does exist no matter if I am around to observe it or not (Keat & Urry 1975; Blaikie 1991:121). Such realist ontology entails a distinction between the empirical, the actual, and the real domains, where the first covers our experiences of events through observation, the second covers events whether observed or not, and the third covers the real processes that generate events (*ibid.*). The world is in other words there, but not directly available to us (Hammersley 1992:69).

3.1.2. Epistemological assumptions

In a world that is not accessible through direct observation, where the empirical rests on our experiences of interaction with it, there can be no objective search for truth (Kuhn 1970). In other words, meaning cannot be discovered, but rather, must be constructed through social processes in which there is a constant struggle over what is considered to be true or false (Winther Jørgensen & Phillips 1999:11-12). The philosophical base for knowledge rests on social practice, and on the practical knowledge[2] of people acting and utilising artefacts in specific social contexts (*ibid.*:11-14). This argument follows John Dewey's pragmatic philosophy in which thought and action never can be separated (Dewey

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[1] Author's translation from German "Gedanken ohne Inhalt sind leer, Anschauungen ohne Begriffe sind blind" (Kant 1787/1968:75).

[2] Theoretical knowledge is, in this view, also a kind of practical knowledge since it involves the social practices of producing and evaluating theories (Tanesini 1999:13-15).

1927/1991), as meaning and knowledge are forged in action (Dewey 1906:306-307). His philosophy of knowledge is also inclusive in the sense that everyone is a capable participant in generating knowledge (Greenwood & Levin 2007:61). But what then is knowledge?

Frank P. Ramsey, another pragmatic philosopher, distinguishes knowledge from belief by stating that belief is knowledge only if it is formed in a reliable process and never leads to mistakes (Ramsey 1931/2001:258). It is thus inadequate to believe something, regardless of the amount of empirical support for it, if that belief leads to errors (Sahlin 1990:4). This is much in line with Popper's idea of falsification in which a theory ceases to be theory when falsified through empirical observation (Popper 2002b). Falsification is, in this approach, the only genuine way for testing theory (Popper 2002a:48), which means that empirical observation may, at best, be consistent with a theory but can never prove it. Knowledge thus comprises beliefs in whose validity we are reasonably confident (Hammersley 1992:50).

Ramsey looks upon theory as being divided into existing entities (here, α, β, γ), axioms and a dictionary, which can be expressed as "($\in\alpha$, β, γ) : dictionary . axioms" (Ramsey 1929/1990:131) and is referred to as the "Ramsey Sentence" (e.g. Mellor 1980; Sahlin 1990). Here, the entities are the building blocks of theory, the axioms are the rules for how the entities function and interact with each other, and the dictionary is our ability to find the entities and axioms in the empirical domain of the world.

The "Ramsey Sentence" not only helps us to understand the relationship between the theoretical and the empirical (Sahlin 1990:140-158), but it also gives us a philosophical framework for managing the complexity in what we perceive when observing the real world. Ramsey (2000) distinguishes between the world, which is home of what we try to explain and understand, and our theoretical construction, which is a tool for making sense of the world. In other words, in order to grasp the complexity of reality, we need to implicitly or explicitly create models of it (Conant & Ashby 1970), or systems, as they commonly are referred to later in this thesis. The vital link between reality and our models is our capability to identify what is relevant for what we attempt to explain, understand or solve, as well as our capability to test our hypotheses for that particular explanation, understanding and solution.

3.1.3. Axiological assumptions

Researchers involved in traditional science should primarily be concerned with the pursuit of knowledge (Weber 1949; Ravetz 1996), and be as neutral as they possibly can in relation to values (Hammersley 2000:12). Although it is impossible to be objective and value-neutral, according to the epistemological assumptions above, we are not destined to only produce subjective accounts from which only political processes can distinguish the successes from the failures (Blaikie 2000:56). For researchers to be as value-neutral as they possibly can, it is essential to strive to be reflexive and to identify, and get beyond, prejudices and biases. Value-neutrality is, in other words, an unreachable vision or ideal that researchers involved in the pursuit of knowledge must chase with great strength and stamina to be able to get as close as possible to the realities under study (Hammersley 2000:17-18).

The vision of value-neutrality is, however, only vital in the pursuit of knowledge itself. It is not required to attempt to abandon values when it comes to what is perceived to be significant in selecting the areas of inquiry (Keat 1981:38-58). Nor are normative values prohibited from being involved in the process of utilising results from traditional science in solving real-world problems. This may also be done with scientific rigour and is the focus of the complementary design science (Lee 2007:44; Wieringa 2009:2).

Traditional science is well equipped to deal with how things are in the world (Checkland & Holwell 2007:3-5), but less so in dealing with how things ought to be (Simon 1996:5). This distinction between “is” and “ought to be”, i.e. between the descriptive and the normative, has been problematic for scientists for centuries, as it is easy to stray over from the former to the latter if proper care is not taken. David Hume was the first to point out this problem and some scholars claim that Hume advocates a complete division between “is” and “ought to be”, which is rather theatrically illustrated by the principle’s common epithet “Hume’s Guillotine” (Black 1964:166).

Statements about “how things ought to be” cannot be empirically inferred from statements about “how things are”, as these two are entirely different from each other (Hume 1739/1978:469). For instance, the normative statement “the authorities should lower the speed limit on all 90 km/h roads to 70 km/h” cannot be empirically inferred from the descriptive statement “the number of fatalities per car in accidents is 38% lower on 70 km/h roads compared to 90 km/h roads”. Descriptive statements should, however, be allowed to inform normative statements, but the statement itself will always be essentially inferred from a value preference, i.e. if we value the potentially saved human lives higher than the costs and inconvenience of longer travel times. It is thus vital to be transparent in what values normative statements rest upon (Hammersley 1992:4).

3.1.4. Reductionism, holism and complexity

Contemporary science is concerned with the pursuit of knowledge of a wide range of phenomena, as well as with solving an equally wide range of problems. How these phenomena and problems should be approached has been debated for decades, mainly in the form of more or less fierce advocacy for two seemingly disparate standpoints; reductionism and holism (e.g. Malanson 1999:746-747).

When looking at this conflict, much appears to depend on the definition of reductionism (van den Bergh & Gowdy 2003:76). If reductionism entails the standpoint that a system is nothing but the sum of its parts (e.g. Polkinghorne 2010), it is irreconcilable with holism. However, if reductionism, instead, entails the idea that to address the whole requires a decomposition of it into its parts and examining relations between these parts, they need not to be fundamentally conflicting (van den Bergh & Gowdy 2003:76).

Reductionist approaches attempt to isolate fundamental parts of a phenomenon or problem, and to examine relations between some of these parts, while assuming others to be constant. Holistic approaches, on the other hand, advocate the view that more complex phenomena or problems as wholes cannot be explained, understood or solved by studying parts in isolation[1] (Smuts 1926:86-87). There are at least two reasons for this. The first may be deducted from the famous statement that *the whole is more than the sum of its parts*[2], indicating that there may be observed regularities in the whole that cannot be obtained by aggregating the regularities of each part (Holland 1998:225). The second is related to the assumption of *ceteris paribus*, that all things that are not explicitly studied stay the same over time. This is refuted if relations between parts are non-linear and precludes attempts to hold selected parts constant (Ashby 1957:5; Anderson 1999:217). However, the vastness and sheer complexity of our universe make it impossible to research anything without reducing it to some extent (Churchman 1970:B43-44).

According to this view, the issue is not whether reductionism or holism is the best approach, but instead how much complexity is allowed to be involved in approaches to particular phenomena or problems (van den Bergh & Gowdy 2003:76). The guiding principles for finding a satisfactory approach regarding complexity are found in the Law of Requisite Variety (Ashby 1957:202-268) and Ockham's Razor[3] (Checkland 1999:35-36). The former states that a model of reality can only model something in reality if it has sufficient complexity to represent it, while the latter asserts that this complexity should be kept to a minimum and limited to only what is relevant for each particular phenomenon or problem (*ibid.*). The decisive feature in relation to how this phenomenon or problem may be approached is thus its complexity.

Although complexity is a contested concept with a wide variety of definitions and uses (see Backlund 2002), it is, in this context, commonly related to the number of involved parts; the number, significance and/or non-linearity of relations between parts and/or

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[1] It is important to note that in order for any parts to be part of a whole they must coincide in space and time, and there must be some kind of causal dependence between them (Mellor 2006:140).

[2] A statement often given as a quote from Aristotle's "Metaphysics", but which the author could not find in any translation.

[3] Also referred to as the principle of parsimony (Sober 1981).

heterogeneity in space[1] and time[2] (e.g. Yates 1978:R201). However, if any theory or model of reality is a social construction and influenced by both descriptive and normative aspects, then the complexity of any phenomenon or problem must also be related to factors associated with the observer (Ashby 1973:1; Flood 1987:177-178; Wu 1999:3). Ashby's analogy of the brain demonstrates this with almost amusing clarity and simplicity:

> *"To the neurophysiologist, the brain, as a feltwork of fibers and a soup of enzymes, is certainly complex [...]. To a butcher the brain is simple, for he has to distinguish it from only about thirty other « meats »" (Ashby 1973:1).*

What is included and what is excluded when addressing a phenomenon or problem are vital considerations (Churchman 1970:B43-44; Midgley *et al.* 1998:467) which are often referred to as boundary judgements to underline their inherently subjective nature (Ulrich 1996:156-158; Ulrich 2002:41).

Boundary judgements, descriptive statements about what we know about the phenomenon or problem, and normative statements about the purpose, objectives, etc of addressing them, are all connected to each other in such a way that changing one automatically induces changes in the others (Ulrich 2000:251-252). It is thus crucial to scrutinise systematically what is included and excluded when addressing any phenomenon or problem, as well as what descriptive and normative statements on which those boundary judgements are based. This is especially so when there are multiple stakeholders in the process, who may agree neither on the boundary judgements nor on the descriptive and normative statements behind them. This systematic scrutiny of boundary judgements is often referred to as boundary critique (Ulrich 1996:171-176; Midgley *et al.* 1998:467-470; Ulrich 2000:254-266).

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[1] What Yates (1978) refers to as broken symmetry.
[2] What Yates (1978) refers to as non-holonomic constraints.

3.2. Theoretical framework

3.2.1. Development, sustainable development and risk

Although the word development has been used for at least 250 years (Harper 2010), it was not until the end of the Second World War that it became an important concept (Thomas 2000b:3). Ideas about development have changed back and forth since then, e.g. the Soviet model of development (Smekal 1991:32-39), modernisation theories (Rostow 1960; Organski 1965), dependency theory (Dos Santos 1970; Frank 1967/2004), World Systems Theory (Wallerstein 1974), Another Development (Hettne 1995:160-206), Human Development (ul Haq 1995). This has spurred numerous and often competing definitions and has made it difficult to communicate about development. It has been suggested that this Babylonian confusion, to a great extent, is the result of the concept being used in three different ways: (1) as a description of a desired future state of society; (2) as a process of change over time; or (3) as deliberate efforts of various stakeholders aimed at improvement (Thomas 2000a:29).

Development may, in other words, refer to a desired state (goal), the process of getting there (change), as well as our efforts to get there (activities). Presenting a desired state of society implies some variable or set of variables (y) that human beings value and aspire to change from its current state. Development is, in other words, inherently normative (Seers 1969/1989). In this context, the process of change is the transformation of the variable or set of variables over time and our efforts refer to purposeful activities we carry out in order to drive or steer this change towards the desired state. The three parts are thus fundamentally related to each other (Thomas 2000a:29), enabling us to look at development as having five components:

1. A variable or set of variables (y) that human beings value and aspire to change.
2. A descriptive statement about the current state of "y".
3. A normative statement about the desired state of "y".
4. A normative description of a preferred expected scenario of change in "y" over time.
5. A set of purposeful activities aimed at driving or steering the change in "y".

Most definitions of development only include one or a few of these components explicitly (e.g. Seers 1969/1989:481; Todaro 1989:620; South Commission 1990:10-11; UNDP 1990:10-11; Chambers 1997; Rist 2006:13). However, these components can be seen as incremental in the sense that it is unfeasible to focus a definition of development on one without at least implicit involvement of the others before it. For example, it is impossible to define a desired state of something in the world without first defining that something and determining its current state that requires development, or to define development activities without expressing this desired state and the required change that the activities are designed to bring about (Örtengren 2003:9-15).

Hettne (1995) argues that development is contextual and therefore eludes any fixed and final definition. Because facilitating sustainable development requires emphasising the importance of human activity, the concept of development in this thesis includes all five components. Development is thus viewed as a preferred expected scenario of change in a variable or set of variables (y) over time from a current to a desired state and includes purposeful activities to drive or steer this change (Figure 3).

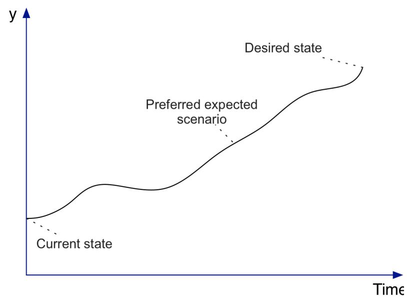

Figure 3. Development as a preferred expected scenario of change in “y” over time from a current to a desired state, including purposeful activity.

Sustainable development is commonly defined as “development that meets the needs of the present without compromising the ability of future generations to meet their own needs“ (WCED 1987:43). Looking more closely into the term “sustainable”, one sees that it is defined as something that is “able to be upheld or defended” (The New Oxford American Dictionary 2005). The first part of this definition indicates that sustainable development is development that can be maintained over time, while the second part indicates that sustainable development is development that can be safeguarded from the impact of negative courses of events and their underlying processes. These two parts are closely related, as it is not only negative courses of events that may impact development, but the means for development may also increase or create new courses of events and underlying processes that in turn make it difficult to maintain development over time. Hence, sustainable development is development that can be maintained over time and be safeguarded from the impact of negative courses of events and their underlying processes.

