Department of Real Estate, Planning and Geoinformatics

Customizing a maturity model for the evaluation of the development of shared situational awareness and the utilization of spatial information

Jaana Mäkelä

Aalto University

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Jaana Mäkelä

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Abstract

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Abstract

This dissertation investigates an organization's maturity in terms of sharing and utilizing relevant information in order to reach its objectives. In disaster management, the timely sharing of information makes possible adequate shared situational awareness (SSA), which is a prerequisite for the effective coordination of actions and the management of resources. Therefore, actors would like to increase their competence to create SSA. Spatial information and spatial methods could support both public and private organizations in improving their productivity and developing innovative solutions to tackle today's global challenges, such as climate change and an aging population. Because of a lack of awareness and competence, organizations have not been able to use the potential of spatial information. In this state of affairs, in both application domains tools are needed to assess the current state of competence, to set a roadmap for organizational improvement, and to assess the effects of development.
In this study, a formal process for the development and use of a customized maturity model was developed. Two customized maturity models were created for multiactor disaster management organizations and one GIS maturity model was developed for individual public and private organizations. The maturity models for disaster management were used and evaluated in Search and Rescue and ICT exercises. The models are based on the essential indicators of shared situational awareness, such as the creation of trust, the communication of information requirements, the timely sharing of information, the coverage of shared information, and human agents' commitment and will to collaborate. The GIS maturity model was used and evaluated in five organizations that were using spatial information. The indicators of the GIS maturity model measure the maturity of the organization's internal spatial infrastructure, the use of spatial information in internal core processes and customer services, and the commitment and the will of both managers and employees to act for the comprehensive utilization of spatial information.
The main conclusion is that even when technical infrastructure and common applications exist, the systems intelligent behavior of human beings – commitment and the will to act towards the achievement of common goals – is crucial for the sharing and utilization of information. Therefore, the indicators of systems intelligent behavior should be included in customized maturity models for disaster management and organizations using spatial information. The research indicates that the creation of trust is important for spatially enabled organizations as well.

Keywords disaster management, shared situational awareness, utilization of spatial information, maturity model, customization, systems intelligence

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Tiivistelmä

Tämä väitöskirja käsittelee organisaation kypsyyttä jakaa ja hyödyntää olemassa olevaa, toiminnan tavoitteiden saavuttamisen kannalta oleellista tietoa. Suuronnettomuudessa tietojen oikea-aikainen jakaminen eri toimijoiden välillä mahdollistaa hyvän jaetun tilannetietoisuuden joka on edellytys toimintojen tehokkaalle koordinoinnille ja resurssien johtamiselle. Paikkatietojen avulla kunnat, kaupungit ja yritykset voivat tehostaa toimintaansa sekä innovoida sovelluksia, jotka auttavat ratkaisemaan globaaleja ongelmia, kuten ilmastonmuutos tai väestön ikääntyminen. Siksi suuronnettomuusorganisaatiot haluavat kehittää osaamistaan jaetun tilannetietoisuuden muodostamisessa ja paikkatietoja käyttävät organisaatiot kyvykkyyttään hyödyntää paikkatietoja kokonaisvaltaisesti, mutta niiltä puuttuvat formaalit menetelmät, jotka tuottaisivat toimintojen kehittämisessä tarvittavaa kvantitatiivista tietoa.

Tutkimuksessa luotiin menetelmä räätälöidyn kypsyysmallin kehittämiseksi ja organisaation kypsyyden arvioimiseksi luodun mallin avulla. Tutkimuksessa määritettiin jaetun tilannetietoisuuden muodostamisen indikaattorit ja niihin perustuvat kypsyysmallit, joita testattiin kahdessa suuronnettomuusharjoituksessa. Indikaattorit mittaavat luottamuksen rakentamista, tietovaatimusten esittämistä, tiedon oikea-aikaista jakamista, jaetun tiedon kattavuutta ja henkilöiden sitoutumista yhteistyöhön. Organisaation paikkatietokypsyyden kehittämistä varten luotiin yksityiskohtainen kypsyysmalli, jota testattiin viidessä eri organisaatiossa. Mallin indikaattorien avulla voidaan arvioida organisaation sisäistä paikkatietoinfrastruktuuria, paikkatietojen käyttöä toiminnan ydinprosesseissa ja asiakaspalveluissa sekä johdon ja työntekijöiden sitoutumista ja yhteistyötä paikkatietojen käytön edistämiseksi.

Tutkimuksen johtopäätös on, että vaikka yhteinen tekninen infrastruktuuri olisi olemassa, niin henkilöiden systeemiälykäs toiminta eli sitoutuminen ja tahto yhteisten tavoitteiden saavuttamiseksi ratkaisevat sen miten hyvin tietoja jaetaan ja hyödynnetään. Tämän vuoksi henkilöiden systeemiälykästä toimintaa kuvaavat indikaattorit on sisällytettävä sekä tilannetietoisuuden muodostamista että paikkatietojen hyödyntämistä arvioiviin kypsyysmalleihin. Tulokset osoittavat myös sen, että luottamuksen rakentaminen on tärkeää myös paikkatietojen hyödyntämisen kehittämisessä.

Avainsanat katastrofin hallinta, jaettu tilannetietoisuus, paikkatietojen hyödyntäminen, kypsyysmalli, räätälöinti, systeemiäly

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KIITOKSET

Elämä kantaa ja yllättää - hyvin usein positiivisesti. Kun nuorena vastavalmistuneena diplomi-insinöörinä lähdin Teknillisestä korkeakoulusta, olin avoin työelämän haasteille, mutta minulla ei ollut minkäänlaisia ajatuksia jatkaa joskus opintojani. Seuraavat 20 vuotta tein töitä hienoissa yrityksissä loistavien kollegojen ja asiakkaiden kanssa. Kunnes syntyi tarve pysähtyä ja katsoa paikkatietoalaa jostain muusta kuin yritysnäkökulmasta. Olen todella kiitollinen Professori Kirsi Virrantaukselle siitä, että hän otti minut geoinformatiikan tutkimusryhmänsä jäseneksi. Palasin korkeakouluun jatko-opiskelijaksi ja tutkijaksi. Vaikka paikkatietojen hyödyntäminen oli primääritutkimusaiheeni, tutkimusryhmän mukana osallistuin suuronnettomuusharjoituksiin ja aloin tutkia myös toimijoiden välisen jaetun tilannetietoisuuden muodostumista. Seuraavien vuosien aikana tein tutkimusta sekä kotimaisissa että kansainvälisissä tutkimusprojekteissa. Opin, miten mielenkiintoista, mutta vaativaa tutkimuksen tekeminen on. Ja miten innostavaa on löytää täysin uusi tutkimusnäkökulma asioihin! Minulle se on ollut systeemiäly. Olen kiitollinen professori Raimo P. Hämäläiselle ja professori Esa Saariselle siitä, että minulla oli mahdollisuus osallistua Luovan ongelman ratkaisun-seminaariin, jossa yhdessä keskustelimme systeemiälyn merkityksestä ja kehitimme osaamista ihmisten ja organisaatioiden systeemiälykkään toiminnan arviointiin.

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List of appended Papers

This dissertation consists of a Summary and of the following six scientific publications, which are referred to in the text by their Roman numerals.

Paper I: Virrantaus, Kirsi; Demšar, Urška; Mäkelä, Jaana (2009). Supporting the development of shared situational awareness for civilian crisis management with Geographic Information Science – research plan. In: A. Krek, M. Rumor, S. Zlatanova and E. Fendel, ed., *Urban and Regional Data Management, UDMS Annual 2009*, Leiden, Netherlands: CRC Press, pp. 217-230.

Paper II: Seppänen, Hannes; Mäkelä, Jaana; Luokkala, Pekka; Virrantaus, Kirsi (2013). Developing Shared Situational Awareness for Emergency Management. *Safety Science*, vol 55, pp. 1-9.

Paper III: Mäkelä, Jaana (2011). Aspects of a Licensing and Pricing Model for a Multi-Producer pan-European Data Product. *International Journal of Spatial Data Infrastructures Research*, vol 6, pp. 344-364.

Paper IV: Mäkelä, Jaana; Vaniala, Riitta; Ahonen-Rainio, Paula (2010). Competence management within organisations as an approach to enhancing GIS maturity. *International Journal of Spatial Data Infrastructures Research*, vol 5, pp. 267-285.

Paper V: Mäkelä, Jaana (2012). Model for Assessing GIS Maturity of an Organization. In: A. Rajabifard and D. Coleman, ed., *Spatially Enabling Government, Industry and Citizens: Research and Development Perspectives*, GSDI Association Press, Needham, MA, pp. 143-165.