An important example of the connection between the two meanings of sustainable development is our dependency on burning fossil fuels for energy. This seems to be the main cause behind the climate change that threatens the development of our society. These threats are manifested both through increasing extreme weather events (Webster *et al.* 2005; Nordhaus 2006; Syvitski 2008; von Storch & Woth 2008; Elsner *et al.* 2008; Gravelle & Mimura 2008; Kasei *et al.* 2010) and through the gradual degradation of entire aquatic and terrestrial ecosystems, on which society depends (Folke & Rockström 2009; Rockström *et al.* 2009). Regardless of whether they are sudden and dramatic, or gradual and obscure, negative courses of events and their underlying processes may cause deviations from our preferred expected development scenario (Figure 4), limiting the sustainability of our development.

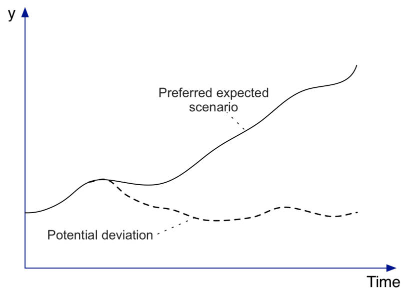

Figure 4. Potential deviation from the preferred expected scenario.

As the future is uncertain (Japp & Kusche 2008:80) and human beings are fundamentally incapable of predicting it (Simon 1990:7-8; Simon 1996:147-148; Taleb 2007/2008), there is not only one but a multitude of possible scenarios that deviate to various degrees from our preferred expected scenario (Figure 5) (Abrahamsson *et al.* 2010:22-23; Hassel 2010:29). Human beings have the ability to design their future by structuring these uncertain scenarios and use them as mental tools to anticipate consequences of different courses of action and then select activities that appear to lead to our desired state or goal (Simon 1990:11; Renn 2008:1). It is in this context that sustainable development can be viewed as requiring the ability to manage risk (ISDR 2004:18-30; UNDP 2004:9-27).

Risk is a contested concept with numerous definitions, creating the potential for miscommunication and misunderstandings (Fischhoff *et al.* 1984; Rosa 1998; Aven & Renn 2009a). In everyday language, the term "risk" stands for a destructive incident that may or may not occur (Sjöberg & Thedéen 2003:16). Researchers use the term more precisely, but the exact definition of the concept varies (Nilsson *et al.* 2000:21; Renn 2008:12-45; Aven & Renn 2009a:1-2). Nevertheless, these definitions have three aspects in common. First they all distinguish between reality and possibility, as the concept of risk makes no sense at all if the future is predetermined or independent of present human activity (Renn 1992:56; Renn 2008:1; Zinn 2008:3-4). The future must, in other words, be uncertain (Renn 1998a:51; Renn 1998b:51; Japp & Kusche 2008:80) and any future event must at least be perceived as being amenable to alteration (Zinn 2008:4), i.e. there would be no risk in gambling if the game were 100 percent rigged. Secondly, all definitions of risk explicitly or implicitly entail that these uncertain futures must have the potential to impact[1] what human beings value (Renn 1998a:51; Renn 1998b:51; Renn 2008:2), or at least be so perceived (Slovic *et al.* 1982; Slovic 1987). In other words, there would be no risk in gambling, even if the game were not rigged, if the stake is a grain of sand and it takes place in a desert. Finally, and closely related to the previous aspect, risk must be defined in relation to a preferred expected outcome (Kaplan & Garrick 1981; Luhmann 1995:307-310; Kaplan 1997; Kaplan *et al.*

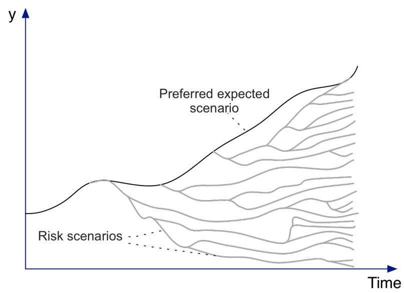

Figure 5. Potential deviations as risk scenarios

[1] Risk is here assumed to relate to negative outcomes (Renn 2008:2), while opportunity denotes positive outcomes.

2001; Johansson & Jönsson 2007:12-14; Zinn 2008:4). This means that there would be no risk in gambling, even if the game were not rigged and the stakes were high, if the participant has no preference for winning or losing. Taking these three aspects of risk together means that risk is a representation of potential negative deviations in any variable or set of variables representing what human beings value (y) from its preferred expected development over time (Figure 5), making risk analysis into the practise of structuring unwanted scenarios, risk scenarios, and compare them against the preferred expected scenario.

The notion of risk depends, in other words, on values and preference, is socially constructed and does not exist ontologically (Slovic 1992:119; Renn 2008:2-3; Aven & Renn 2009a:8-10). However, what does exist ontologically is the complex combination of events and their underlying processes that determine what actually happens (Aven & Renn 2009a:8-10). The actual course of events that produce consequences that human beings experience, interpret and include when making sense of the present as well as structuring scenarios for envisaging the future. These direct or indirect experiences create a link between risk as a social construction and reality (Renn 2008:2), making it vital not to mix ontology and epistemology (Rosa 2010), since these are entirely different philosophical assumptions.

The realist ontology presented in Chapter *3.1 Philosophical assumptions* does not require the epistemological realism of viewing risk as real and objective (Slovic 1992:119; Kunreuther & Slovic 1996:119; Renn 2008:2-3; Aven & Renn 2009a). Nor does the social-constructivist epistemology require an ontological constructivism that reduces risk to only subjective issues of power and interest (Renn 2008:3; Aven & Renn 2009a:9). Instead, the ontology and epistemology presented in this thesis form a philosophical foundation for highlighting this link between risk, as socially constructed, and the real world. It is important to note that all human beings take part in experiencing and interpreting the world, making the social construction of risk rooted equally in science and in public values and preferences (MacGregor & Slovic 2000:49; Renn 2008:3-4; Aven & Renn 2009a:8-9).

This conceptual approach to development, sustainable development and risk indicates that all three concepts are essentially connected to each other. Facilitating sustainable development entails purposeful human activity to make sure that any potential deviation from the preferred expected development scenario is avoided or minimised. Anticipating potential deviations, or risk scenarios, is therefore vital for managing risk. Hence, analysing risk is a requisite for sustainable development (Haimes 2004:101-106).

Since analysing risk, according to this approach, is the practise of structuring risk scenarios and comparing them with the preferred expected scenario, a risk analysis is the answer to three questions (Kaplan & Garrick 1981:13): (1) What can happen?; (2) How likely is it to happen?; and (3) If it happens, what are the consequences? Answering these questions, often referred to as "set of triplets" (Kaplan & Garrick 1981; Kaplan 1997; Kaplan *et al.* 2001) or "risk triplets" (Kaplan 1982; Garrick 2002), entails a systematic analysis of what human beings value, the initiating events that can have a negative impact on those valued elements, and how susceptible they are to the impact the initiating events.

3.2.2. Values and what is expressed as valuable

Values may be seen as "desirable trans-situational goals, varying in importance, that serve as guiding principles in the life of a person or other social entity" (Schwartz 1994:21). In other words, values are what people care about (Keeney 1992:3). To grasp what human beings value in relation to analysing risk, it is important to understand how values come to be ascribed to whatever is declared to have value.

"No man is an island, entire or itself" (Donne 1624:415). This timeworn quote by a 17-century English poet indicates that human beings are social beings, functioning together in society. Giddens takes this idea further by stating that how human beings experience their social context influence how they perceive and understand it, and therefore also how they will act in that social context (Giddens 1984). These actions in turn produce and reproduce social structures, which guide and restrict the actions human beings may take (*ibid.*:25-26).

Human actions are thus fundamentally linked to social structures, which are representations of established patterns of behaviour and have the purpose of keeping order while coordinating stable activities (Hardcastle *et al.* 2005:224). What human beings value is, in other words, socially constructed in context, where prolonged human action creates social structures that direct human beings in what value to ascribe to objects. It is however rare that society is totally homogenous, granting room for individual variation as there may be several social structures competing for dominance. Indicating that the more heterogeneous the society, the more individual variation is possible in what human beings value. Values may thus be seen as acquired "both through socialization to dominant group values and through the unique learning experience of individuals" (Schwartz 1994:21).

Values are notoriously difficult to measure (Slovic 1995:369) and the methods used are predisposed to biases (Payne *et al.* 1992:121-122; Hassel *et al.* 2009:36-37) regardless of the assumptions upon which the value elicitation is based (Fischhoff 1991). However, for the purpose of analysing risk it is not the values themselves that we need to elicit, but what human beings express as valuable and as important to protect.

In order to understand what people express in particular contexts, it is important to consider that "we can know more than we can tell" (Polanyi 1966/1997:136). What people know can be divided into explicit knowledge and tacit knowledge (Nonaka 1994:16). Explicit knowledge consists of concepts, information and insights that are possible to specify, store and directly transmit to others (Connell *et al.* 2003:141). Tacit knowledge, on the other hand, is not directly transmittable and consists of knowledge that makes up our mental models for creating meaning to our experiences, as well as our know-how and skills to apply in specific contexts (Polanyi 1967; Nonaka 1994:16; Polanyi 1966/1997:139-140). Explicit and tacit knowledge are, however, closely connected, as "explicit knowledge must rely on being tacitly understood and applied" (Polanyi 1966:7).

Tacit knowledge is comprised of subsidiary awareness and focal awareness, where the phenomenon in our focal awareness is made identifiable to us by subconsciously assembled clues in our subsidiary awareness which are not identifiable in isolation (*ibid.*:2-7). An example of this is the psychiatrist showing his students a patient having a seizure. After letting the students discuss if it was an epileptic or a hystero-epileptic seizure, he settles the argument by stating "you have seen a true epileptic seizure. I cannot tell you how to recognize it; you will learn this by more extensive experience" (Polanyi 1961:458). The statement that the seizure was a true epileptic seizure is possible to transmit across to the classroom and is an example of explicit knowledge. The knowledge that the psychiatrist uses for diagnosing the patient is, however, tacit knowledge and is less straightforward to share with the students. It is then only the diagnose itself that is in his focal awareness and accessible to him, as he is only subsidiary aware of each of the many clues and indicators that he more or less subconsciously had observed.

What is in our focal awareness is not only determined by individual characteristics, knowledge, etc, but is constantly changing depending on context. Each situation gives us a sense of what is relevant for what we are doing. Our experience of similar situations, our idea of what the situation calls for or demands, our sense of aim or direction, etc, all combine in supplying us with this "relevance structure" (Marton & Booth 1997:143). What we have talked about recently, what roles the people around us have, what goals we think they have, etc, are thus crucial for how we understand, interpret and remember incoming information. These mental structures or processes are referred to in cognitive science as "schemata" and are constantly amendable (Bartlett 1932/1995:208). The current schemata of an individual guide her interpretation of the incoming situation as well as her expectations of, and attention to, it (Boland *et al.* 2001:394). Our tacit knowledge comprises, in other words, a part of our schemata (Nonaka 1994:16). Another closely-related cognitive tool that we utilise to get by in our complex world is called "script". Scripts are cognitive chains of expectations of actions and effects in particular situations (Schank & Abelson 1977; Abelson 1981), which assist individuals in their reaction in those situations without focusing much of their focal awareness on their actions. A main function of schemata and scripts is to facilitate coherence in our perception and experience of a situation by filling in gaps in the actual information available.

What stakeholders consider valuable and important to protect is usually not explicitly stated when analysing risk, but instead relies on an implicit assumption that all stakeholders agree on this issue (Nilsson & Becker 2009). The theoretical framework presented makes such assumptions appear dubious at best and flawed at worst. Paper II and III investigate further the validity of such assumptions.

To summarise, what individuals express as valuable in any given situation is socially constructed in context, and is determined by their values and by what they have in their focal awareness at that time. This takes into account the functions of their current schemata and scripts, and it indicates that human beings construct their own mental models of reality through active selection and interpretation of information around them (Vennix 2001:14). It may then be argued that it is of no use to discuss what is valuable and important to protect, as each account is destined to be subjective and fragmented. However, explicit dialogue may facilitate the integration of individual mental models, each of which giving a limited perspective on the world, into one shared model, which is vital for creating a common understanding of the challenge at hand (*ibid.*). It is probably true that each individual account is unlikely to give a complete picture of what is considered valuable on their own. But it is likely, in a dialogue between several individuals, that what is mentioned triggers additional scripts and amends schemata, thus activating additional knowledge by moving it from their subsidiary awareness to their focal awareness. What the group comes up with is however also highly contextual, but it is still likely to be a richer picture than the sum of each individual account. And more importantly, it is their common picture of what is valuable, making it achievable for the stakeholders involved to formulate and pursue common goals when analysing risk. Without such an explicit common picture, there is a grave danger that the stakeholders might unwittingly impede each others' work by focusing on protecting different things, e.g. the ministry of agriculture focusing on securing state revenues by promoting the production of cash crops, while the Red Cross Society might focus on working to reduce the risk of famine by increasing diversity of food crops.

3.2.3. Expanding risk scenario space

The more common contemporary approach to analyse risk starts with identifying and selecting a set of hazards (Coppola 2007:31). Establishing the initiating events that can have a negative impact is important but generally subjective, as it is determined by human beings' values and perceptions of risk. Various demographical factors have been identified as influencing risk perception (Slovic 1987:281; Flynn *et al.* 1994; e.g. Bontempo *et al.* 1997; Sjöberg 1998:86-87; Hermand *et al.* 1999; Fordham 2000; Sjöberg 2000:7-8; Johnson 2004:111; Lam 2005; Armaş 2006; Chauvin *et al.* 2007), but how these differences influence the way hazards are ranked has not been as well researched. Paper IV investigates this further.

This crucial step of identifying and selecting a set of hazards is sometimes referred to as hazard analysis (e.g. Coppola 2007:34-39) and is aimed at establishing necessary spatial, temporal and magnitudinal aspects of each initiating event included in our risk analysis. A clear definition of the location and spatial extent of each initiating event, its speed of onset and duration, its magnitude or intensity, as well as its frequency or likelihood are requisites for this part of the analysis (*ibid.*:31-39). The more specifically each initiating event is defined, the easier it is to construct risk scenarios. That said, it is impossible to include all possible initiating events in a risk analysis, which calls for categorising such events and allowing one specific initiating event to represent a number of them. This is referred to as partitioning the risk scenario space (Kaplan *et al.* 2001:810-811).