Paper VI: Mäkelä, Jaana; Virrantaus, Kirsi (2013). A Customizable Maturity Model for Assessing Collaboration in Disaster Management. In: S. Zlatanova et al. (ed.), *Intelligent Systems for Crisis Management, Lecture Notes in Geoinformation and Cartography*, Springer-Verlag, Berlin/Heidelberg, pp. 251-262.

Author's contribution to the Papers

The contribution of the author of this dissertation to the appended Papers I-VI is outlined below.

Paper I: the author discussed the relevance of trust and systems intelligence in disaster management organizations throughout the paper and participated in writing the corresponding sections.

Paper II: the author is responsible for categorizing the factors that hampered SSA in SAR operations (Figure 1) and the development of the frameworks of systems trust and role layers of a human agent. The author is responsible for writing the corresponding sections of the theories (chapters 2.2 and 2.3) and results (chapter 5.3) in the paper.

Paper III: the author is responsible for writing the paper and the development of the new pricing and licensing model of the EuroDEM.

Paper IV: the author had the main responsibility for initiating and writing the paper, and developed the GIS maturity scale and studied the role of systems intelligence in organizations using spatial information. All the authors contributed evenly to the development of the GIS maturity enhancement model, which was based on the studies of the first and the second authors.

Paper V: the author is responsible for writing the paper and the development and evaluation of the GIS maturity model.

Paper VI: the author had the main responsibility for writing the paper, and developed and evaluated the maturity models for disaster management organizations. The second author contributed to the formalization of the customizing process and commented the paper.

Abbreviations

ABC	Activity-Based Costing
BSC	Balanced Scorecard
CBAO	Command Body of the Area of Operation
CBSS	Command Body of Supporting Services
CCRRS	Command Centre of Regional Rescue Services
GI	Geographic Information
GIS	Geographic Information System
GIC CMM	Local Agency GIS Capability Maturity Model
CMM	Capability Maturity Model
COP	Common Operation Picture
CTEF	Command Team Effectiveness model
DEM	Digital Elevation Model
EM-CMM	Emergency Management Capability Maturity Model
EuroDEM	European Digital Elevation Model
ICT	Information and Communications Technology
INSPIRE	Directive 2007/2/EC of the European Parliament and of the Council of 14 March 2007 establishing an Infrastructure for Spatial Information in the European Community (INSPIRE)
IOH	International Operational Headquarters
IT	Information Technology
MNE5	Multinational Experiment 5
MNE6	Multinational Experiment 6
N2C2M2	NATO Network Enabled Command and Control Maturity Model
NATO	North Atlantic Treaty Organization
NMCA	National Mapping and Cadastral Agency
NSDI	National Spatial Data Infrastructure
SA	Situational Awareness
SAFAR	Strategic Alliance Formative Assessment Rubric
SAGAT	Situation Awareness Global Assessment Technique
SAR	Search and Rescue
SDI	Spatial Data Infrastructure
SHIFT	Shared Information Framework and Technology
SSA	Shared Situational Awareness
TQM	Total Quality Management
UNISDR	United Nations International Strategy for Disaster Reduction
USA	the United States of America

Contents

1. Introduction

This research encompasses two application domains: shared situational awareness in disaster management organizations and the utilization of spatial information in public and private organizations. Shared situational awareness (SSA) between different actors means that they have a holistic understanding of the situation and can synchronize their actions (Nofi, 2000). In disasters such as natural hazards and major accidents a good shared situational awareness between all actors is needed in order to achieve a fast and coordinated response. The fast and efficient management of disasters can save people's lives, reduce property losses, and minimize damage to critical infrastructure. This research focuses on the response phase of disaster management, which is the acute phase after a disaster. Spatial information is information that has "a direct or indirect reference to a specific location or geographical area" (European Commission, 2007a, p. 5). Spatial information is used in organizations to support decision making, improve productivity, and innovate new products and services. Security actors such as rescue authorities, the police, and the military have traditionally been substantial users of spatial information and spatial methods because they enable the analysis and visualization of event information to take place (Cova, 1999, Zlatanova and Li, 2008, Zlatanova et al., 2013). The link between these two application domains is spatial information and in this research the information required in disaster management operations involves spatial information as well. Throughout the dissertation, a disaster management organization is defined as a temporary multiactor organization, and an organization that utilizes spatial information is defined as an individual public or private organization.

1.1 Background and motivation

In Finland, agencies such as rescue services, the police, medical services, the border guard, the military, cities, and ministries drill their preparedness and collaboration in annual exercises, such as search and rescue (SAR) and information and communications technology (ICT) exercises. SAR is an internationally established concept for managing major traffic accidents such as aviation and sea traffic accidents (European Aviation Safety Agency, 2013, International Maritime Organization, 2004, Seppänen and Valtonen, 2008). The terms “search” and “rescue” describe the two phases of a rescue operation. An SAR organization is established to coordinate the rescue operation. In ICT exercises agencies practice their preparedness for disturbances in information systems and networks. Previous research conducted in the Finnish SAR exercises (Kuusisto, 2007, Nissinen, 2009, Seppänen and Valtonen, 2008) showed that the major factors that hamper the SAR organization in achieving adequate SSA are information gaps, the lack of fluent communication, and the fact that there is no common operational picture (COP) in use. Problems that affect the information gap are agents focusing only on their own tasks, unclear information delivery processes, shortages of incident information, agents’ passivity, and a lack of the latest information. According to human agents in SAR exercises, fluent communication is open communication where common concepts are used, trust exists, and relevant information can be accessed easily. Human communication also seems to be the biggest problem in multi-national civilian crisis management operations, such as the Multinational Experiment 5 (MNE5). One reason for incomplete communication is a lack of trust. In a lack-of-trust system actors do not share their information and knowledge even if commonly used web-based collaboration tools such as Shared Information Framework and Technology (SHIFT) in MNE5 are available (Vesterinen, 2008, Virrantaus et al., 2009). One of the main reasons why these national and multi-national problems persist might be that they are too general in nature to be solved. For example, trust is not a binary value but a multidimensional one and thus needs more detailed analysis. Therefore, the collaboration capabilities that support the development of SSA need to be specified at a more detailed level.

The evaluations of the SAR and ICT exercises, as well as other civilian and military disaster management exercises, are often reported qualitatively, with a verbal and general description of the successes of the collaboration and aspects that should be improved in the future. The reports are basically created on the basis of observation information and data collected by questionnaires. Some statistical analyses have been carried out, but their use has not been systematic and no follow-up has been possible. The problem is that the existing evaluation methods do not clearly identify the problems and they do not produce quantitative data for the evaluation and the development of collaboration. Therefore, more quantitative and measurable methods and constant assessment of progress are needed (Rintakoski and Autti, 2008, Valtonen, 2010). According to Virta (2002), the constant assessment of the development is important because the successes and failures in exercises influence the future collaboration and its outcomes.

In spite of the increasing availability of spatial data sets and the use of spatial information in local and regional governments and in private industry, the full potential of the exploitation of spatial data has not yet been reached. In Finland, the shared use of spatial data has a long history (Vahala, 1986, Masser, 2005), the technical infrastructure is of a high standard, and a lot of spatial data is available. Furthermore, cooperation between the organizations that produce and exploit spatial data is active, for example in the Inspire Network of Finland, which was established to support the national implementation of the INSPIRE Directive (National Land Survey of Finland, 2012). Still, the exploitation of spatial data has not increased as quickly as might have been expected (Mäkelä and Warsta, 2008, Mäkelä and Hilke, 2011, Kiuru et al., 2012). The studies by Mäkelä and Warsta (2008) and Mäkelä and Hilke (2011) revealed significant variations in the utilization of spatial information in public organizations in Finland and especially in their strategic attitude. A study by Vaniala (2008) indicated that a lack of awareness of the full potential of spatial information is common in organizations that already use spatial information to some extent, whether they work in the public or private sectors. The results pointed to the obstacles relating to competence management rather than technical or resource-related issues. Kok and van Loenen (2005) also state that organizations usually pay more attention to technical issues than to the institutional framework and human resources. There also seems to be a lack of awareness and understanding of the potential of the National Spatial Data Infrastructure (NSDI) (Mäkelä and Warsta, 2008). The discussions in the meetings of the Inspire Network of Finland (Mäkelä, 2010) revealed that even if organizations would like to increase their competence to utilize spatial information in their businesses, it is not always clear which subjects of development are worth investing in. In this state of affairs, tools are needed to assess the current state of competence, to set a roadmap for organizational improvement, and to assess the effects of development.

Maturity was chosen as an approach to study the problems of these two application domains. A maturity model is used as a tool for the assessment and development of both the creation of shared situational awareness and the utilization of spatial information because it enables a comprehensive approach to be taken to essential elements such as technical infrastructure and human factors. Maturity assessment produces quantitative data for the development of the system. The existing maturity models are seldom suitable as they are. National goals and cultural differences seem to affect the contents of the models. In a dynamic and complex disaster operation it is not possible to perform a detailed and laborious maturity assessment that needs time and resources, whereas in a permanent user organization utilizing spatial information more time and resources may be available. Consequently, the main research problem is how to customize a maturity model. What is essential is the definition of appropriate and measurable indicators, and the testing of the model in real life.

The scientific framework of this dissertation builds on theories of systems intelligence, shared situational awareness, trust, spatial data infrastructure and the capabilities of a learning organization. Systems intelligence emphasizes the power of the human element in a system and the small changes in human behavior that can bring about something major. Thus, the original motivation for the study was to explore whether the theory and practice of systems intelligence would bring something more to trust and the sharing of information in disaster management organizations and to capabilities in organizations that use spatial information where the maturing process has slowed down or stopped. The majority of our experiences are from Finnish case studies, but the problems have been identified in multi-national experiments and contexts as well.

1.2 Structure of this dissertation

In addition to this summary, this dissertation comprises the six appended papers. The summary is organized as follows. The introductory section provides the background to the research and describes the key concepts, related research and objectives of the research. Section 2 introduces the scientific background and the interconnections between the key theories and the customized maturity model. Research methods and materials are introduced in Section 3. Section 4 summarizes the main findings of the research. Discussion about the results is provided in Section 5 and conclusions from the research in Section 6.

1.3 Disaster management

The diversity of disasters and collaboration in multi-organizational environment set challenges for disaster management operations. One of the core tasks of societies is to enhance their preparedness to manage both sudden local disasters and also events with geographically wider and temporally long-lasting effects. Both natural and man-made disasters seem to occur more and more often and they seem to be of a serious and complex character. Because of climate change, the world will be dramatically warmer by the end of the century. Storms and floods are increasing and sea levels are rising 60 percent faster than forecast (Rahmstorf et al., 2012, World Bank, 2012). Hundreds of millions of people live in low-lying areas and they can become refugees, which can lead to conflicts and crises. These extreme natural phenomena can also cause serious disturbances in the power supply, public utilities, and transport logistics. Because of urbanization and globalization the amount of traffic is constantly growing and the probability of major accidents on land, at sea, or in air traffic is increasing. International terrorism and the spread of all kinds of crimes add their additional effect to the unwanted events.

Disaster management operations are multi-organizational, multi-cultural, and multi-jurisdictional. For instance, in multi-national civilian crisis management operations a multi-cultural and multi-valued group of people from military, governmental, and non-governmental organizations collaborates in a common structure but the organizations follow their own processes and structures and the organizations as a whole cannot be commanded (Vesterinen, 2008). And the management of operations is governed by national and international legislation. A characteristic feature of disaster management operations is that the actors are distributed and have to make decisions and operate remotely (Perla et al., 2000, Virrantaus et al., 2009). In addition, the procedures are more and more based on self-organization and on self-synchronization. Hierarchies are flat and human agents have to act instead of just waiting for orders (Perla et al., 2000, Vesterinen, 2008).Thus, SSA is a vital prerequisite both for successful self-synchronization of actions and the coordination of the steps that are taken (Nofi, 2000). In SSA the question is about a comprehensive view of fragmented and distributed pieces of information and the use of efficient technical tools in collecting and sharing, as well as interpreting, the available data. Spatial information and GIS software allow the information which is critical in the disaster management processes to be integrated, analyzed, and visualized on a common ground. Therefore, strategies aiming at improving the role of spatial information in disaster management should focus on increased SSA.

1.4 Utilization of spatial information

The role of spatial information in the information society is significant. According to the European Commission, digital contents such as spatial data and digital services are the core of an information society (European Commission, 2007b). Spatial information is economically one of the most valuable areas of public sector information. In Europe it composes approximately one half of all public sector information (Dekkers et al., 2006, Pira International Ltd, 2000). Rajabifard (2010) calls a society spatially enabled when the public sector and private companies make widespread use of spatial information to improve their productivity and develop innovative solutions to tackle today’s global challenges, such as climate change, an aging population, and the financial crisis. The use and scope of spatial analyses (O'Sullivan and Unwin, 2003) will grow substantially as more and more spatial data become available (Daratech Inc., 2011).

Today better access to data is promoted by spatial data infrastructures (SDI) and open data policies. SDI is a infrastructure that enables the creation, sharing and use of spatial data. The Directive for establishing an Infrastructure for Spatial Information in the European Community (INSPIRE), for instance, obliges the Member States of the European Union to build national SDIs that offer network services to discover, evaluate fitness for purpose, and download spatial data sets held by public authorities (European Commission, 2007a). Recent studies demonstrate that the provision of public sector spatial data free of charge or at marginal cost at most speeds up companies’ sales growth and brings financial benefits to the public administration as well (Danish Enterprise and Construction Authority, 2010, Koski, 2011). Therefore, many European countries are increasingly opening public spatial data sets for free use to all potential users. One of the goals of the Finnish Government is for public digital contents such as spatial information to be widely used in society and so they promote innovation and research, the development of digital products and services, and the effectiveness and transparency of administration (Finnish Government, 2011). In addition to the official sources of spatial data, spatially referenced information from crowdsourcing and social media are used, for instance, in disaster management (McDougall, 2012).

Recent studies in Europe and the USA show that the benefits of more extensive and efficient use of spatial information can be considerable. For instance, the main benefits in local government are improved democracy, decision making, and productivity (Almirall et al., 2008, Mäkelä and Hilke, 2011). Web services and better visualization of plans and propositions engage more and more citizens in local decision making and make administration more transparent. Strategic and operational decision making is supported by Geographic Information Systems (GIS) applications which enable business information to be integrated and analyzed. One of the benefits of spatial information solutions is improved productivity, for instance, in transport and customer services (Coote and Smart, 2010). In addition to economic benefits, the improved efficiency of transport can have notable positive environmental impacts as a result of the reduction in the emissions of greenhouse gases. Present studies predict that the productivity gains in local government could even be doubled (Vickery, 2011) and in case studies both from private industry and the public administration benefit-cost ratios from 2:1 to 150:1 have been identified (Longhorn and Blakemore, 2008). According to Vickery (2011), better data access, data standards, and improved skills and knowledge could increase the benefits by 10-40%.

1.5 Key concepts

The key concepts that are related to disaster management and the utilization of spatial information, maturity, and systems intelligence are introduced in this chapter.

An *emergency* is “a threatening condition that requires urgent action” (UNISDR, 2009, p. 13) or “a serious, unexpected, and often dangerous situation requiring immediate action” (Oxford University Press, 2012). *Emergency management* involves plans and institutional arrangements that engage and guide agencies to respond to emergencies in a comprehensive and coordinated way. Without an effective response an emergency can descend into a disaster (UNISDR, 2009). According to the United Nations (UNISDR, 2009, p. 9), a *disaster* is “a serious disruption of the functioning of a community or a society involving widespread human, material, economic or environmental losses and impacts”. Disruptions may affect critical infrastructure such as the power supply, public utilities, and telecommunication or information systems. Disasters can result from natural hazards such as earthquakes, floods, lava flows, wildfires, and hurricanes. The Oxford Dictionary (Oxford University Press, 2012) defines a disaster as “a sudden accident or a natural catastrophe that causes great damage or loss of life”. In this research the concept of a disaster covers both natural and man-made disasters. Quarantelli (2000) makes a clear distinction between emergencies and disasters. Emergencies are everyday routine accidents, whereas in disasters, such as in an airline crash, organizations have to work with unfamiliar groups, adjust to losing part of their autonomy of action, apply different performance standards, and operate in public-private interfaces. *Civilian crisis management* can be defined as a joint activity between military forces, governmental organizations (such as the fire and rescue services), and non-governmental organizations (such as humanitarian aid organizations) to help the population in a crisis-affected area. The European Union defines civilian crisis management as “an outside intervention in a humanitarian crisis that is threatening or has taken place in a state, region or society as a result of a conflict, a disaster or an environmental catastrophe”. The interventions require both military and civilian organizations as actors and focus on “policing, civil protection, and on strengthening the rule of law as well as civilian administration in situations of crisis” (Ministry of the Interior, 2008). In this research emergency management, disaster management, and civilian crisis management comprise the response phase and preparedness exercises where collaboration and an effective response are practiced. *Safety* and *safety management* and *security* and *security management* are high-level concepts that include emergency management, disaster management, and crisis management. The concepts of safety and security have various definitions and they are sometimes used with the same meaning. Safety is a state, whereas security refers to the means that are needed to maintain safety. For example, safety in Finland is maintained when the vital functions of society are secured in all circumstances by coordinated measures between both the civilian and the military sectors (Alén et al., 2012, Ministry of Defence, 2012). The International Maritime Organization defines the objective of safety management as ensuring safety in the marine environment by preventing human injury or loss of life and avoiding damage to the environment and property (International Maritime Organization, 2013).