Having identified a relevant initiating event, it is important to analyse the factors that contribute to it, as these may be connected to, and amplified by, processes related to human activity (e.g. Hewitt 1983:25; Kates *et al.* 1990; Renn 2008:5). Examples of such connections are mining and pollution, logging and flash floods, irrigation for agriculture and sinkholes, etc. It is also important to note that a specific initiating event can impact on contributing factors for other initiating events, e.g. earthquakes or heavy rain may trigger landslides.

Given that sustainable development demands the capacity for managing a wide range of risks (Haimes 1992:415; Haimes 2004:101-106), it is vital to include a wide range of initiating events in the analysis. More dramatic, and often sudden, initiating events may give rise to highly destructive courses of events, often referred to as catastrophes (Scawthorne 2000; Freeman *et al.* 2002; Perrow 2008), disasters (Campbell 1990; Coppola 2007; Fordham 2007) or emergencies (Hernandez & Serrano 2001; Condorelli & Mussumeci 2010; Korf 2010). Most scholars use these terms more or less synonymously or to signify quantitative differences in scale, while others assign qualitatively different meanings to them (Quarantelli 2000). Regardless of label, these are well understood as posing major threats to sustainable development[1] (Humphreys & Varshney 2004; UNDP 2004:9-27; Sachs 2005; Schipper & Pelling 2006:20; Fordham 2007:339-340; Becker 2009:12).

Our predisposition for the spectacular, however, should not make us forget the many smaller courses of events, which on their own might seem relatively trivial, but whose cumulative impact on society in many ways vastly surpasses the few and dramatic. For instance, in 2004, the Indian Ocean tsunami raised the total global death toll in disasters to around 250,000[2] people (CRED 2010), while armed conflict directly killed more than 180,000 people (WHO 2008:58). This is obviously terrible enough, but consider then that it is estimated that almost 900.000 people died from malaria, 1.2 million in road traffic accidents, 1.5 million from tuberculosis, 2 million from HIV/AIDS and 2.2 million from diarrhoeal diseases that same year (*ibid.*:54-58). Still, these horrific numbers do not even come close to the top three global causes of death in 2004, namely, lower respiratory infections (4.2 million), cerebrovascular disease (5.7 million), and ischaemic heart disease (7.2

[1] Less acknowledged is that such scenarios may be beneficial to development for some groups in society, e.g. women or previously marginalised ethnic groups, as they may increase access to vital resources for short or long term (Delaney & Shrader 2000; Enarson 2000; Bradshaw 2002).

[2] EM-DAT: The international disaster database (www.emdat.be), search for the total number of deaths in all countries and all disaster types for 2004.

million) (*ibid.*:54-58). All such less significant courses of events may impact on what human beings value like water drops eroding stone. It is thus vital to be prepared to expand the risk scenario space when analysing risk for sustainable development.

3.2.4. The susceptibility of impact

Simon (2002) states that "[t]he reading of history persuades me that the most dangerous villains we will encounter along the way will rarely be the forces of nature". Regardless of whether an initiating event derives from natural, technological or antagonistic processes, it will not result in unwanted consequences unless it occurs in a conducive setting (Wisner *et al.* 2004:3-16). Such a setting is one determined by factors from all spheres of society (ISDR 2004:16; Wisner *et al.* 2004:49-84; Bolin 2007:114-129; Coppola 2007:146-161), and is primarily a result of human activity (Hewitt 1983:24-29; Oliver-Smith 1999). This further explains the idea, forcefully put forward already in the mid 1980s by Wijkman and Timberlake (1984), that most disasters stem from unresolved development issues[1]. Destructive courses of events, set off by any type of initiating event, are therefore not discrete, unfortunate and detached from ordinary societal processes, but are intrinsic products of everyday human-environment relations over time (Hewitt 1983:25; Hearn Morrow 1999; Oliver-Smith 1999; Ariyabandu & Wickramasinghe 2003:33-37; Fordham 2007:338-339; IRP 2007:10).

This susceptibility to harm is often referred to as vulnerability[2], and is never a general attribute, but must always be defined in relation to the impact of a specific initiating event (Blaikie *et al.* 1994:9-10; Salter 1997:61-62; Dilley & Boudreau 2001:232; Hollenstein *et al.*2002; Twigg 2004:13; Wisner *et al.*2004:11-13; Gallopín 2006:294; Aven 2007:747; Coppola 2007:146-149; Johansson *et al.* 2007:6; Jönsson 2007:61-63; Cannon 2008:351; Aven & Renn 2009b:588-589).

[1] An idea that later has been emphasised by many (Stephenson 1994; Yodmani 2001; UNDP 2004:9-10; Shultz *et al.* 2005; Schipper & Pelling 2006; Fordham 2007:338). However, Wisner(2001) reminds us of the importance, when considering connections between development and disasters, of specifying what development we have in mind.

[2] O'Keefe, Westgate and Wisner (1976) introduced the concept of vulnerability to risk and disaster-related research in the mid-1970s.

However, vulnerability is not only associated with potential consequences, but also with uncertainties in determining these consequences (Aven 2007:747; Aven & Renn 2009b:589). Such uncertainties multiply the potential risk scenarios, making a vulnerability analysis into the answer to three questions: (1) What can happen, given a specific initiating event?, (2) How likely is that to happen, given that initiating event?, and (3) If it happens, what are the consequences? (Jönsson 2007:63; Hassel 2010:35).

When analysing vulnerability it becomes clear that it is not only structural issues, in the sense of a complex combination of physical and environmental, social and cultural, political and economical factors, that determines susceptibility to harm. Human agency also plays a vital role (Renn 2008:xiii), as purposeful human activity influences the answers to the three questions. This might be directly, through reactive activities that influence the course of events in a specific risk scenario (Jönsson 2007:81; Jönsson *et al.* 2007), e.g. recognising the need to evacuate before flood waters reach a critical level, the actual evacuation to safer grounds, rapid salvation of damaged food crops, or indirectly, by proactive activities influencing what risk scenarios are feasible altogether, e.g. constructing permanent levees to protect settlements from flood water, awareness-raising campaigns clarifying when and where to evacuate in case of flood, analysing risk to inform the location of temporary shelter. It is thus important to include the capabilities of individuals and organisations to take actions in the risk scenario to limit the impact.

Although activities with more indirect influence on risk scenarios are vital for managing risk to facilitate sustainable development, they are, to a large extent, already set at the beginning of the time period that we want to analyse and are thus less feasible to incorporate directly when analysing risk. This is not at all to say that analysing and reducing risk, as well as preparing for effective response and recovery, only takes part before an initiating event has triggered some destructive course of events. On the contrary, these activities must be ongoing even in the midst of calamity to protect what human beings value.

While capability and capacity may be considered synonymous in a purely linguistic sense, they are used deliberately in this thesis to separate capabilities to act in and influence specific risk scenarios from other capacities relevant for managing risk in general. Analysing capability is the answer to three questions (*ibid.*:7): (1) What can happen when an actor is performing a specific activity, given a specific scenario?, (2) How likely is that to happen?, and (3) If it happens, what are the consequences?

3.2.5. Participants in analysing risk for sustainable development

Managing risk for sustainable development requires the involvement of various stakeholders (Haimes 1998:104; Renn 2008:8-9; Renn & Schweizer 2009). The complexity of risk in this context requires the integrated knowledge and effort of stakeholders from most functional sectors and all administrative levels of society. Unfortunately, efforts to manage risk and development losses have had a tendency in the past to reduce the problem into parts that fit functional sectors and organisational mandates[1] (Fordham 2007). This is likely to represent a major weakness as it clouds the bigger picture of risk (Hale & Heijer 2006:139). However, there is a deficiency of research into what general challenges may arise if one focuses on individual functional sectors or administrative levels in isolation. Paper I and Paper V investigate these issues further.

Managing risk for sustainable development is thus not about dividing the issue into parts that fit the agenda or mandate of specific stakeholders, but rather is about grasping the dynamics and non-linear interdependencies in the complex system of factors determining risk (Hollnagel 2006:14-17). Geographical borders are also complicating factors, as their delimitations are geopolitical, impeding collaboration between stakeholders to various degrees, but rarely limiting the geographical spread of calamity. Analysing risk for sustainable development therefore requires the participation of various stakeholders across functional, administrative and geographical borders.

[1] As well as academic disciplines.

There has also been prolonged debate on whether it should be up to the public to decide about matters concerning risk or if this should be the sole domain of experts (e.g. Cole & Withey 1981; Slovic *et al.* 1982; Slovic 1987; Keren 1992; Shanteau 1992; Rowe & Wright 2001; Sjöberg 2001). Much of this debate has the appearance of a clash between two seemingly incompatible positions. However, influential accounts present a persuasive alternative way forward, arguing for the need for as broad participation as possible, from experts, the public, decision makers, and other stakeholders (Fischhoff *et al.* 1982; Renn 2001). According to this view, it is not only formal expertise that is vital, as the educated common sense of other stakeholders can be rather effective in this process and render some degree of moral force and political influence to the results (Ravetz 1999:651). Vickers (1968) takes this even further when claiming that:

> *"Over many decades, things which used to be regarded as "acts of God" - war, famine, pestilence; or as part of the nature of things - crime, destitution, ignorance, have come to be regarded as controllable and are hence assumed to be somebody's responsibility. They can all be "fixed"; it is just a matter of know-how. It is true and welcome that the degree of our control is slowly extending but the assumptions based on this extension are false and dangerous. Not everything can be fixed; and fixing is never just know-how. It is always decision, made at the cost of not fixing something else. Until both governors and governed have a common and realistic view of what can be controlled and how far and at what cost, the relations between them are bound to be disturbed; and these disturbances may be as dangerous to the system as any"*

It is, in other words, not only for reasons of effectiveness that analysing risk for sustainable development necessitates a wide participation of stakeholders, but also for pre-empting public discontent by distributing responsibility and facilitating realistic expectations. Public discontent that seems to be increasing in the wake of recent examples of calamity (Renn 2008:1).

As a result of the complexity of risk and of the functional, administrative and geographical disjointedness of stakeholders, multiple risk analyses are often performed, with various purposes and by various stakeholders. For instance, there may be several municipal risk analyses and a detailed risk analysis of a chemical plant in a province, all with different purposes and based on different assumptions, which the provincial administration needs to combine to make an overall analysis of risk for their jurisdiction. Hence, analysing risk for sustainable development requires ability to integrate the results of several risk analyses performed by different groups of stakeholders.

3.2.6. The world represented as a human-environment system

The five preceding sections all emphasise from different perspectives that risk and analysing risk for sustainable development are complex issues. This is however not the only area in which complexity constitutes a daunting challenge for scientific inquiry. Living organisms, the brain, culture, society, climate, and ecosystems are only a few examples, all with something in common. Living organisms are made up of the complex interaction of myriads of cells, the brain is a vast network of neurons transmitting signals, society is made up of individuals and organisations, etc. In short, they can all be approached as wholes made up by complex sets of parts[1]. In attempts to manage and learn from this complexity, some scholars find it helpful to look at the entity under study as a system, as did von Bertalanffy (1960) in regarding the living organism, Ashby (1960) in regarding the brain and Buckley (1968) in regarding society. These approaches, so-called systems approaches[2], span various disciplines, all having "a particular set of ideas, systems ideas, in trying to understand the world's complexity" (Checkland 1999:3). A system is here defined as "a group of interacting, interrelated, or interdependent elements forming a complex whole" (American Heritage Dictionary 2000).

As indicated in earlier sections, risk is determined by structural factors from all spheres of society, as well as by human agency. However, it is not only the multifarious nature of conducive factors that make risk complex, but the intricate relations between these factors (Turner *et al.*

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[1] Even Franz Boas (1927) argues in his now classical anthropological writings that culture cannot be reduced into parts but must be studied as a whole or as a system of many interrelated parts.

[2] E.g. General Systems Theory (e.g. von Bertalanffy 1968), System Dynamics (e.g. Forrester 1969), Systems Thinking (e.g. Checkland 1999; Senge 2006), Cybernetics (Rosenblueth *et al.* 1943; e.g. Ashby 1957) etc.

2003a). This is indicated by the influential Pressure and Release (PAR) model (Wisner *et al.* 2004:51), and highlighted by the productive research community around the recurring *Symposium on Resilience Engineering* (e.g. Dekker 2006; Hollnagel 2006; Leveson *et al.* 2006; Hollnagel 2009; Woods *et al.* 2009).

Destructive courses of events that threaten sustainable development are, in this view, not results of linear chains of events, like dominos falling on each other (Hollnagel 2006:10-12), but are instead non-linear phenomena that emerge within complex systems themselves (Perrow 1999a; Hollnagel 2006:12). They thus limit the effectiveness of frameworks for analysing risk that focus on linear combinations of discrete events, since they fail to represent risk sufficiently by their ignoring of complexity (Hollnagel 2009:125-127), and by indicating that frameworks for analysing risk in more complex contexts must be systemic in the sense of relating to a system, as opposed to particular elements. Ignoring interdependencies may not only result in inadequate representations of risk. Paper I investigates the other negative results that may arise in general from focusing on specific elements without acknowledging interdependencies between elements.

The PAR model is not only instrumental in illustrating how various factors interact to create unsafe conditions, but also in emphasising that risk emerge in the intersection between the social and the environmental. Renn (2008) takes this relation further and states that risk is largely a by-product of how human beings transform the natural environment into a cultural environment for the purpose of serving human needs and wants. Such a transformation has brought about immense changes in the world over the last 300 years, and continues to do so at an ever-increasing pace (*The Earth as transformed by human action,* 1990). It is in this nexus of the social and the environmental that sustainability science has risen to address the core challenges of humankind (Kates *et al.* 2001; Clark & Dickson 2003; Olsson & Jerneck 2010). This is done by increasing our understanding of the complex and dynamic character of our world and by supporting the capacity of society to guide its development through avoiding or minimising deviations from its preferred and sustainable future (Kates *et* *al.* 2001). One way of managing this complexity and dynamic character is to approach our world as a complex human-environment system (Turner *et al.* 2003a; Turner *et al.* 2003b; e.g. An *et al.* 2005; Haque & Etkin 2007; Metzger *et al.* 2008; Reenberg *et al.* 2008) and to view both the risks of, as well as the actual destructive courses of events, as rooted in the same complex human-environment system that supplies human beings with opportunities (Haque & Etkin 2007).