Comprehensive *emergency* or *disaster management* consists of four phases: mitigation, preparedness, response, and recovery (Cova, 1999). The *mitigation* phase focuses on risk assessment and vulnerability analysis. *Preparedness* aims to build the operational capabilities needed to manage disasters efficiently (UNISDR, 2009). The contingency plans of organizations and collaboration are tested in preparedness exercises. *Response* is “the provision of emergency services and public assistance during or immediately after a disaster in order to save lives, reduce health impacts, ensure public safety and meet the basic subsistence needs of the people affected” (UNISDR, 2009, p. 24). In Finland, the minimization of material damage in major accidents such as aviation accidents is an important task in the response phase as well. The goal of the *recovery* phase is to return life back to normal circumstances (Cova, 1999).

Bardach (1998, p. 17) defines *collaboration* between agencies as "any joint activity by two or more agencies that is intended to increase public value by working together rather than separately". According to Valtonen (2010, p. 25), *interagency collaboration* is a "set of joint activities among agencies or other actors obligated or authorized to cooperate towards common goals coordinated by a competent authority".

Situational awareness (SA) is a person's "perception of the elements in the environment within a volume of time and space, the comprehension of their meaning, and the projection of their status in the near future" (Endsley et al., 2003, p. 13). In disaster management operations the actors need to develop *shared situational awareness* (SSA), which is "the degree to which team members have the same SA on shared SA requirements". The development of SSA is supported by a *common situation picture*, also called a *common operation picture* (COP), which is a single identical display of relevant information shared by more than one actor (Joint Chiefs of Staff, 2001). The relevant information can be visualized on a situation picture map.

Spatial data is "any data with a direct or indirect reference to a specific location or geographical area". A *spatial data set* is "an identifiable collection of spatial data" (European Commission, 2007a, p. 5). *Spatial information* is spatial data that have been given a meaning in a certain context or processed from spatial data in order to be useful. Goodchild (2010) emphasizes that in addition to a link to a location on the Earth, geographic information (GI) can have a link to a point in time or a time interval. According to Longhorn and Blakemore (2008), GI is a combination of spatial data and attributes of things in two-, three-, or four-dimensional (x, y, z, time) reference systems. In the literature and in practice the concepts of geographical data, geographical information, geoinformation, geospatial data, spatial data, and spatial information are often used as synonyms. The *utilization* of spatial information is making practical and effective use of the information (Oxford University Press, 2012). A *Geographic Information System* (GIS) is a computerized tool for solving geographic problems (Longley et al., 2005) and it is used to capture, manage, analyze, or visualize spatial data.

Maturity is the degree to which a system has developed, as measured by some indicators (Simpson, 2012). A *maturity model* "represents phases of increasing quantitative or qualitative capability changes of a maturing element in order to assess its advances with respect to defined focus areas" (Kohlegger et al., 2009, p. 59). A maturity model usually contains five maturity levels and key areas, also called key components or focus areas, and their sub-areas over the five maturity levels (Kohlegger et al., 2009, Paulk et al., 1994).

Systems intelligence is "intelligent behavior in the context of complex systems involving interaction and feedback" (Hämäläinen and Saarinen, 2006, p. 3). The concept of systems intelligence was introduced by Professors Raimo P. Hämäläinen and Esa Saarinen in 2002 and the conceptual basis of systems intelligence is currently being developed by the Systems Intelligence Research Group at Aalto University in Finland (Systems Intelligence Research Group, 2013).

1.6 Related research

This chapter introduces recent studies from both application domains. Chapter 1.6.1 presents factors that have been found important in collaboration and creating SSA in disaster management organizations. Organizational elements that influence the use of spatial information and GIS are described in Chapter 1.6.2. Chapter 1.6.3 introduces maturity models that have been developed for disaster and crisis management organizations and for organizations that utilize spatial information and GIS. Finally, the benefits and weaknesses of maturity models are discussed.

1.6.1 Collaboration and development of SSA in disaster management

Valtonen (2010) explored in detail the concept of collaboration and the common criteria for the successful collaboration of security actors. The actors should be able to adapt their actions for the achievement of a common goal. The key focus on the development should be collaboration expertise and especially the processes that support information management and situation awareness. Valtonen (2010) found that successful collaboration between security actors is based on professional skills and the reliability of the actors, and that commitment, willingness to collaborate, and personal contacts are important factors at the individual level. Professional and interpersonal skills are emphasized by other researchers as well (Alberts and Hayes, 2007, Hof et al., 2010). The creation of trust has been highlighted as one of the key capabilities in collaboration because trust has a positive impact on communication, information sharing, and inter-organizational performance (Foulquier and Caron, 2010, Hof et al., 2010, Mishra, 1996, Virrantaus et al., 2009). Collaboration processes permit the efficient coordination of actions and sharing of information (Seppänen and Valtonen, 2008). For example, the

Finnish SAR processes consist of three sub-processes: the alarm, the firefighting and rescue, and the investigation and supporting services. The processes describe the main duties of each agency and the culmination points of the SAR operation. The SAR processes provide human agents a holistic understanding of the management of a disaster situation.

Response organizations must have a structure that enhances interoperability (Harrald, 2006). The collaboration structure impacts on the availability of information, information sharing, and decision making (Schraagen et al., 2010). Military and governmental organizations are traditionally hierarchical organizations. The decision making follows the chains of command and information is passed from the lower levels up to the top management, which makes the most important decisions. Network organizations are more common in public-private collaborations, and they need good coordination in order to perform well. A network organization has decentralized decision making and information is also exchanged horizontally between teams (Jones, 2004, Ödlund, 2010). Schraagen et al. (2010) studied information sharing during crisis management in hierarchical vs. network teams. They found that network teams are faster than hierarchical teams and a network structure enables information to be shared more quickly and mutual trust to be built. However, networking also creates complexity because of the various interests and relationships of the participating organizations (Virta, 2002).

Collaboration has several stages. Frey et al. (2006) aggregated different models that describe stages of collaboration into a seven-stage model. The collaboration starts from coexistence and develops through networking, cooperation, coordination, coalition, and collaboration to coadunation. Valtonen (2010) proposed that four stages, networking, coordination, cooperation, and collaboration, cover both the depth and the level of commitment of the collaboration of security actors well. The different stages of collaboration and their descriptions are also used as a basis for the development maturity levels in maturity models.

Development of SSA

Koskinen-Kannisto (2013) studied the development of SSA in maritime environments in the multinational experiments MNE5 and MNE6. She suggests that the following capabilities are needed in building SSA in multinational collaboration: a common process and structure that supports information sharing, working practices that support information sharing at the individual level, and capabilities that support identifying technical information-sharing problems and increase the awareness of technical information exchange. She highlights the point that technology itself is not valuable but its value is based on how it supports the activities and takes into account both organizational and social factors of collaboration.

Harrald and Jeffersson (2007) discuss how the military command and control model used in the Homeland Security National Response system impacts on the SSA of response organizations. In the model, the development of SSA is mainly based on the collection of all possible data, which is processed for decision makers, and on an information and communication technology structure that supports emergency managers in decision making. According to Semling and Rist (2012), SSA is a crucial performance indicator for civilian-military collaboration. They highlight the culture of collaboration and put less emphasis on detailed structures and procedures. However, coordination and a continuous flow of information are prerequisites for the creation of SSA. Semling and Rist (2012) suggest that a well-developed SSA depends on the degree of shared goals, coordinative actions, human agents' motivation to share information, and trust. In addition, social media should play a more important role in supporting the interaction processes between human agents.

1.6.2 Diffusion of GIS in organizations

The comprehensive utilization of GIS is also called diffusion of GIS or enterprise GIS or GIS maturity. In a diffusion process older technologies and practices are replaced by more advanced technologies and more efficient and beneficial ways of doing things. The diffusion of GIS is a multi-stage process whereby GIS is adopted and taken up by various user groups (Masser et al., 1996). The process has three phases: adoption, implementation and utilization. In the adoption phase, GIS and its merits are accepted in the organization. In the implementation phase the components of GIS are designed, purchased, installed, and operationalized (Somers, 1998), and in the utilization phase GIS is used in practical and effective ways. According to Masser et al. (1996), the diffusion of GIS has experienced the same organizational and technical bottlenecks as other information systems and earlier the utilization of GIS depended heavily on the limited availability of spatial data. Two elements of organizational cultures are important in the diffusion of GIS: the styles of bureaucracy and the approach to decision making. First, norms and values, routine practices, styles of leadership, and the staffing structure impact on an organization's capability to cope with change and adopt new practices. Second, the role of information and the contribution of spatial information in an organization's decision-making processes influence the use of GIS. Masser et al. (1996) emphasize that the implementation of GIS is a long process and changes to old practices are often regarded as threats. If problems arise, the organization may stop the diffusion process. This can be one reason why, for example public organizations in Finland have not been able to develop the better use of spatial information even if the technical infrastructure facilitates it. Scientific research into the factors that are today playing the key role in the comprehensive utilization of spatial data has not been conducted in Finland. Only some practical studies have explored the use of GIS in local and regional public organizations.

The term enterprise GIS (or corporate GIS) partly reflects the ideas of GIS maturity. Definitions of enterprise GIS emphasize, for example, the needs of organizational objectives instead of individual needs (Sipes, 2005), or, in the words of Wade and Sommer (2006, p. 69), "integration through an entire organization so that a large number of users can manage, share, and use spatial data and related information to address a variety of needs, including data creation, modification, visualization, analysis, and dissemination". However, it is not sufficient for an organization to have an enterprise agreement for software licenses or a web map portal; a more business-oriented touch is required. The use of spatial information has to be integrated into organizational workflows and support the attainment of the priorities of the organization.

According to Somers (1998), an organization must have a strategic vision of the role and scope of GIS in the organization. Other factors, which influence on the use of GIS, are the number of users, applications, and spatial databases and their distribution throughout the organization. In addition, the integration of GIS into business applications, and the operational structure of the organization, such as the autonomy of its business units impact on the use GIS. Employees must also be competent to use spatial information and spatial solutions. The competence levels suggested in the document Geographic Information Science and Technology: Body of Knowledge (DiBiase et al., 2006) could be applied at the organizational level as well. All the potential users of spatial information in the organization should be competent in the routine use of spatial information and GIS. In addition, some employees should have knowledge and skills in database management, spatial analysis, and computer programming. Even if the term GIS diffusion describes the process of the development of the comprehensive utilization of spatial information and spatial applications, in this dissertation the concept of GIS maturity is used because it covers both the maturing process and the evaluation model.

1.6.3 Maturity models and other evaluation models

A maturity model can be used to assess the current state of competence, to set a roadmap for organizational improvement, and to assess the effects of development. A maturity assessment identifies the strengths and weaknesses of the key capabilities of an organization and produces quantitative values as a result (Paulk et al., 1994). The Capability Maturity Model (CMM) introduced at Carnegie Mellon University in 1991 (Paulk et al., 1994) was one of the first maturity models and was developed to improve software development processes. Since then maturity models have been built up to help both private companies and public agencies to improve their abilities, for instance in project management, knowledge management, product development, risk management, or in the utilization of information technology or GIS (Alberts et al., 2010, Auer, 1994, Dalkir, 2005, Rezvani, 2008).

Maturity models for disaster management

Several maturity models have been developed for disaster and crisis management and the degree of shared information or shared awareness has been included as a measure in some of the models. The NATO Network Enabled Command and Control Maturity Model (N2C2M2) (Alberts et al., 2010) was developed for civilian-military peace-keeping operations and the Emergency Management Capability Maturity Model (EM-CMM) (Krill and Dzirio-Ayvaz, 2008) for global emergency management operations. Kuusisto (Kuusisto, 2008) combined his information exchange meta-model and the N2C2M2 in order to enable information exchange processes to be developed both in national and multi-national collaboration situations. Griffin et al. (2012) emphasize spatially enabled emergency management and they proposed a tool for evaluating the maturity of interoperability in a national network-centric environment. The Strategic Alliance Formative Assessment Rubric (SAFAR) (Gajda, 2004) supports the development of collaboration maturity in national Safe School/Healthy School Initiatives in the USA. The focus in these maturity models is on the capabilities that are required at each level of collaboration, such as positive personal relations and commitment (Alberts and Hayes, 2007, Gajda, 2004, Krill and Dzirio-Ayvaz, 2008), common processes (Alberts and Hayes, 2007, Griffin et al., 2012, Krill and Dzirio-Ayvaz, 2008), enabling technologies (Griffin et al., 2012, Krill and Dzirio-Ayvaz, 2008), and the sharing of information (Alberts and Hayes, 2007, Kuusisto, 2008).

The names of the maturity levels describe the stages of collaboration. The lowest maturity level is typically named “Conflicted” or “Ad hoc” and the focus is on individual organizations which do not interact or share information with other organizations. At the highest level, "Edge or Agile" or "Optimized" peer-to-peer interactions are rich and the degree of shared situational awareness and understanding is high (Alberts and Hayes, 2007, Griffin et al., 2012, Kuusisto, 2008). Alberts and Hayes (2007) describe the second level, "De-conflicted" as being where an organization can manage only situations where cause-and-effect relationships are generally well understood but not complex situations which involve changes and behaviors that cannot be predicted in detail. The organization must mature to the third "Coordinated" level in order to be able to manage complex situations. At this level some task-specific groups that have members from different organizations are possible and coordination processes and linked plans exist as well.

Civilian disaster management is based on the close coordination of actions because civilian organizations cannot be commanded in the way military organizations can. This has to be acknowledged when maturity models for civilian purposes are being developed. In addition, the models should not contain military terms but terms that are familiar to the civilian organizations (Virrantaus et al., 2009).

Some other formal methods exist for measuring the effectiveness of collaboration in disaster management. The Command Team Effectiveness model (CTEF) was developed to measure and improve team conditions, processes, and outcomes in military exercises and operations (Hof et al., 2010). The CTEF model has been applied during an International Operational Headquarters (IOH) exercise and during the international naval anti-piracy mission Operation Atlanta. The Situation Awareness Global Assessment Technique (SAGAT) is used to measure the level of the operator's situational awareness (Endsley, 2008a). SAGAT includes queries about the perception of data, comprehension of meaning, and projection of the new future, and it was used, for example, in Multinational Experiment 6 to measure situational awareness in a maritime environment.

GIS maturity models

GIS maturity models have been developed both for private companies and public organizations. Because GIS is a subset of IT maturity models for IT can be used as a framework for GIS maturity models. IT maturity models contain components such as competence, management, technology, and processes (Auer, 1994, Thinking Business Group, 2004). Usually, at the lowest levels of IT maturity models, the focus is on technology and the internal operations of an organization. At the highest levels, the focus is on business productivity and customers (Coriale, 2007). Auer (1994) states that even if strong management is emphasized in the maturity models, every individual's competence is essential when the organization wants to achieve the highest maturity levels. In the IT maturity models the first and lowest level is often called restrictive, initial, or non-aware (Coriale, 2007, Paulk et al., 1994, Thinking Business Group, 2004). When an organization matures, it can reach, if this is set as a target, the fifth and highest level, which is called optimized or innovative (Paulk et al., 1994, Coriale, 2007).

Mangan (2008) suggests that a maturity model for Enterprise GIS should evaluate the following core components: data architecture and management, accessibility to all potential users, integration into working processes and systems, proved return on investment, alignment with the company's strategic goals, and sustainability. The Local Agency GIS capability maturity model (GIS CMM) includes technical elements such as data and applications, policies, and institutional arrangements, which Babinsky (2009) calls enabling capabilities, and the competence of the staff to maximize the use of spatial data and applications are referred to as execution abilities. The Local GIS CMM emphasizes the importance of the GIS unit of an organization and the development of the competence of its staff. Conversely, for example in Finland, the employees have great influence and both responsibility for and freedom in their duties. Therefore, a GIS maturity model should emphasize the development of the GIS competence of all the employees of those branches that would clearly benefit from the use of spatial information. Each nation has its own cultural characteristics and these should be reflected in the corresponding maturity models. The corresponding names of the maturity levels of IT maturity models have been used in GIS maturity models as well (Babinsky, 2009, Lance, 2006, Rezvani, 2008).