In order to facilitate the much-needed shift towards sustainable development, sustainability science states that we must be able to: (1) span the range of spatial scales of various phenomena; (2) account for both urgency and temporal inertia; (3) manage functional complexity; and (4) recognise a wide range of perspectives as usable knowledge from both society and science (Kates *et al.* 2001:641; Ness *et al.* 2010:479).

The five preceding sections stress that analysing risk is about structuring risk scenarios based on explicit information regarding what human beings value, on the events that can have a negative impact on that, and on how susceptible that is to the impact of each event[1]. In order to be able to do that in this complex setting, we need to construct a model of the world (Conant & Ashby 1970), i.e. a human-environment system. Any framework for analysing risk for sustainable development should therefore be systemic.

3.2.7. Constructing human-environment systems

There are many ways to construct human-environment systems. Jackson (2003) specifies four incremental methods for modelling systems: (1) causal loop diagramming; (2) system archetypes; (3) stock-and-flow diagramming; and (4) microworlds. The two former are qualitative and the two latter are quantitative.

The basic building blocks for constructing a human-environment system are elements and directional relations between elements that can be

[1] Including the capabilities that are available in a particular scenario to limit the impact of the event

either positive or negative[1] (Maani & Cavana 2000:26-27; Boardman & Sauser 2008:67). These relations cause a change in one element to spread to associated elements, creating a branching chain of causal relations through which any impact on the system could propagate to distant parts of it (Rinaldi *et al.* 2001; Hollenstein *et al.* 2002:56-61; OECD 2003:44-45; Jiang & Haimes 2004:1215-1229; Dobson *et al.* 2007). The propagation of a change between each pair of elements may be immediate or delayed to various degrees, making the time period over which to analyse risk important, as the timescale of appearance of adverse effects is important when linking risk to sustainable development (Renn 2007:15). These delays, often indicated by two parallel lines crossing the relations (Figure 6), are also major contributors to the complexity of the system (Maani & Cavana 2000:33; Senge 2006:88-91). It is therefore not only the number of elements that determine complexity, often referred to as detail complexity (Senge 2006:71), but also the relations between elements (Yates 1978:R201; Flood 1987:180). This leads to what Senge (2006) refers to as dynamic complexity by the separation of cause and effect in both space and time.

The chains of causal relations sometimes create loops, causal loops, feeding back the propagating changes to elements earlier in the chains (Figure 6) (Ashby 1957:53-54; Maruyama 1963/1963; Maani & Cavana 2000:28; Senge 2006:73-79; Boardman & Sauser 2008:67). Such causal loops are prevalent in our world (Senge 2006) and are yet another source of complexity (Yates 1978:R201; Flood 1987:180), as they give rise to nonlinear dynamics.

These causal loops can be either reinforcing, i.e. resulting in either continuous growth or to a decline in the element of interest, or balancing, i.e. resulting in stability, through dampening or negating changes in the element or in meeting a set target (Maani & Cavana 2000:28-33; Senge 2006:79-88). It is however important to note that growth, decline and stability may all be positive or negative depending

[1] A positive relationship means that a change in one element leads to a change in the same direction for the associated element, while a negative relationship means that a change in one leads to an opposite change in the other (Leveson *et al.* 2006:107-108).

on values and perception. Balancing loops that drive systems to meet set targets for specific elements are rather easy to identify, as they attempt to reduce gaps between the actual and the desired state of the elements in question (Senge 2006:83-88). However, balancing loops without such explicit targets are not always as intuitively obvious to distinguish from reinforcing loops, as this distinction depends on which element one focuses on. For example, if one focuses on the element marked by "α" in Figure 6, any change in "α" will continuously reinforce itself since the change propagating from "α" has the same polarity as the subsequent change coming in to "α" (Maani & Cavana 2000:32). If one focuses on the element marked by "Ω", on the other hand, any change in "Ω" will be dampened as the change propagating from "Ω" has an opposite polarity to the subsequent change coming in (*ibid.*).

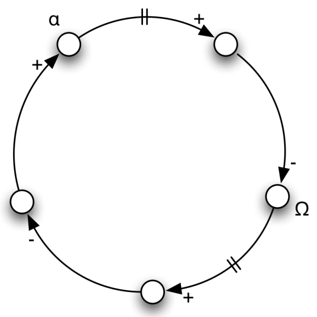

Figure 6. A causal loop of elements, directional relations and delays.

When constructing qualitative models using causal loop diagramming, for which the output is a more or less complex system of causal loops, it is at times possible to identify systems archetypes. A systems archetype in this case is a set of elements and relations that can be generalised and used in analysing systems behaviour or in guiding the construction of the human-environment system. In constructing quantitative models, on the other hand, key elements and relations are transformed into what are referred to as stocks and flows[1], but are still part of the causal loops (Figure 7) (Forrester 1994). A stock in this context is some variable that

[1] Or levels and rates (Forrester 1994).

is increased or decreased over time, and a flow (inflow or outflow) is what changes a stock over time. Thus, the name stock-and-flow diagramming.

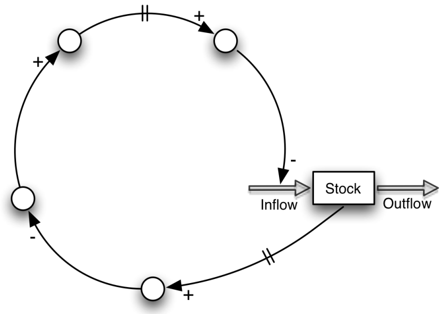

Figure 7. A causal loop including a stock and flows.

Once a quantitative model has been developed, it can be extended into a microworld by providing an interactive and user-friendly interface for users to experiment with the model (Wolstenholme 1999; Cavana & Maani 2000). In complex systems, it may be challenging to mathematically model all the relationships between the elements that appear on the surface to be involved in what the system does. However, it is still possible to "determine the most important structural aspects that lie behind system viability and performance" (Jackson 2003:21). This means that qualitative methods can also elicit information on both structural and functional aspects for the human-environment system, which is central for analysing risk in this context.

3.2.8. Wholeness, hierarchy and multiplicity of descriptions

The challenge when building a human-environment system for enabling the construction of risk scenarios is to find a balance between including enough information to sufficiently capture the complexity of the context of the analysis as a whole (referred to as the principle of wholeness) while limiting it to include only what is relevant in light of the purpose of the analysis and the resources available. Section 3.1.4 in Chapter *3.1 Philosophical assumptions* presents the principles behind finding such a balance. In short, the primary issue for making boundary judgements is relevance to what we address and to what we want to accomplish (Simon 1990:7-13).

Parts of the world that are not directly a part of the human-environment system, but still influence or are influenced by it to a degree deemed relevant, may be referred to as belonging to the surrounding of the system (Ingelstam 2002:19). What distinguishes these elements in the surrounding from the elements within the system itself is that it is only their transboundary relations with the system that are of interest, and not the relations amongst themselves. For instance, it may be relevant to include how changing global weather patterns may impact floods in our municipality, but it is probably not relevant to include the global causal factors of climate change into the municipal risk analysis. In short, it is the purpose of our analysis and the resources available that determine how the human-environment system is demarcated. However, all elements on the outside that influence it to a degree deemed relevant for the functioning of the system, in light of the purpose and available resources, should be included.

Because building a human-environment system to facilitate the structuring of risk scenarios is likely to result in a web of elements and relations that is complex and essentially impossible to grasp, it is necessary here to introduce the principle of hierarchy. This principle states that human-environment systems are hierarchical in the sense that the system of interest is part of a system on a higher level and is made up of systems on a lower level (Simon 1962:468; Simon 1996:184; Blanchard & Fabrycky 2006:5). Most systems in our world are of this type (Simon 1962:477-482; Simon 1996:186-188). This hierarchy plays a vital role in assisting the management of complexity as it makes it possible to simplify the system by aggregating sets of interdependent elements into subsystems (Simon 1962:473-477; Simon 1990:12; Simon 1996:197-204). This enables us to describe and explain the behaviour of an element/subsystem at any particular level with no need for a detailed representation of, and with only moderate concern for, the structures and behaviour on the levels above and below (Simon 1990:12).

In addition to the principles of wholeness and hierarchy, large complex systems require a third principle when building our human-environment system; the principle of multiplicity of descriptions (Blauberg *et al.* 1977:132). This principle states that to represent sufficiently any large and complex part of our world requires constructing a range of different descriptions, each of which only covers certain aspects of the wholeness and hierarchy of the human-environment system. The principle of multiplicity of descriptions becomes particularly important since analysing risk for sustainable development entails involving a wide range of stakeholders and often integrating various risk analyses. This requires the human-environment system to be explicit, since effective collaboration depends on having a shared vision of what to accomplish together (Jackson 2003:22; Senge 2006:187-197).

Hierarchical Holographic Modeling (HHM) builds on the idea of this third principle and supplies a basic framework for understanding complex systems. This is done by merging these complementary descriptions into one multidimensional picture (Haimes 1981; Haimes & Li 1991; Haimes *et al.* 1995; Haimes 1998; Haimes 2001; Lambert *et al.* 2001; Jiang & Haimes2004; Haimes 2004; Lian & Haimes 2006). However, HHM focuses on multi-objective settings in which many stakeholders may vary but a number of them are kept constant. This is unlikely to be the case in the wider context of analysing risk for sustainable development, which complicates things even further.

3.2.9. Risk- and vulnerability analysis as sustainability science tools

An interesting survey of tools for analysing sustainability issues presents its most complex category, called integrated assessment tools, as tools used for supporting decisions related to a project or policy in a specific location (Ness *et al.* 2007:503-505). These integrated assessment tools include conceptual modelling and systems dynamics; multi-criteria analysis; risk analysis and uncertainty analysis; cost-benefit analysis; and environmental impact assessment[1]. These are all established categories of tools used for different purposes and often by different groups of

[1] Impact assessment in original.

stakeholders, but with large overlaps opening up for further categorisation.

Ness *et al.* (2007) indicate the first overlap themselves when stating that many of the six categories of integrated assessment tools are based on systems approaches. In the context of sustainability science, all applications of these categories of tools must be able to integrate relations between elements in human-environment systems. Conceptual modelling and systems dynamics may, in this context, thus be viewed as an integrated part of the other five categories and not as a stand-alone category of tools for integrated assessment.

Ness *et al.* (2007) also state that in the context of sustainability science, the categories of integrated assessment tools have an ex ante focus on supporting decisions that have impacts on the future. Assuming that there are uncertainties in what may happen in the future and that these uncertainties, at least to some extent, are included in the analyses, the decision situation becomes limited to decisions under uncertainty based on one criterion or multiple criteria (Keeney & Raïffa 1976). The three questions to answer when analysing risk[1] or when analysing vulnerability[2] indicate that risk is uncertainty about what could happen and what the consequences would be (Aven 2007:747; Aven & Renn 2009a; Aven & Renn 2009b:588). On the other hand, vulnerability is uncertainty about what could happen and what the consequences would be, given a specific initiating event (Aven 2007:747). Both risk and vulnerability analysis may focus on one or several variables that human beings value, resulting in two main categories of tools for integrated assessment: (1) risk analysis, also covering multi-criteria analysis and cost benefit analysis; and (2) vulnerability analysis, also covering environmental impact assessment.

[1] (1) What can happen?, (2) How likely is that to happen?, and (3) If it happens, what are the consequences? (Kaplan & Garrick1981:13).

[2] (1) What can happen, given a specific initiating event?, (2) How likely is that to happen, given that initiating event?, and (3) If it happens, what are the consequences? (Jönsson 2007:63; Hassel 2010:35).

Hence, given that uncertainties are involved to some extent in multi-criteria analyses, these tools can be viewed as risk analyses focusing on more than one variable representing what human beings value. Cost benefit analyses can also, under these circumstances, be considered a special case of multi-criteria risk analysis, as they, by definition, entail at least one selected variable and another variable representing the cost of implementing different activities somehow influencing the selected variable(s). Similarly, environmental impact assessment may be seen as a special case of vulnerability analysis, where the initiating event not only is clearly defined but also controlled by purposeful human activity. Consequently, different types of systemic risk analyses and vulnerability analyses could be viewed as the two main categories of tools for ex ante assessments to support decisions related to sustainable development. There are several examples of sustainability science approaches to vulnerability analysis (e.g. Turner *et al.* 2003a; Turner *et al.* 2003b; O'Brien *et al.* 2009b), but this thesis attempts only to supply justifications for key requirements for sustainability science approaches to analysing risk.

4. Methodological issues

"How does one determine scientifically what science is?" – Bent Flyvbjerg (2001)

4.1. The sciences of the complemental

The philosophical assumptions presented in Section *3.1.3 Axiological assumptions* portray traditional science and design science as different in their relation to values. This difference is however neither unambiguous nor pitting the two against each other. Even if traditional science demands the pursuit of the unreachable vision of value-neutrality in the production of knowledge about how the world is, its relevance can only be judged in relation to normative values. This relevance generally refers to the utility of the scientific knowledge for solving problems affecting humankind, even if traditional science is mostly satisfied by simply assuming that the knowledge produced will be used at some point in the future (Lee 2007:44). Describing how the world is, however, is not appropriate for solving problems on its own, as that entails normative statements about how the world ought to be. Design science, on the other hand, is equipped for solving problems (Simon 1996), but not for describing how the world is, which also is necessary for defining the problem and for anticipating the results of potential activities (Ness *et al.* 2010:479). It is important to note that problem-solving can also be scientifically rigorous, even if based on principles other than traditional science (Checkland & Holwell 2007:3-4). Traditional science and design science are thus complementary parts in facilitating sustainable development (Figure 8).

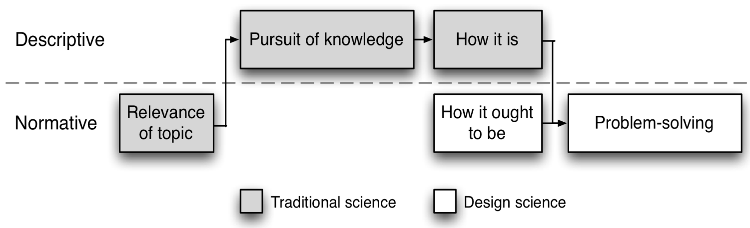

Figure 8. Traditional science and design science as complementary.