Other approaches which are close to GIS maturity models are the multi-view frameworks that are used to assess the maturity of SDIs (Fernández et al., 2005, Grus et al., 2008, Longhorn, 2009, van Loenen and van Rij, 2008). They focus on the maturity of SDIs at the national or local level and provide useful tools for assessment. The idea of a these frameworks is that they can be flexible, permitting continual changes (Grus et al., 2008, van Loenen and van Rij, 2008). The basic components of SDIs incorporate human and financial resources, standards, technologies, data sets, and policies. The suitability of business management methods for the assessment of SDIs has been discussed in the research of Toomanian and Mansourian (2009). Balanced Scorecard (BSC), Activity-Based Costing (ABC), and Total Quality Management (TQM) were used to monitor an organization's performance against set financial and non-financial goals. BSC allows managers to evaluate the business and measure performance from financial, internal business, customer, and innovation and lerning perspectives (Kaplan and Norton, 1992). ABC is an accounting method that assigns indirect costs to products based on identified activities of the company and TQM is is a method to monitor and develop the quality of processes such as manufacturing processes of products (Toomanian and Mansourian, 2009). In these methods the financial measures seem to get greater attention than non-financial measures. However, Tooman and Mansourian (Toomanian and Mansourian, 2009) suggest that BCG could be a proper framework for the evaluation of SDIs.

Benefits and weaknesses of maturity models

One of the major benefits of maturity models is that they enable organizations to progress in a systematic and orderly way. Maturity models specify the evolutionary levels and visualize the issues that should be achieved in order to get to the next level (Dalkir, 2005). Maturity models have been criticized for not describing how to perform the required development activities effectively and it has been said that they are often inefficient for small and medium-sized companies (Mettler and Rehner, 2009). Another limitation is that maturity models often only represent a static view of an organization. Therefore, customizing is necessary in the development of maturity models. Kohlegger et al. (2009) and Mettler and Rehner (2009) have also stated that not much has been reported in the literature on how appropriate the assumptions are on which the maturity model is based and how to develop a maturity model. For this reason, the definition of the indicators and the structure and the development process of a maturity model should be described openly and in detail.

Interagency collaboration happens, on the one hand, on a very professional level and, on the other hand, on very human and sensitive levels. Also, in organizations that use spatial information employees' resistance to change is human and should not be trivialized. Thus, the evaluation method should be positive and encouraging. Maturity can be considered as a positive term and a maturity model is a forward-looking roadmap for organizational improvement. This is a contrast to the models used in business life, which tend to rather measure and visualize the unattained goals in a discouraging way.

1.7 Objectives and research questions

The main objective of the research is to customize a maturity model for the development of shared situational awareness in disaster management organizations and the comprehensive utilization of spatial information in public and private organizations. The following four research questions arose from the objective:

1. **What is the role of the systems intelligence of the human beings involved in the development of shared situational awareness and in the utilization of spatial information?**

   In organizations, the core competencies of people are the prerequisites for organizational operations. However, the human component in a successful utilization of information needs to be explored. Systems intelligence is an interesting approach when organizational maturity is being developed. It studies the system from the inside as a whole and emphasizes the potential of human behavior in understanding the complex dependencies among the subparts of the system. Understanding the system structure and seeing the "big picture", as well as the viewer's own role in the totality, lies at the core of systems intelligence. Systems intelligence can thus be a potential concept from which the measures of maturity can be derived and on which the development of the method can be based.

2. **Which indicators can be used to assess the development of shared situational awareness in interagency collaboration in disaster management? What kind of information about maturity do these indicators give in disaster management?**

   Situational awareness in disaster management needs to be accessed in an analytical and systematic way. SSA is not just one big black box, but is built on several factors which interact and thus are all required in a working system. The factors should be identified and their existence should somehow be measured in terms of quantitative values or at least values that can be ordered in a sequence. Although information and communication technology, such as tools for managing and displaying a common situation picture, is important in the creation of shared situational awareness, it was given only a minor part in this research. The disaster management organizations wanted to emphasize the role of other components than ICT in SSA.

3. **Which indicators can be used to assess the comprehensive utilization of spatial information in organizations? What kind of information do these indicators give about the maturity of the organizations?**

Most organizations would like to benefit more from their geographic information systems and from both internal and external spatial databases. However, they do not always know which subjects of development are worth investing in. Therefore, factors that enhance the comprehensive utilization of spatial information and spatial methods should be identified. A holistic approach to organizations' competencies is needed. Furthermore, the possibilities offered by NSDI and the latest achievements of research and development should be considered in the approach because they have seldom been put into full use in practice.

4. What should the content of a customized maturity model be and how should the model be developed and used in an organization?

A method for the development of a customized maturity model and for the maturity assessment is needed. The main factors of the model must be defined and a method for using the core model in a customized way is required. Customizing means that the core model is never applied as such but the circumstances and special goals of each case are taken into account. The main steps in the creation of the model need to be outlined.

2. Theoretical foundations

This chapter briefly introduces the scientific framework and the theories that are relevant to the development of a customized maturity model. Recent studies on collaboration (Alberts and Hayes, 2007, Foulquier and Caron, 2010, Hof et al., 2010, Valtonen, 2010) and organizational structures (Virta, 2002, Harrald, 2006, Schraagen et al., 2010, Ödlund, 2010) in disaster management and studies on the diffusion of GIS in organizations (Masser et al., 1996, Somers, 1998) give valuable information on elements that should be taken into consideration in this development.

The main purpose in the choice of the theories is to concentrate on areas that, on one hand, provide a basis for the research and, on the other hand, provide new insights into the application domains, and can, at their best, feed each other. An approach of this sort is supported by Drabek (2004), who emphasizes the variety of approaches and theories in the development of disaster management. Theories of shared situational awareness (Hunt, 1999, Nofi, 2000, Endsley, 2008a) and spatial data infrastructure (Rajabifard et al., 2003, Nebert, 2004, Masser, 2005) provide a basis and intoduce elements that need to be taken into account when SSA and the utilization of spatial information are being developed. Systems intelligence (Hämäläinen and Saarinen, 2006) and the capabilities of a learning organization (Senge, 2006) give new perspectives on systems in which a better understanding of human potential and new adaptive capabilities for change are needed. The importance of trust in disaster management has already been acknowledged in the earlier research. However, trust is not just an interpersonal issue but a multifaceted one and should be understood better in order to be developed. Figure 1 illustrates the above-mentioned theories and their core concepts and provides brief definitions.

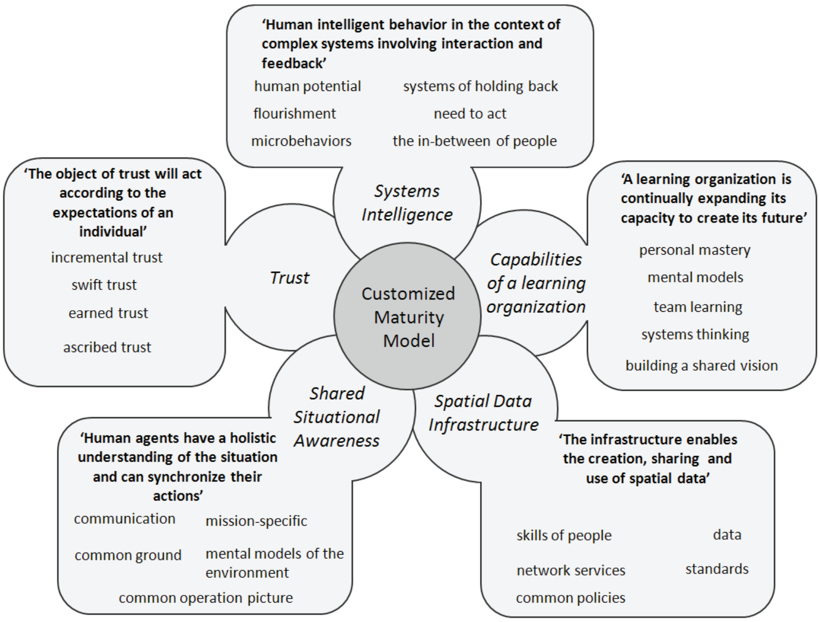

Figure 1. The interconnections between the key theories and the customized maturity model.

Other theories such as knowledge management (Bhatt, 2001, Sveiby, 2001), organizational learning (Easterby-Smith and Araujo, 1999), and complexity theory in organizations (Anderson, 1999) are referred to only briefly in this research. The subjects have been partly discussed in the context of recent studies in Chapter 1.6. Knowledge is meaningful information and it is managed through the interaction between people, technology, and techniques (Bhatt, 2001). Therefore technologies and social systems are equally important in knowledge management. Knowledge is dynamic and personal, and people use their capacity to act to create and share knowledge internally and externally to the organization (Sveiby, 2001). Seppänen et al. (2013) have studied knowledge sharing in social contexts in disaster management organizations and Mäkelä et al. (2010) have discussed knowledge sharing as a part of competence management in organizations that utilize spatial information. According to Easterby-Smith and Araujo (1999), the literature on organizational learning concentrates on organizations' internal processes, whereas the literature on learning organizations is more action-oriented. The latter point of view is also emphasized in this research. The complexity of an organization arises from the organization structure or/and from the surrounding environment (Anderson, 1999). An organization can have a complex structure with several hierarchical levels or departments across the organization or the organization can be geographically distributed (Daft, 1992). In a complex environment an organization has to deal simultaneously with different elements of the environment (Anderson, 1999).