Solving problems entails changing something from a current state, that at least one human being perceives as unsatisfactory, to a desired state (Ackoff 1962:30). This signifies intentional and purposeful activities to change the world to suit human purposes (Wieringa 2009:1). However, the changes that human agency can cause in the world are limited to what our activities can influence[1]. Purposeful products of intentional human activities are referred to as artefact (Hilpinen 1993) and it is through designing and utilising these artefacts that human beings shape their present and as well as their future (Simon 1996). Artefacts that can be either physical (tools, constructions, etc) or conceptual (symbols, methods, etc) (Hilpinen 1993; Simon 1996).

Building on Rasmussen's (1985) work on functional hierarchy, Brehmer (2007) suggests that every artefact has purpose, function and form. The purpose answers the question why the artefact exists, the function what it must do to meet that purpose, and the form how the function is fulfilled in the real world (Brehmer 2007:212-214; Brehmer 2008:5-6; Brehmer 2009:2-3; Brehmer 2010:4). The purpose is, in other words, the highest level of abstraction while the form is the most concrete (Rasmussen 1985). As an artefact is evaluated on the relationships between its purpose, intended character, and its actual character (Hilpinen 1995:140), evaluation means assessing how well the form fulfils the required functions to meet the purpose when utilised.

The main activities of traditional science are to theorise and justify, while the main activities of design science are to build and evaluate (March & Smith 1995). The purpose and overall research question of this thesis require both sets of activities, as design science supplies the structure for designing the framework scientifically, while traditional science informs the argumentation for the purpose and design criteria that are defined to guide the development of the framework.

4.2. The design process

Recent applications of design science in similar contexts supply us with comprehensive design processes (Abrahamsson 2009:22-24; Hassel

[1] Which according to Simon (1996) is much more than we cannot.

2010:42-47). This argues persuasively for an increase in scientific rigour in designing artefacts when applying a systematic and transparent design process in which normative assumptions regarding purpose and design criteria are explicitly stated, and the choices directed by those assumptions are justified through logical reasoning (Abrahamsson 2009:22-24; Hassel 2010:42-47). The scientific design process used in this thesis is developed from these innovative examples (Figure 9).

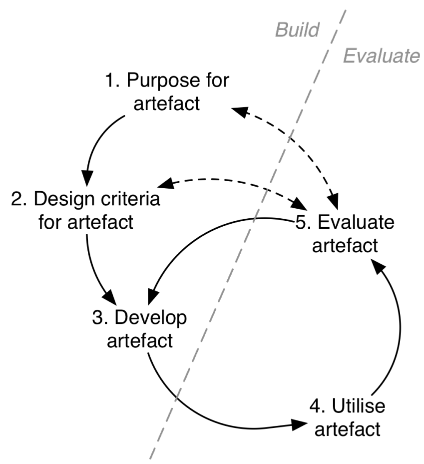

Figure 9. A scientific process for designing artefacts(developed from Abrahamsson 2009:22-24; Hassel 2010:42-47).

The first step in this process is to clearly define the purpose (or purposes) of the artefact (Simon 1990:13; Simon 1996:4-5,114; Cook & Ferris 2007:173-174; Abrahamsson 2009:22; Hassel 2010:43). This purpose is generally described in rather abstract terms and acts like an overall guiding principle for the rest of the design process (Hassel 2010:43). The second step is to define the design criteria that the artefact must meet (Abrahamsson 2009:22; Wieringa 2009:1-2). These design criteria are normative assumptions about the required function (or functions) of the artefact, which must be appropriately justified through logical reasoning informed by established theory or new empirical research (Hassel 2010:43-44). The third step of the design process is to develop the actual form of the artefact, based on our initial judgements regarding what is needed to meet the design criteria and purpose. The word develop is here used to signify that there may already exist artefacts to improve or build upon. The fourth step is to utilise the artefact in the intended context, or in a setting that is designed to approximate that context (*ibid.*:45). Utilising the artefact in the intended context is vital, as there may be various contextual factors that influence the performance of the artefact (March & Smith 1995:254; Simon 1996:5-6). Moreover, it provides an opportunity to test theories about the context (March & Smith 1995:255). The application of the artefact can therefore cause learning that may inspire modifications in purpose and in design criteria. The fifth step of the design process is to evaluate the performance of the artefact against its design criteria and purpose. If the result of this evaluation is unsatisfactory, either the artefact must be further developed or the purpose and design criteria adjusted. Such adjustments of purpose and design criteria may be constructive if spurred by increased understanding of the context, but not if caused solely by demands to show improvement by reducing the gap between the artefact's actual and desired state (Senge 2006:107-108).

4.3. Research methodologies and methods

Both descriptive research, to further inform the justifications behind the establishment of key design criteria, and normative research, to build and evaluate initial ideas for the framework, involve scientific research methodologies and data collection methods with different strengths and weaknesses.

4.3.1. Reliability, validity and workability

The methodologies applied in the appended papers are case study research, survey research and design research. The most fundamental divide among these three methodologies is the divide between the two former and the latter. The purpose of case study research and survey research is to increase our understanding of phenomena, which makes them part of traditional science, while the purpose of design research is to develop artefacts to address problems affecting humankind, which makes it part of design science. This distinction in purpose entails differences in the principles for assessing the quality of the research.

The quality of traditional science is commonly assessed in terms of the reliability and validity of the result (Kirk & Miller 1986:20). Reliability refers to the degree of consistency of empirical results between different researchers, or by the same researcher on different occasions (Hammersley 1992:67). In other words, it refers to the degree to which these results are independent of unintentional circumstances (Kirk & Miller 1986:20). Validity, on the other hand, refers to the accuracy with which an empirical description of a particular phenomenon represents the theoretical construction that it is intended to represent and captures the relevant features of this phenomenon (Hammersley 1992:67). In other words, it refers to the degree to which the empirical results are interpreted in an adequate manner (Kirk & Miller 1986:20).

Reliability depends essentially on transparently describing the research procedures, making it possible to distinguish at least three types reliability (*ibid.*:41-42): (1) reliability as a single research method continually yielding an invariable result[1], (2) reliability as stability of a result over time[2], and (3) reliability as similarity of results within the same time period using different data[3]. The first two types of reliability are not particularly useful in assuring quality when researching complex human-environment systems. The first suffers from the fact that it allows a single flawed method to continuously generate erroneous results (Kirk & Miller 1986:41) and the second for the fact that the world is constantly changing (Dewey 1922; Keynes 1938/1994:287) and the elements and relations under study are impossible to isolate (Anderson 1999:217; Checkland & Holwell 2007:5-6). What is left is reliability in the sense of corresponding results by different research methods, which is commonly called triangulation (Webb *et al.* 1966:3; Mikkelsen 1995:31; Buckle *et al.* 2003:83; Pelling 2007:383-384; Denzin 1970/2009:297-313). Blaikie (1991; 2000:262-270), however, warns us that the use of the metaphor of triangulation often connotes naïve ontological and epistemological assumptions that it is possible to pinpoint reality by applying multiple research methods in the same way

[1] What Kirk and Miller (1986) refer to as 'quixotic reliability'.
[2] What Kirk and Miller (1986) refer to as 'diachronic reliability'.
[3] What Kirk and Miller (1986) refer to as 'synchronic reliability'.

that a surveyor pinpoints a geographical location. Although the metaphor itself is misleading, diverse data that lead to similar conclusions may still render us a little more confident as different data have different biases (Atkinson & Hammersley 2007:183). This assumes, of course, that the methods used do not share the same bias (Blaikie 2000:263).

With no direct access to reality, we cannot know for certain whether, or to what extent, a theoretical construction is valid (Hammersley 1992:69) regardless of the quantity and quality of the empirical data (Atkinson & Hammersley 2007:11). However, we must still assess the validity of such a theoretical construction in relation to the adequacy of the collected empirical data (Hammersley 1992:69). Assessments of validity are thus based on judgements about (1) the compatibility of the theoretical construction, or the empirical data supporting it, with our assumptions about the world that are presently taken to be beyond reasonable doubt[1], and/or (2) the likelihood of error, given the conditions in which the theoretical construction was made[2] (Hammersley 1992:51; Hammersley 2002:73). These are judgements whose own validity never can be established (Hammersley 1992:78). Validity is thus related to the collective judgement by the scientific community (Bernard 1995:43), which Kuhn (1970) refers to as a paradigm and Said (1978) calls "an academic-research consensus".

In short, the purpose behind the ideas of reliability and validity is to provide grounds for someone to trust the research results. This makes Ramsey's (2001) idea of a reliable process central, as it becomes vital to be transparent in how data are collected, analysed and presented in order for others to be able to assess the reliability and validity of the results. It also becomes vital to be transparent in what judgements and assumptions about the world are included in the research itself, as well as in the assessment of the quality of the research.

Although design science has a similar need to have people trust the research results, and reliability and validity do play roles here as well,

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[1] What Hammersley (1992; 2002:73) refers to as plausibility.
[2] What Hammersley (1992; 2002:73) refers to as credibility.

solving problems involves an additional way of assessing the quality of the research. When the purpose of the research is to address a problem, instead of understanding a phenomenon, the quality of the results can be assessed in terms of the workability of the proposed solutions (Olsen & Lindøe 2004:372). Workability can be assessed by whether or not the proposed solution resolves the identified problem (Greenwood & Levin 2007:63-64), or, in design science terminology, whether or not the form of the artefact generates a result that fulfils the required functions, as specified in the design criteria, to meet the purpose when utilised in the intended context.

To summarise, the three research methodologies selected to meet the purpose of this thesis by answering its research question, entail different principles for assessing the quality of the research. Both the more traditional empirical studies, to inform the justifications for key design criteria for the initial version of the framework, and the process of collecting and analysing data for evaluation while utilising it in practice, involve promoting reliability and validity by ensuring transparency in process, assumptions and values. The quality of the actual framework itself is however assessed by judging its workability.

4.3.2. Statistical and analytical generalisations

The next fundamental divide among the three methodologies is the divide between survey research and the pair of case study research and design research. This divide concerns the basis for making generalisations of the theoretical constructions or solutions to problems produced through the use of the methodologies.

Although there are many data collection methodologies, called surveys, that are not quantitative (Fowler 2002:1-2; Punch 2003:1-2), survey research is commonly related to the methodology of collecting quantified data from a collection of items under consideration. This activity is usually for purposes of description or to identify causal relationships or predictive patterns of influence between variables (Sapsford 2007:3). The quantitative character of survey research may have limitations (Babbie 2007:276-277; Weisberg 2008:223-231), but it still provides a potent means for making generalisations. The use of such a technique for providing statistical generalisations depends however on the sample (size in relation to total population, and how it was selected) and how precise one needs to be in the generalisations (significance or confidence level, and confidence interval). The result is that survey research is anything but simple. However, by carefully navigating the well-described strengths and weaknesses of the methodology, statistical generalisations can shed light on many interesting research questions.

Case study research, on the other hand, is often criticized for providing little basis for generalisations (Yin 1994:10; Flyvbjerg 2001:66). This is undoubtedly correct for statistical generalisations, as not even the best possible selection of a small number of cases would give us a compelling representation or a reliable statistical base (Stake 1998:101). Case study research is nonetheless well suited for providing analytical generalisations (Flyvbjerg 2001:73-77). The selection of cases is, in other words, not a sample of a bigger population, but more like the cases chosen for making experiments. Studying cases in this sense is like doing experiments to base the analytical generalisations on (Yin 1994:31). However, knowledge developed in one case cannot be generalised "through abstraction and loss of history and context", but may be transferred to other situations through "conscious reflection on similarities and differences between contextual features and historical factors" (Greenwood & Levin 2007:70). This fundamental focus on context is shared by design science in the sense that to develop a specific artefact, it must be utilised in its intended context (March & Smith 1995:254; Simon 1996:5-6). As this context expands, the artefact must be utilised in the new context, evaluated and further developed. This potentially expands the applicability of the artefact if the changes made do not lower its workability in the previous contexts.

To summarise, the three methodologies used in this thesis differ in their basis for generalisations. Survey research allows for statistical generalisations, while case study research provides for analytical generalisations regarding phenomena and design science regarding the applicability of its artefacts. Although Paper I, II III and V involve case study research, Paper IV involves survey research, and Paper VI, design research, none of them claim to be directly generalisable outside the contexts of the studies. As Paper I-V are used to empirically inform the argumentation for key design criteria, the results are used more to support the argument that the parameters under study may play important roles in other contexts as well and should thus be included. The application of the initial ideas for the framework in Paper VI is indicative of how well it fulfils the required functions, as specified in the design criteria, to meet the purpose in that particular context. However, the more the results of utilising the framework indicate satisfactory performance in several contexts in the future, the bolder the analytical generalisations that are possible to justify.

4.3.3. Quantitative structure and qualitative depth

As the three methodologies used in this thesis have different purposes, ways of assessing quality, and bases for making generalisations, they require different research methods for collecting data. The data-collection methods used in the thesis are structured interviews, semi-structured interviews, focus groups, transect walk and observation. These methods differ in several ways, and of these, two will be elaborated on in this thesis.

First of all, the type of data collected by the different methods ranges from quantitative to qualitative, where the former refers to data that can be captured in numbers, or transformed into numbers, while the latter refers to data that can be captured in, or transformed into words (Blaikie 2000:185-187; Bernard 2006:24-25). I will not go into the perennial debate over which type of data is most valuable in social inquiry, as both contribute in different ways and are equally important (Bernard 2006).

The second difference between the research methods is the level of structure in how the data are collected. The more standardised the data collection method is, the easier it is to compare and analyse between respondents, contexts, researchers, etc. On the other hand, less structure allows for flexibility to go further in-depth or to explore wider the basis of the information collected. Furthermore, less structure is more appropriate if the focus is not just to collect specific information, but also for input on potential reasons behind that specific information. Less structure in interviews also allows for more two-way communication, which may facilitate in building trust between researcher and respondent regarding sensitive questions, as it resembles more of a dialogue (IFRC 2007:61).

The choice of method is therefore not a simple choice of the best research method, but is rather an informed choice guided by the purpose, research question and, ultimately, the selected research methodology. Survey research requires a method that can collect highly structured quantitative data, i.e. the structured interviews in Paper IV, while case study research and design research generally are more flexible in type and structure of data. However, the applications of case study research and design research in Paper I-III, V and VI involve mainly qualitative data, even if the data are to some extent analysed quantitatively in Paper II and III. Semi-structured interviews are used in Paper II and V to collect mainly qualitative data, guided by set interview themes to provide enough structure to enable one to compare and contrast the results from different respondents. The focus groups of Paper III and VI are similar to the semi-structured interviews, with themes to guide the dialogues between respondents. However, the interaction between respondents makes the focus groups more difficult to control, which at times results in less structure. Transect walk is used in Paper VI to collect qualitative data from a specific geographical location (a part of a township). The transect walk itself is structured in the sense that the route and the main elements to look for are predetermined, but it still allows for flexibility to adapt or expand the walk while underway when interesting data emerge. Last but not least, Paper I involves observation, which is used to collect qualitative and highly unstructured information. The differences in type and structure of data collected in these applications of the different research methods are summarised in the figure above (Figure 10).

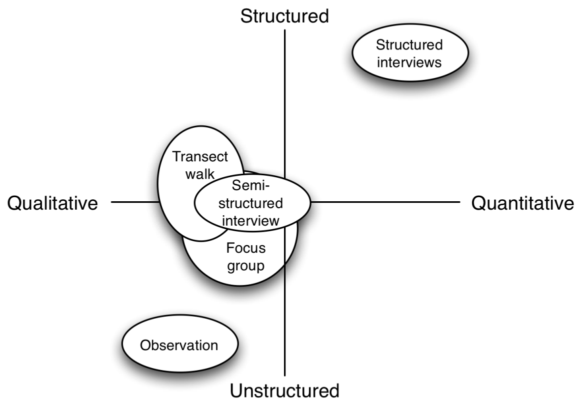

Figure 10. A comparison of level of structure and type of data of how the methods are applied.

5. Research contribution

"Our task is not to predict the future; our task is to design a future for a sustainable and acceptable world, and then to devote our efforts to bringing that future about" - Herbert A Simon (2002:601)

5.1. Empirically informing justifications for key design criteria

5.1.1. The importance of acknowledging interdependencies (Paper I)

The argumentation for the need to represent the world as a human-environment system presented in Chapter *3.2 Theoretical framework* is based on the notion that risk is a complex issue involving all spheres of society (ISDR 2004:16; Wisner *et al.* 2004:49-84; Bolin 2007:114-129; Coppola 2007:146-161). It is suggested that this complexity is a major challenge for effective risk management (Perrow 2008:164-165) and that sustainable development requires the ability to grasp such complexity (Kates *et al.* 2001:641), generally by not focusing on individual elements of the world in isolation but on their interdependencies (Haimes 1998:104; Turner *et al.* 2003a:8077). It is also suggested that more holistic approaches to risk are needed to overcome this challenge (McEntire *et al.* 2002; Cochard *et al.* 2008; Marvin *et al.* 2009), but no indications are given regarding what general negative results may arise if vital interdependencies are not taken into account. Paper I thus examines the need for acknowledging interdependencies of factors related to risk in international development cooperation. The research question of Paper I is:

<u>What general results may come from focusing international development cooperation on specific factors influencing disaster risk without acknowledging interdependencies with other factors?</u>

The limited study looked at two post-tsunami housing reconstruction projects in southern Sri Lanka and two capacity development projects with Tsentrospas (Search and Rescue Unit) in Tajikistan. The data were collected during three missions for the Swedish Red Cross (SRC) and Swedish Rescue Services Agency (SRSA). The methods used for collecting the data were observation and qualitative interviews (both formal and informal). The respondents included potential beneficiaries, national authorities and civil society organisations, and international organisations. The respondents among the beneficiaries were selected out of convenience (Bernard 1995:96), while all other respondents were selected through purposive sampling to obtain informants from as wide selection of stakeholders as possible (*ibid.*:95-96). The data were analysed to extract indications on the purpose, results and actual effects of the four studied projects.

The study reveals that new and well-constructed houses were erected in both projects in Sri Lanka, but one of these newly established communities was not equipped with a sewage and waste water system while the other was constructed inland, far from the majority livelihood base of fishing, and was composed of houses that were too small for the average family-size. The correct number of houses was built according to plan in both projects, but the intended beneficiaries could not live in them due to the unsanitary state of the former and the lack of livelihood opportunities and comfort of the latter.

The study reveals similar results for the two capacity development projects in Tajikistan. The first project equipped Tsentrospas with much needed hydraulic equipment for rescuing people trapped in collapsed buildings and crashed vehicles. However, no activities were implemented to ensure lasting capacities for how to use and maintain the equipment. This resulted in the fact that Tsentrospas still had not used the equipment several years after obtaining it. The second project in the knowledge and skills base for the unit, which faded away as soon as the international support ended due to staff turnover and to the fact that the training was never institutionalised into the domestic training system.

It is clear in all four examples that crucial factors for reaching the purposes of the projects were ignored and left out. The ineffectiveness of these projects illustrates what systems approaches call sub-optimisation problems (Boland & others 1981:115; Liu & Leung 2002:341), in which the specific issue of giving shelter to tsunami affected families in Sri Lanka and developing the technical capacity of Tsentrospas in Tajikistan became the overriding focus, while losing sight of the overall picture and what real effects the projects were intended to have. Without an understanding of what other factors were needed to reach the intended purposes, it did not matter how well specific project activities were implemented.

The four projects also illustrate that if there is no understanding of the relations between the purpose, efforts (costs) and actual effects of a project, it is difficult to monitor and evaluate its effectiveness. This is a second general outcome stipulated by systems approaches when interdependencies are ignored (Davies 2004; Davies 2005). It is clear in the four examples that the focus of the monitoring and evaluation of the projects was on the implementation of individual project activities and not on their complete intended effects.

Hence, the study indicates that ignoring interdependencies may (1) result in sub-optimisation problems where the desired outcome is not reached as the factor focused on and/or the desired outcome are dependent on other factors that are ignored, and (2) make it difficult or impossible to monitor and evaluate the actual effects of international development cooperation for managing risk.

5.1.2. The importance of explicit dialogue of what is valuable (Paper II-III)

What human beings value is at the core of any notion of risk (Renn 1998a:51; Renn 1998b:51; Renn 2008:2). However, there is rarely an explicit dialogue among stakeholders regarding what is to be considered valuable and important to protect when managing risk, thus indicating an inherent assumption that all stakeholders implicitly agree on this matter. Such an assumption may hold with only a few of the individuals involved, but the question is whether it is valid in the context of analysing risk for sustainable development with a multitude of stakeholders. Paper II and III are attempts to examine the need for an explicit dialogue among stakeholders about what is valuable and important to protect when managing risk. Paper II explores what various stakeholders in Fiji express as valuable and important to protect individually, while Paper III investigates what groups of Swedish civil-servants express as valuable and important to protect together. The research questions for Paper II is:

<u>What do stakeholders in disaster risk reduction in Fiji express as valuable and important to protect?</u>

And the research questions for Paper III is:

<u>What do groups of municipal and county council civil servants express as valuable and important to protect and what underlies these expressions?</u>

In order to answer the research question of Paper II, 11 semi-structured interviews were conducted with stakeholders from all relevant administrative levels in Fiji, all possible levels of the traditional leadership, the most important market sectors, and from civil society. The interviews were divided into two themes in which the respondents were asked to give their opinions on what they considered to be valuable and important to protect in everyday life, as well as in disaster situations. The length of the interviews varied between thirty minutes and two hours, but the majority of them were about one hour long. Paper III, on the other hand, is based on four focus groups with 7-21 municipal or county council civil-servants in Sweden, who were asked to identify what they regarded as valuable and important to protect in their organisational contexts. What was elicited was captured on a whiteboard and the conversation was recorded in three of the focus groups. Each focus group lasted for 30-60 minutes.

The study in Fiji indicates that there may be great variation in what stakeholders express as valuable and important to protect. This may not be surprising, as each respondent has her or his own roles, responsibilities, goals, experiences, values and sets of cognitive abilities. The variation in itself is nonetheless enough to raise a serious question about the validity of any approach to risk that is built on the assumption that all stakeholders implicitly agree on what is valuable and important to protect. This point to the need for explicit dialogue regarding this issue, given the assumption that stakeholders need to pull in the same direction for effective risk management. However, the study in Sweden indicates similar variation in what is expressed as valuable and important to protect between groups of stakeholders. This may again not be surprising considering the range of social, cognitive and contextual factors that may influence the dialogue among the stakeholders. However, an explicit dialogue seems to be vital for the formulation of common goals within the group and is likely to generate a rich picture of what is considered valuable. The objective of such dialogue is not to list and prioritise individual elements, but instead to build a system of what is valuable and how these elements relate to each other. This way of eliciting what stakeholders together view as valuable is likely to facilitate consensus among stakeholders, as most of what each one expresses individually may be included in the system. The final result of the dialogue can then be used as a tool for guiding risk analyses as it visualises and specifies in practice what is valuable and important to protect in that particular context.

Therefore, explicit dialogue of what is valuable is vital for analysing risk for sustainable development, as stakeholders initially may have different opinions on what to protect, which may result in them pursuing irreconcilable goals. The outcome of such dialogue is unlikely to give a complete picture of what is valuable and important to protect, and there may still be variation in outcome between groups of stakeholders. However, the picture supplied is likely to be richer than the sum of individual accounts and to provide a mutual framework for acting together towards common goals.

5.1.3. The importance of including various demographic groups (Paper IV)

The perception of risk is suggested to be central to any effort to manage risk (Paton & Johnston 2001). Several factors have been identified as influencing risk perception, e.g. culture (Slovic 1987:281; Bontempo *et al.* 1997; Lam 2005), gender (Flynn *et al.* 1994; Fordham 2000; Armaş 2006), age (Sjöberg 1998:86-87; Hermand *et al.* 1999), income level (Johnson 2004:111), education (Sjöberg 2000:7-8), personality traits (Chauvin *et al.* 2007), etc. It is also important to study how such factors influence the internal order in which individuals rank hazards in their communities, as potential differences could mean that any risk management measure might focus on the priority risks of only part of the population.

Women are generally viewed to be more averse to risks and men to be more tolerant to risks (Flynn *et al.* 1994; Fordham 2000; Armaş 2006), so paper IV is an attempt to investigate if women and men rank the hazards within their communities differently. However, the study includes a wide range of factors in addition to gender that are also included in the analysis. The research question of Paper IV is:

<u>How do women and men of three municipalities in El Salvador rank hazards in their communities?</u>

To answer the research question, 69 randomly selected respondents from three randomly selected municipalities in El Salvador were included in a questionnaire survey. The questionnaires were answered using face-to-face structured interviews. The sample was generated through a field PPS method (Probability Proportionate to Size) (Bernard 2006:160-162), using grid systems and with randomisation using dice. The questionnaire included various demographic variables and a hazard ranking exercise. The data were statistically analysed using SPSS. Pearson's χ^2 (chi-square) was used for nominal variables, γ (gamma) between ordinal variables, paired-sample t-test for analysing differences in the mean between hazards within each group, and independent-sample t-test for analysing equality of mean values for each hazard between groups.

Statistical analysis of the survey data indicates that there are no significant differences between the ranking of hazards by women and men in the studied communities. This is a somewhat surprising result considering the large volume of peer-reviewed literature on gendered differences in risk perception. However, the findings do not constitute a criticism of the view that women and men perceive risks differently, but rather, they indicate that, regardless of how different women and men may view hazards, there is a possibility that they still rank them in a similar order. The analysis shows, nevertheless, a range of other variables as having statistically significant associations with how hazards are ranked, e.g. type of livelihood, location of household, level of education, etc.

Hence, the short answer to the research question is that the participating women and men rank hazards in similar order. There are nonetheless a number of other factors that seem to influence how hazards are ranked. This indicates that regardless of whether there are gender differences in risk perception or not, hazards may be ranked in similar order. It also indicates that there are dividing lines other than gender that may influence priorities of risk management initiatives. It is thus vital to communicate with, and to include, as wide group of people as possible to participate in analysing risk. This applies not only to women and men, but also to representatives with various livelihoods, income levels, level of education, ethnic background, locations of their dwellings, etc. If not, there is a danger that vital needs and opinions might be left out and community commitment to risk management measures reduced. The process may take longer, but even if risk perceptions may differ between different people, there is still a chance that risk management measures can focus on the priority of several different groups, without conceding precedence to any one group over another.

5.1.4. The importance of integrating multiple administrative levels (Paper V)

The destructive impacts of disastrous courses of events are not evenly distributed in the world. Developing countries are bearing the brunt of the suffering and devastation (UNDP 2004), and the international community is urging more affluent countries and international organisations to assist these countries in developing their capacities for managing risk, including adapting to climate change. Capacity assessment has been identified as a vital tool to pursue this capacity development agenda (Lopes & Theisohn 2003; UNDP 2008b; UNDP 2008a; UNDP 2009).

Influential guidelines clearly state that capacity assessment can be conducted at various administrative levels (e.g. UNDP 2008a:5), but most assessments focus only on one level. This can potentially skew the foundation for effective development of capacities for managing risk.

Paper V is thus an attempt to explore the need for integrating information from multiple administrative levels when analysing risk and capacities for managing risk. This can be done by investigating similarities and differences between what stakeholders on different administrative levels express regarding their system for managing risk and disaster situations in Fiji. The research question is of Paper V is:

<u>What are the similarities and differences in expressed flows of information and assistance regarding risk and disasters between different administrative levels involved in managing risks and disaster situations in Fiji?</u>

The data were collected through semi-structured interviews with five respondents holding successive posts, from the village, to the national, level, in the system for managing risks and disaster situations in Fiji. The interviews focused on what type of information and assistance regarding risks and disaster situations the respondents give, or are requested to give, to stakeholders on other administrative levels and what information and assistance they receive or request, in everyday circumstances as well as during disaster situations. The total length of the interviews varied between thirty and eighty minutes, but most of them were about one hour long.