2.1 Systems intelligence

Systems intelligence is a valuable concept for exploring human behavior in complex environments and when actions for change are needed. Systems intelligence extends systems thinking by combining insights from many disciplines, such as action research, positive psychology, positive organizational scholarship, and philosophy (Hämäläinen and Saarinen, 2007).

A system "is a complex whole the functioning of which depends on its parts and the interaction between those parts" (Jackson, 2007, p. 3) and systems thinking is "a discipline for seeing wholes" (Senge, 2006, p. 68). The core idea of systems thinking is that the only way to fully understand and solve a problem is to understand a part in relation to the whole and the effect of the whole on the part. Systems thinking is a conceptual framework, a body of tools that makes the full patterns clearer and helps us to see how to change the patterns effectively. While systems thinking takes a holistic, rational, and external point of view on a system, systems intelligence concentrates on exploring human behavior and interaction from inside the system. From the systems intelligence point of view the ability to see oneself and one's active role in the system, also through the eyes of other stakeholders with different framings of the system, is crucial (Hämäläinen and Saarinen, 2006).

A systems intelligent human being is aware of how his/her own actions influence the whole and how the whole influences him/her. The basic idea of systems intelligence is that small changes in the system can transform into something major. The focus is, on the one hand, on what human beings do right and, on the other hand, on what they could improve in the system (Hämäläinen and Saarinen, 2006). The main aim is to generate positive changes in the system. A systems intelligent organization fosters positivity, inquiry mode, and behaviors that refer to others and reduces negativity, advocacy mode, and self-referring behaviors (Hämäläinen and Saarinen, 2007).

The terms used in systems intelligence can be used to identify and describe human behaviors and systemic structures and their mutual dependencies. Examples of these terms are 'systems of holding back', 'unused possibilities', 'optimism for change', 'the need to act', 'microbehaviors', 'human potential', 'scope to act', 'thinking on the fly', 'the in-between of people', 'systems of mutual support', and 'flourishment'. Systems intelligence is a key competence of a human being. We always have a possibility to act in a more systems intelligent way as we become conscious of the impact of our behavior on the system in which we operate (Hämäläinen and Saarinen, 2007).

2.2 Shared situational awareness

One of the main concepts in disaster management is situational awareness (SA), which can be defined as a dynamic mental model of the environment (Nofi, 2000). It is a result of how an individual perceives and understands events in his/her environment ("What is going on in my environment?") and includes mental projections of possible ways in which the environment can change ("What could happen next?"), as well as the individual's response to these changes ("What options do I have for action?"). Each member of each group acting in any disaster management mission has his/her own individual situational awareness, as each of us constantly develops our own respective mental model of the environment. This model is based not only on observed facts, but also on the individual's skills, experience, culture, and background. Furthermore, it is mission-specific and changes over time.

Goals direct the development of SA in disaster management operations. On the basis of the goal, a human agent seeks and inquiries information that is relevant for the achievement of the goal (Endsley, 2008a). At the same time he/she also interprets other available information and makes decisions about whether new goals need to be set. Technology cannot provide SA but information systems enable the information that has been collected to be analyzed and displayed in a situation picture. In reality, the concepts SA and situation picture are sometimes used as synonyms. In sum, a human agent's SA is the integration and interpretation of several information sources, such as the situation picture, other human agents and the environment (Endsley, 2008b). According to Endsley (2008b), there is no threshold of SA that can guarantee a given level of performance. Therefore relative comparisons should be made when the development of SA is evaluated. SA supports a human agent's decision making and as the level of his/her SA increases, the probability of making good decisions and performing well increases.

Shared situational awareness (SSA) occurs when the actors in the disaster management have a holistic understanding of the situation and can synchronize their actions (Nofi, 2000). In order to develop SSA human agents have to share their mental models by the effective communication of each person's perception of the situation to the other agents. Thus, communication is the most critical issue in creating SSA (Nofi, 2000). To be able to successfully share these unique mental models into one single group mental model, it is necessary to find a common frame of reference or common ground, which is a core collection of common concepts and views (Hunt, 1999) (Figure 2). The quality of the shared situation awareness as a common mental model depends on how effectively this common understanding can be created.

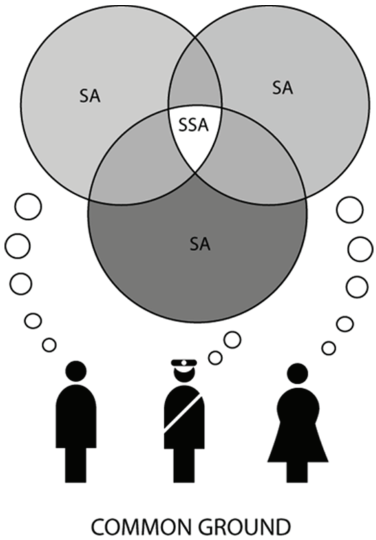

Figure 2. Development of shared situational awareness (SSA) from individual situational awarenesses (SA) (adapted from Paper I).

2.3 Trust

The definition of trust varies in social sciences, in economics, in philosophy, and in management theories (Lane, 1998). In organizational theory the concept of trust is multidimensional and can be studied from different points of view: as individual expectations, in interpersonal relations, in interorganizational relations, and in social structures (Hosmer, 1995).

Only individuals can trust, but individuals, teams, technology, and both technical and social systems such as interorganizational networks can be objects of trust (Blomqvist, 2002, Sydow, 1998). Trust is a belief that the object of trust will act according to the expectations of the individual (Cummings and Bromiley, 1996, Hosmer, 1995). Thus, trust is based on personal perceptions and experience. Moreover, trust is not a static mental condition but task-specific, situation-specific, and context-specific

(Blomqvist, 2002). An individual can also trust another individual because he/she is a representative of a certain profession and acts according to his/her professional role. Barber (1983) calls the latter technically competent role performance, which is emphasized in task-oriented social systems. Harrè (2001) discusses ‘ascribed trust’ and ‘earned trust’. Ascribed trust is a pre-given property of a person and earned trust is based on the experience of the actions and behavior of another person.

In interpersonal relations, “the trusting person expects helpful and cooperative behavior from the other” (Meeker, 1983, p.231). Competence, openness, and accurate information are communication factors that affect human perceptions of trustworthiness (Hosmer, 1995, Mishra, 1996, Shockley-Zalabak et al., 2000, Ödlund, 2010). In contrast to this Luhmann (1995) does not define trust as being based on the communication of information but, conversely, states that shared information is an indicator of interpersonal trust. Further, according to Luhmann (1995), an individual who creates trust broadens his/her scope for action.

Interorganizational trust is “the confidence of an organization in the reliability of another organization, regarding a given set of outcomes or events” (Sydow, 1998, p. 35). Organizations that trust each other can balance mutual requirements. They are, for example, able to focus on information that is relevant to the disaster management process (Foulquier and Caron, 2010). Common processes (Zucker, 1986) and technical interoperability (Harrald, 2006) can be regarded as mechanisms that contribute to interorganizational trust. Common processes enhance awareness and the predictability of the future actions of different actors. Information technology is one critical factor for the effectiveness of a disaster management organization because it facilitates the internal and external communication of teams, information management, and both applications and analytical tools to manage disaster situations (Mathieu et al., 2001).

Luhmann (1979) introduced the concept of ‘system trust’, which is built up and attained by continuous positive experiences with using a system. This definition and the idea that a system can be both an object of trust and its source was used in this research to study the role of trust in disaster management organizations.

The constitution of trust can be intentional creation or emergent development (Sydow, 1998). “Trust needs time and shared experience to grow” (Ödlund, 2010, p. 104). This kind of incremental trust is often called traditional trust (Blomqvist, 2002). Typical features of traditional trust are a common history, shared values, predictable behavior, and good competence. Meyerson et al. (1996) state that trust does not need incremental development and therefore they introduced the concept of swift trust. Swift trust is needed in temporary groups when there is no time for traditional trust-building activities. “Swift trust may be a by-product of a highly active, proactive, enthusiastic, generative style of action” (Meyerson et al., 1996, p.180). Swift trust is trust in a human being’s “faithful enactment of his critical role” (Meyerson et al., 1996, p. 190). Sydow (1998) also emphasizes that trust is mainly produced via action. Actually, the actions that produce swift trust could also be described as systems intelligent behavior.