The focus of the analysis is on identifying potential similarities and differences between the individual accounts regarding information and assistance passed up and down between administrative levels. The data are analysed by categorising it according to the six guiding principles of risk management in Fiji[1] (DISMAC 2000) and searching for similarities and differences in what respondents express in their descriptions of the same flow of information and assistance between administrative levels.

The analysis indicates substantial discrepancies between what respondents at different administrative levels express regarding most issues not directly regulated by the Natural Disaster Management Act and the National Disaster Management Plan. For instance, the

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[1] Which are clearly drawn from the Hyogo Framework for Action and its regional framework for the Pacific.

respondents at the national and divisional levels state that the provincial level initially manages any disaster situation, but when such situations are beyond the provincial capacities, the divisional level is activated, and when beyond the divisional capacities, the national level is activated. The respondent at the provincial level, on the other hand, states that regardless of disaster, the province have to deal with it on their own with no external support.

Similarly, the respondents at the national level state that they regularly request and get risk and vulnerability analyses from the divisional level, identifying all risk areas and what vulnerable people and infrastructure are located in those areas, and that the divisional level requests and get the same from the provincial level. However, the respondent at the divisional level, after initially more or less concurring with that, admits that reports are only written and submitted to the national level after disaster has struck. The respondent at the provincial level describes that they never document and submit anything regarding risk and vulnerability to the divisional level. The respondent at the municipal level states that they are not a central part of reducing risk and managing disaster situations at all, which is indirectly confirmed by the other respondents as none of them ever mentioned the municipal level during the interviews. The respondents at the divisional and provincial levels both describe that they are active in public awareness and education, independently of each other, but that these activities are neither known to the respondents at the administrative levels below, nor were visible in any of the villages visited during the field research. Interestingly enough, it is only the respondent at the municipal level who express that their administrative level plays a role in reducing underlying risk factors, e.g. working to maintain storm water drainage in urban areas, inspecting buildings against building codes, etc. Hence, even if the focus is claimed to be shifting to reducing risk, the system for managing risk and disaster situations in Fiji still seems to be highly focused on response to, and recovery from, disaster situations.

The differences between the respondents at the national level and the others regarding the expressed focus in disaster risk reduction is likely to be the result of the top-down approach of the implementation of the

Hyogo Framework for Action 2005-2015. This is a process that is trickling down slowly to lower administrative levels in most countries around the world (GNCSODR 2009). A more general explanation of the differences between the accounts of the respondents may be that some respondents' answers relate to how it is in practice, while others, to how it ought to be, or they extrapolate a few good examples to make them appear general. Other explanations could be that the respondents' roles, responsibilities, goals, experiences, values and sets of cognitive abilities altogether interact with the context of the interview situation, influencing what was elicited at that particular time. Alternatively, the interviewer could have just misunderstood what was said entirely. Regardless of reason, the results entail substantial discrepancies regarding how the system for managing risks and disaster situations in Fiji functions.

In summary, Paper V illustrates that there may be substantial discrepancies between what stakeholders on different administrative levels express when explaining how their system for managing risk and disaster situations functions. This demonstrates a potential for bias if a capacity assessment would have included only one administrative level in the process. The paper does not claim that this is always the case, but only that there may be a possibility for it. Analysing risk would, in other words, benefit from efforts to include information from different administrative levels in attempting to construct one comprehensive view of the current capacities and future capacity needs.

5.2. Designing a framework for analysing risk

5.2.1. Building and evaluating a framework for analysing risk (Paper VI)

In the context of developing capacities to manage risk, any organised efforts are unfeasible without having a clear idea of what risks to manage in the first place. Analysing risk is thus a requisite for any capacity development effort in this context. There are many frameworks for analysing risk developed over the past four decades or so (e.g. Haimes 1998; Aven 2003). However, Paper VI presents justifications for six key requirements for analysing risk for sustainable development, which are based on normative arguments informed by established theory and the empirical investigations of Papers I-V. Paper VI attempts to outline, test and evaluate initial ideas for a framework for analysing risk that meets these requirements through applying the design process presented in Chapter *4.2 The design process*.

The purpose of the desired framework is to guide the analysis of risk aimed at informing efforts to develop capacity for managing risk to facilitate sustainable development. In order to meet that purpose, the framework must fulfil at least six key requirements concerning the ability to:

1. Integrate phenomena on various spatial and temporal scales, as well as structural and functional complexity (systemic);
2. Accommodate different stakeholder values (multi-value);
3. Incorporate a wide range of initiating events that may impact what stakeholders value (multi-hazard);
4. Integrate a multitude of factors and processes contributing to the susceptibility of what stakeholders' value to the impact of the events (multi-susceptive);
5. Involve various stakeholders across functional, administrative and geographical borders (multi-stakeholder);
6. Integrate several risk analyses performed by different groups of stakeholders (multi-analysis).

The initial ideas of the framework are to facilitate analysing risk by constructing explicit models of the world, or human-environment systems, and to use these models to guide the structuring of risk scenarios. The explicit model is constructed using causal loop diagramming, including elements of the world that are deemed relevant, as well as directional relations between these elements which indicate how any changes would propagate through the system.

As argued in Paper II and III, analysing risk starts by explicitly establishing what is valuable and important to protect. This is done with broad participation from various stakeholders. Also important is the facilitating of dialogue by mapping what stakeholders express as valuable, as well as how these valuable elements are related to each other. The result is a system of interdependent elements, which not only guides us in what to have in mind when identifying relevant initiating events but also in how their consequences would spread between elements. Questions 1-3 below are used to guide this part of the analysis (Table 2).

Establish what is valuable and important to protect	1. What is valuable and important to protect? 2. Why is it valuable? 3. Which other elements are valuable in securing that valuable element?
Establish which events can have a negative impact on these valuable elements	4. Which events may happen that can have an impact on what human beings value? 5. Which factors contribute to these events occurring? 6. How likely is each event to occur?
Establish how susceptible these valuable elements are to the impact of the events, including the capability to act to reduce the impact where relevant	7. What can happen to what human beings value, given a specific event, considering actors performing tasks that may influence the outcome where relevant? 8. Which factors contribute to their susceptibility? 9. How likely is that to occur? 10. If it happens, what are the consequences for what human beings value?

Table 2. Ten questions for building human-environment systems and structuring risk scenarios.

The second step in the analysis is to establish what initiating events are capable of having a negative impact on what has been established as valuable and important to protect. After identifying potential initiating events, it is time to define necessary spatial, temporal and magnitudinal aspects of each. This is done by allowing a definite number of initiating events to represent the entire known collection of possible initiating events. For each selected initiating event, the contributing factors are identified and included in the system, potentially connecting it to what stakeholders have expressed as valuable and important to protect. Finally, the likelihood of each initiating event is estimated. Questions 4-6 are used to guide this second part of the analysis (Table 2).

The final part of the analysis is to establish how susceptible each valuable element is to the direct or indirect impact of each initiating event. Therefore, for each initiating event that has been identified, it is vital to define how such an event would impact each identified valuable element, including purposeful human activity to reduce the impact where relevant. For each valuable element that may be impacted by a specific initiating event, any contributing factors for its susceptibility, which has not been included in the previous steps, are identified and included in the system. As there is uncertainty in determining what would happen exactly, even given a specific initiating event, it is important to define different potential courses of events and estimate the likelihood of each one happening. After having established the direct consequences of the impact of a specific initiating event on a specific element, it is time to analyse how this consequence would impact the elements dependent on it. Tracing the impact trough the system. Questions 7-10 are used to guide this part of the analysis (Table 2).

This initial version of the framework was applied in a district municipality in North-West Province, South Africa. The data were collected through focus groups at the district municipal and local municipal levels, and through transect walk, including informal interviews, at the ward level. The method was also applied at the district municipal level in the Western Cape, South Africa, in order to initiate exploration of possibilities for generalisation of the higher levels of the human-environment systems.

Focus groups were selected as the primary method since they provide opportunities for dialogue, which facilitates the formation of an explicit, comprehensive and shared mental model of the world among stakeholders. The three focus groups included between 7-10 members, who represented different municipal departments and other organisations having roles in the institutional structures for managing risk in their respective areas. The focus groups were recorded, generating 6 hours 49 minutes of recorded discussions from which elements and relations are elicited. A full day transect walk in one ward was then used as reference to verify the information given at the higher administrative levels.

The application of the framework in this limited South African example generates a lot of data. Around 100-120 elements and 200-250 relations are elicited from each focus group, making the raw data cumbersome to use in their original form. The elements and relations are therefore aggregated into subsystems on different hierarchical levels, with increasing level of abstraction the higher the level. It is important to restate that the resulting human-environment system is not in any way an objective picture of reality, as both the raw data collected and the system and subsystems are constructed.

Paper VI indicates that the approach of building an explicit human-environment system is beneficial in grasping the complexity of risk in relation to sustainable development. The framework in its current form makes it possible to qualitatively analyse how a change in the system may propagate, reinforce or balance itself, and combine with other changes, creating nonlinear dynamics that may have eluded or even deluded stakeholders in more traditional risk analyses. The focus on relations between elements in the human-environment system, together with the integration of delays, also make it possible to track indirect consequences of a change to spatially and temporally distant parts of the system. Allowing for analysis over multiple time periods and facilitating the integration of long-term or delayed consequences of an immediate impact, as well as pressing consequence of gradual changes. The framework also seems to facilitate the integration of various spatial scales, as the human-environment system is possible to organise hierarchically.

Although the framework would benefit immensely from the quantitative modelling of stock-and-flow diagramming and microworlds, such approaches may still be somewhat distant as there are many complex relations that remain difficult to quantify. Systems archetypes (e.g. Jackson 2003:70-73), on the other hand, may be a more feasible step in the development of the framework.

Paper VI also indicates that the framework can accommodate different stakeholder values and thus reduce the potential for debate and conflict around these issues. Explicit dialogue also seems to mobilise stakeholders who may not usually consider themselves important for risk management. As they realise that their input is vital for analysing risk in their context, it may reinforce their awareness of the importance of managing risk in general, as well as their interest in supporting such activities.

Specifying what is considered valuable and important to protect also seems to facilitate the incorporation of a multitude of different initiating events in the analysis. This is also facilitated by including multiple stakeholder values which provides a wide range of elements that different initiating events can impact. Furthermore, bringing each specific element systematically to mind facilitates their identification.

Paper VI indicates that the initial framework not only emphasises the analysis of the susceptibility of specific elements to the impact of specific initiating events, but also demands more detailed descriptions of these factors and processes. It also provides a systematic approach to integrating them into the analysis. The framework also emphasises that the capability of individuals, organisations and societies to act in specific scenarios is vital in such analysis. Since the framework allows for multiple stakeholder values, it also allows for multiple types consequences in the analysis of risk. Similarly, multiple time periods for analysis generate different sets of these consequences for each specific time period. The main challenge in using the framework lies therefore in managing the vast amount of information in both input and output. Although the development of systems archetypes may somewhat reduce this problem by providing a scaffold for more systematic construction of human-environment systems, the optimum solution is to integrate the framework into some tool for information management, e.g. Geographical Information Systems (GIS).

Paper VI indicates that the framework is well designed for involving various stakeholders. The explicit dialogue of what is to be considered valuable and important to protect demands direct interaction between stakeholders across functional boundaries and opens up opportunities for involving the public if the resources are available. Such a broad range of stakeholders can also be involved in identifying initiating events that can impact what they value, as well as experts who may be more capable of adding scientific insight into the dynamics of the initiating events and their contributing factors. The initial framework also seems to facilitate the involvement of stakeholders across administrative and geographical borders, as the hierarchical structure of human-environment systems makes them possible to aggregate and disaggregate. However, the multifarious nature of our world generates challenges with aggregation that need further attention in the development of the framework.

It is not possible to evaluate sufficiently the requirement of integrating several risk analyses performed by different groups of stakeholders, as this application of the framework does not include multiple risk assessments performed by different groups of stakeholders. However, Paper VI outlines reasons for further emphasising the importance of this design criterion.

Finally, although the initial framework seems to meet the six stated requirements to certain extent, there are still modifications and more applications that can be added if necessary. However, representing the world as an explicit human-environment system, while involving a multitude of stakeholders, seems central to the task of analysing risk in the complex context of sustainable development, and appears to be an appropriate path to follow for further research.

5.3. Discussing and concluding the research contributions

The setting for the studies in Paper I-VI is facilitating capacity development for managing risk and actual destructive courses of events. Since this is only one of many possible settings within the context of analysing risk for sustainable development, it is vital to keep in mind that the empirical foundation for the discussion and conclusion in this chapter is limited to this particular setting. The potential for more general implications is presented in Chapter *6.1 Implications for analysing risk for sustainable development in general.*

5.3.1. Discussing the six key design criteria

Risk analysis is a requisite for guiding decisions today that will determine our tomorrow. It is our major instrument for attempting to manage the contingent nature of our future and constitutes, together with vulnerability analysis, the two main categories of sustainability science tools for ex ante assessment of issues concerning sustainable development, given that uncertainty is explicitly involved in the analysis. However, all frameworks for analysing risk do not automatically qualify to fill the purpose of facilitating sustainable development. For that purpose, there is a range of specific requirements needed, of which this thesis presents and justifies six. The justifications for these six key design criteria are based on logical reasoning informed by established theory and, where necessary, by new empirical research (Paper I-V).

Sustainable development is about being able to maintain and safeguard the development of society from a current to a desired state and includes purposeful activities to drive or steer this change. Analysing risk in this context requires the ability to accommodate various stakeholder values in the analysis (multi-value). It is therefore not only uncertainty that is common to all approaches to analyse risk for sustainable development, but also the process of involving multiple criteria for measuring direct and indirect consequences and integrating these in the evaluation of risk in relation to development goals. Having diverse stakeholders involved in the process increases the likelihood that these stakeholders differ in what they consider valuable and important to protect (Paper II). There is a real potential for undermining the effectiveness of managing risk for sustainable development if what stakeholders value makes them pursue irreconcilable goals. Explicit dialogue about what is valuable is thus vital for analysing risk in this context (Paper II and III). What stakeholders express as valuable and important to protect in the studied contexts is rarely conflicting, but may, in fact, be related to each other. This serves to create a system of valuable elements representing what is relevant to protect over time in the particular contexts (Paper VI). A range of social, cognitive and contextual factors can still create variation in what groups of stakeholders express together as valuable and important to protect (Paper III). However, the picture supplied is likely to be richer than the sum of individual accounts and could also provide a framework for acting together towards common goals.

Because of this holistic approach to what human beings value in society, analysing risk for sustainable development may also require the ability to incorporate a wide range of initiating events in the analysis (multi-hazard), or what Kates *et al.* (2001) call multiple stresses, as well as various factors and processes contributing to the vulnerability of what stakeholders' value to the impact of these events (multi-susceptive). Including various initiating events in the analysis is particularly important as representatives from different demographic groups may rank different initiating events in different order (Paper IV). This has the potential for limiting the commitment to specific risk management activities to only certain parts of the community.

Although the world is dynamic and complex with more or less immeasurable interdependent connections between elements directly or indirectly determining risk, human beings seem to have an almost relentless fixation with dividing this issue into parts that suit functional sectors, organisational mandates and academic disciplines. This is disruptive to sustainable development, since focusing on one functional sector, while ignoring interdependencies with other sectors, is likely to result in sub-optimisation problems and challenges for monitoring and evaluating the actual effects of specific activities (Paper I). Similarly, including only one administrative level in the analysis may produce a biased view of the challenges at hand, as there may be differences in how stakeholders at different levels describe their system for managing risk and disaster situations (Paper V). Sustainability science provides a clear break from this fruitless pattern, as it attempts to provide a basis for collaboration between global and local, poor and affluent, society and science, etc. In short, analysing risk for informing efforts to develop capacity for managing risk to facilitate sustainable development requires the ability to involve various stakeholders across functional, administrative and geographical borders (multi-stakeholder).

Accommodating multiple stakeholder values and involving a variety of stakeholders also introduces the requirement of being able to integrate several risk analyses performed by different groups of stakeholders (multi-analysis). The application of the initial ideas of the framework (Paper VI) does not allow the fulfilment of this requirement to be sufficiently evaluated. Nevertheless, the implications of this requirement is that each risk analysis must include an explicit systems model, must clearly state what are considered negative consequences in the analysis, and the risk scenarios that have been identified must be clearly described together with estimates of their respective likelihood of occurrence and consequences.

Finally, the complexity of our world separates cause and effect in space and time, thus making it futile to analyse risk in the context of sustainable development without at least attempting to grasp this structural and functional complexity. This core challenge is the main focus of sustainability science and can be considered the foundation for all five requirements previously presented. Hence, analysing risk for sustainable development requires ability to integrate phenomena on various spatial and temporal scales, as well as structural and functional complexity (systemic).

5.3.2. Presenting the developed framework

The purpose of the actual framework developed in this thesis is to guide the analysis of risk for informing efforts to develop capacity for managing risk to facilitate sustainable development. It is in order to meet this purpose that the framework must fulfil at least the six key requirements, or design criteria, presented above[1]. The actual form of the framework can then be summarised as three principles, two tools and a description of how the three principles and two tools are utilised in practice (Figure 11).

5.3.3. Discussing the scientific development of frameworks

The initial ideas for a framework for analysing risk for sustainable development presented in this thesis is not enough to lay claim to having a functioning framework ready for general use. For that, more

[1] (1) systemic; (2) multi-value; (3) multi-hazard; (4) multi-susceptive; (5) multi-stakeholder; and (6) multi-analysis.

development work is necessary. However, the overall research question of this thesis is not to present the developed framework per se, but to explore how such a framework can be developed scientifically. This can be done by using a combination of traditional science and design science, involving different research methodologies and principles for assessing scientific rigour, in a systematic and transparent design process. The application of the initial ideas for the framework thus supplies simply the context for exploring the scientific rigour of the design process used.

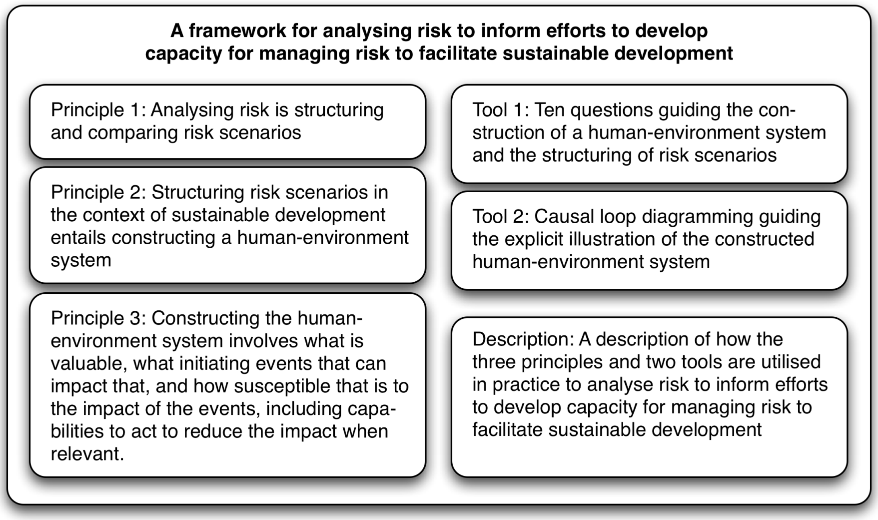

Figure 11. Summary of the initial framework for analysing risk to inform efforts to develop capacity for managing risk to facilitate sustainable development.

Design science supplies us with the principle of workability, in addition to the principles of reliability and validity of traditional science. However, the scientific rigour of the design process is determined by the degree to which the scientific community trusts its results. As in all scientific work, this trust relies to a large extent on the possibility for outsiders to see and understand what the researchers involved have done during the course of the project.

To scientifically develop a framework for analysing risk for sustainable development therefore demands full clarity and transparency in all steps of the design process. This is particularly vital when justifying the purpose and required functions (design criteria) of the framework, since not only empirical statements usually are allowed to influence these core assumptions, but also, and more importantly, normative statements based on value preference. These are all assumptions that guide the development of the framework, as well as serving as references against which the framework is evaluated to judge its sufficiency. It is thus vital to not only explicitly state and justify the purpose and the required functions, but also to make sure to show clearly how these assumptions are related to each other, as well as to the actual form of the framework developed. Such transparency is also of fundamental importance as it is impossible to list all potential design criteria, and by having a systematic and transparent design process, one can allow and invite not only scientific scrutiny but also further scientific development.

The scientific development of the framework also has a practical side, as it is impossible to evaluate the performance of any framework if it is not possible first to apply it in practice. It is therefore necessary to make sure that the actual form of the developed framework makes it possible to utilise it in practice, in its intended contexts. Finally, to judge the workability of the framework, its sufficiency must be assessed in terms of its utility to fulfil the required functions to meet its purpose, and the outcome of this evaluation must be used to guide further development. Neglecting any of these requirements automatically reduces the scientific rigour of the design process.

5.3.4. Answering the overall research question

So, what criteria should guide the design of a framework for analysing risk for sustainable development, and how should such a framework be developed scientifically?

As stated above, it is obviously unfeasible to list all design criteria that could potentially guide the development of such a framework. However, in response to the first part of the overall research question above, this thesis suggests, and provides justifications for, six key design criteria that should be included in such endeavour. These design criteria demand that a framework for analysing risk for sustainable development should be able to:

1. Integrate phenomena on various spatial and temporal scales, as well as structural and functional complexity (systemic);
2. Accommodate different stakeholder values (multi-value);
3. Incorporate a wide range of initiating events that may impact what stakeholders value (multi-hazard);
4. Integrate a multitude of factors and processes contributing to the susceptibility of what stakeholders' value to the impact of the events (multi-susceptive);
5. Involve various stakeholders across functional, administrative and geographical borders (multi-stakeholder);
6. Integrate several risk analyses performed by different groups of stakeholders (multi-analysis).

In response to the second part of the overall research question, concerning how to scientifically develop such framework, this thesis emphasises the importance of three scientific principles: the principles of reliability and validity of traditional science, and the principle of workability of the framework itself in its intended contexts. Developing such framework scientifically thus requires a systematic and transparent design process in which:

a. The empirical and normative statements behind the framework's purpose and required functions, as specified in the design criteria, are explicitly justified and stated;
b. The actual form of the developed framework makes it possible to utilise it in practice;
c. The connections between purpose, functions and form of the framework are clear;
d. The framework is utilised in its intended contexts;
e. The utility of the framework is measured in how well its form fulfils the required functions to meet its purpose;
f. The outcome of the evaluation of the framework guides further development.

6. Final remarks

"Never look down to test the ground before taking your next step; only those who keep their eye fixed on the far horizon will find their right road" - Dag Hammarskjöld

6.1. Implications for analysing risk for sustainable development in general

Although the empirical base for this thesis is facilitating capacity development for managing risk for sustainable development, it may hold broader implications for analysing risk for sustainable development in general.

First of all, sustainability science requires the ability to integrate phenomena on various spatial and temporal scales, as well as structural and functional complexity, in all descriptive and normative aspects of sustainable development. It is therefore plausible that analysing risk for sustainable development would benefit from following that requirement in general. Especially since it is likely that not taking vital interdependencies into account may cause sub-optimisation problems and problems in monitoring and evaluating the actual effects of our activities in general.

The requirement of being able to accommodate different stakeholder values is also likely to be a general one for analysing risk for sustainable development in a broader sense, given that multiple elements may be expressed as valuable in such contexts. This is especially the case since it is reasonable to believe that multiple stakeholders are necessary in such contexts, both to shed light on, and facilitate, a mutual understanding of the challenges at hand, as well as to generate broad commitment to reach common goals. The requirement of being able to involve various stakeholders across functional, administrative and geographical borders is also likely to be valid for analysing risk for sustainable development in general. Explicit dialogue about what is considered valuable in these contexts may thus be of vital importance, since it is probable that different stakeholders initially may have different ideas about this issue.

A broad societal focus in general, involving various stakeholders and multiple values, is also likely to entail the requirement of being able to incorporate multiple initiating events in analysing risk for sustainable development, as well as that of integrating a multitude of factors and processes contributing to the susceptibility of what stakeholders' value to the impact of these events. This is because it is implausible that only involving one or two potential courses of events that may reduce the sustainability of our society would give a comprehensive enough picture to base today's decisions on in order to achieve our preferred tomorrow. In view of the complexity of having a broad societal focus when analysing risk for sustainable development in general, it is likely that obtaining the required comprehensive picture may necessitate the ability to integrate several analyses performed by different stakeholders.

Finally, the six conditions for scientifically developing a framework for analysing risk to inform efforts to develop capacity for managing risk to facilitate sustainable development (a-f) are likely to be of general application for developing frameworks for analysing risk for sustainable development. This is because the design process presented in this thesis builds on general design science that is, and has been, applied to solve a multitude of problems in various contexts.

6.2. Ideas for future research

Although a couple of centuries of unsustainable development have set the world in this grave state and there are unfortunately few signs of any major change of direction, let us hope that Simon's (2002:605) heartening prophecy comes true:

> *"Perhaps our very salvation will come from the severity of the problems we will have to solve: finding an ecologically sustainable state for the Earth and all its living inhabitants, injecting far stronger criteria of fairness into the allocation of available resources and their products, and disarming the vicious competitions that now take place between every imaginable sort of 'we' and 'they'."*

Researchers have important roles in facilitating such a dramatic and critical change in the transactions of humankind (Kates *et al.* 2001). Such a change is necessary for the survival of the world as we know it. Most disciplines have a role to play, but the transdisciplinary approach of sustainability science is imperative in this context as it brings together "scholarship and practice, global and local perspectives from north and south, and disciplines across" all sciences (Clark & Dickson 2003:8060).

The most immediate need for future research in relation to this thesis is more applications of the framework in order to develop it further. More applications of the framework would also allow for researching the possibility of developing archetypes for the higher hierarchical levels of the human-environment systems constructed. This will serve in making the framework more efficient and user friendly by guiding the search for the more detailed and context-specific information needed. Such a process of systematic mapping of sub-systems can also be done independently of the framework itself, inviting various disciplines to contribute parts in order to construct a comprehensive whole: The core function of sustainability science.

More descriptive transdisciplinary research is thus needed to advance our understanding of the dynamics of complex human-environment systems in which a multitude of interdependent conditions and processes of change generate courses of events that undermine sustainable development. For instance, systemic mapping of factors behind why human beings live in dangerous locations, investigating the relations between land use, water resource management and sinkholes, etc. The more we learn, the more comprehensive our modelling of such systems can be, facilitating a merging of qualitative and quantitative tools in the future. In addition to understanding these phenomena, there is also a need for more normative transdisciplinary research to address these sustainability problems by designing better processes, methods and tools for managing risk for sustainable development. Examples of this are: a framework for analysing capacity in societies to manage risk, an add-on to Logical Framework Approach to facilitate its use for capacity development for risk- and disaster management, etc. When understanding phenomena and having artefacts to address problems, researchers need to focus more on innovation activities, on supporting the design, implementation and evaluation of projects that promote sustainable development in practice. This by applying their research results in collaboration with relevant partner communities (policy, management, practitioner, or beneficiary).

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Appendix: The Papers

Paper I	Becker, Per (2009). 'Grasping the hydra: The need for a holistic and systematic approach to disaster risk reduction'. *Jàmbá: Journal of Disaster Risk Studies*, 2(1), 12-24.
Paper II	Becker, Per (2009). 'The importance of explicit discussions of what is valuable in efforts to reduce disaster risk'. submitted to *Asian Journal of Environment and Disaster Management*
Paper III	Nilsson, Jerry and Becker, Per (2009) 'What's important? Making what is valuable and worth protecting explicit when performing risk and vulnerability analyses'. *International Journal of Risk Assessment and Management*, 13(3/4), 345-363.
Paper IV	Becker, Per (2010) 'Whose risks? Gender and ranking of hazards'. forthcoming in *Disaster Prevention and Management, An International Journal*
Paper V	Becker, Per (2010). 'The importance of integrating multiple administrative levels in capacity assessment for disaster risk reduction and climate change adaptation'. forthcoming in *Australian Journal of Emergency Management*
Paper VI	Becker, Per and Tehler, Henrik (2010). 'Risk informed capacity development for managing risk to facilitate sustainable development'. submitted to *Journal of Contingencies and Crisis Management*