2.4 Spatial data infrastructure

The components and interoperability of SDIs are mainly discussed and evaluated at the national, regional, and global levels. However, they form the basis for the development of SDIs at the organizational level as well. Spatial data infrastructure (SDI) is a collection of technologies, policies, and institutional arrangements that facilitate the availability of spatial data and access to them (Nebert, 2004) and the exchange and sharing of spatial data between different stakeholders (Masser, 2005). Stakeholders represent all levels of government, the commercial sector, the non-profit sector, academia, and citizens (GSDI Association, 2009).The main objective when developing SDIs is to provide easy access to spatial data that can be used in spatial analysis to improve economic, social, and environmental decision making from the organizational to global levels (Rajabifard et al., 2003).

The core components of an SDI are data, access network, policy, standards, and people. Access networks, standards, and policies, such as the licensing and pricing principles of spatial data sets, are means by which spatial data sets are made accessible to potential users (Rajabifard et al., 2003). The access networks should also include helpful services for users. Therefore, for example, the INSPIRE Directive instructs that national SDIs should be based on interoperable network services that enable spatial data to be discovered, transformed, viewed, and downloaded (European Commission, 2007a). Standards, such as data quality standards, are essential for the interoperability of both spatial data sets and network services (Smith and Kealy, 2003). The success of SDIs is based on people and their skills of developing the technical infrastructure and also using and adding value to spatial data. Kok and van Loenen (2005) state that often less attention is paid to the organizational aspects of an SDI, such as the institutional framework, human resources, and policy, or they are described as a stable factor. However, organizational components are relevant in the development of a mature and sustainable SDI and the four critical components are: leadership, a vision, communication channels, and the ability of the spatial information community for self-organization.

SDIs build up from an organizational level to national and global ones, as presented in the hierarchical model of SDIs presented by Rajabifard et al. (2003). In this model, national spatial data infrastructures (NSDI) presume the development of organizational SDIs because spatial data sets from organizations form the basis for upper-level data supply, and, vice versa, an NSDI facilitates the development of organizations' SDIs. This necessitates close interaction and collaboration between all the authorities and organizations that participate in the development of SDIs (Rajabifard et al., 2003).

2.5 Capabilities of a learning organization

Organizations that know how to foster people's commitment and capacity to learn at all organizational levels will succeed (Senge, 2006). In a learning organization people expand their capabilities to achieve the goals and results they wish to attain. According to Senge (2006), the five core capabilities of a learning organization are systems thinking, personal mastery, mental models, building a shared vision, and team learning. Systems thinking is the ability to see the "big picture' instead of a snapshot of the separate parts of a system. Personal mastery and mental models guide our energies and actions. Personal mastery is continual clarification of our personal vision and focusing our capacities on the desired actions we consider desirable. The organization's capacity for learning cannot be greater than that of the individuals in it. Mental models are pictures of how we see and realize the world around us and how we take the actions we do. When an organization is building a shared vision it has to foster people's commitment to shared goals, values, and missions. According to Senge (2006), possible attitudes toward a common goal are commitment, enrolment, and compliance. A committed person feels "fully responsible for making the common goal happen". He/she even creates "new laws" when needed. A committed person "brings energy and passion" to the collaboration. An enrolled person wants the common goals to be realized. He/she puts his/her energy into the operation but follows the laws. A compliant person supports common goals and does what is expected of him/her. Team learning is proactive interaction and thinking together and therefore, patterns of interaction that dilute team learning must be recognized and changed. Senge (2006) emphasizes that an organization should develop the five core disciplines as a unity. Systems intelligence theory and practice rely, among other things, on these disciplines.

Finger and Brand (1999) argue that the concept of a learning organization focuses mainly on the organization's culture. It emphasizes both individual and collective learning at all organizational levels, but does not connect learning processes very well to strategic goals. They also point out that it is not possible to change a bureaucratic organization by concentrating only on learning initiatives. However, people can accept changes more easily when their capabilities of learning are emphasized.

3. Research methods and materials

The main research strategy was to use case studies in the development of the new method. Interviews, questionnaires, observation, and discussions were used to collect quantitative and qualitative data both from the national and multi-national disaster management exercises and the organizations that use spatial information for the definition of indicators. The maturity models that were developed were tested in national SAR and ICT exercises and in public and private organizations that actively utilize spatial information. Table 1 summarizes the six published papers with the research questions, the research methods, and the scopes of these papers.

Table 1. Summary of appended papers

Paper	**Research questions**	**Research methods**	**Scope**
Paper I Supporting the development of shared situational awareness for civilian crisis management with Geographic Information Science – research plan	1	State-of-the-art paper	Disaster management SSA Trust Multi-national
Paper II Developing Shared Situational Awareness for Emergency Management	1 2	Case study Literature study Observation Categorizing factors of SSA	Disaster management SSA Role of a human agent System trust National
Paper III Aspects of a Licensing and Pricing Model for a Multi-Producer pan-European Data Product	1	Case study Literature study Interview Questionnaire	Commercial utilization of a spatial data product System approach Multi-national
Paper IV Competence management within organizations as an approach to enhancing GIS maturity	1 3	Survey Literature study Interview Questionnaire	Utilization of spatial data GIS maturity Organizational
Paper V Model for Assessing GIS Maturity of Organizations	3 4	Case study Discussions Categorizing factors of GIS maturity Questionnaire SWOT analysis Sensitivity analysis	GIS maturity model Maturity assessment Maturity model evaluation Organizational
Paper VI A Customizable Maturity Model for Assessing Collaboration in Disaster Management	2 4	Case study Literature study Interview Questionnaire	Disaster management Maturity model for SSA Quick maturity assessment National

Paper I gives an overview of the field of research and describes the state of the art. Paper I reviews the theory of situational awareness and the research challenges for building shared situational awareness. The importance of trust in multi-national crisis management and the consequences of a lack of trust are discussed on the basis of observations and the literature with reference to Multi-national Experiment 5 and the Barents Rescue SAR exercise. A preliminary framework of the collaboration processes was drafted before the exercise by the researchers of Helsinki University of Technology, later Aalto University. During the exercise, the framework was used to record all the temporal stages of the actions of different actors.

Paper II introduces the previous research conducted in Finnish SAR exercises during 2007-2008 and aggregates the main factors that hamper human agents or help them in achieving an adequate shared situational awareness. Paper II also reviews the theories and concepts of systems thinking, systems intelligence, and trust, and outlines the capabilities of human beings to collaborate on the basis of these concepts and on experimental data. Qualitative experimental data on systems intelligent behaviors were obtained by observing human agents and recording the activities in the Command Centre of Regional Rescue Services (CCRRS) in the SAR 2009 exercise and by collecting feedback from the participants after the exercise. A formal data sheet was used for the data collection and it included separate columns for the following issues: event/information, time, channel, from whom, to whom, how it was published, what actions the event triggered, and additional info. For each event, the above-mentioned eight issues were recorded. As a result the components of system trust and the role layers of a human agent were drafted.

Paper III describes a systemic approach to the development of a practical and acceptable pricing and licensing model for EuroDEM. EuroDEM is a pan-European geographic data product that has been produced and is owned by National Mapping Agencies (NMCA). The paper reviews the theory of a value chain and the European Union's Information Policies in order to identify the commercial rules and legal obligations that guide the collaboration. Experimental information about the collaborative actions that facilitate the better utilization of EuroDEM was collected through questionnaires from the NMCAs and through interviews with existing and potential customers. A formal questionnaire was sent by email to fourteen NMCAs that were members of the Business Interest Group of EuroGeographics. Seven members, representing Belgium, Denmark, France, Finland, Germany, Malta, and Switzerland, answered questions that dealt with the commercial use of EuroDEM. They described their visions and viewpoints with regard to the most probable customers of

EuroDEM in the near future, new technical ways of distributing geoinformation, and revenue development from EuroDEM sales. Directors and managers from four international commercial companies and one international organization were interviewed in order to get detailed information about their business plans and needs in relation to EuroDEM. The companies that were interviewed represented different areas of business, such as map publishing, IT and business services, products and services for risk management, and the distribution of remote sensing-based products and services. The market areas of these companies varied from global to only some European countries.

Paper IV introduces the concept and scales of GIS maturity on the basis of the literature. The paper explores factors which impede or enhance the comprehensive utilization of spatial data by organizations. The identification of the factors is based on the literature and on a survey which included in-depth interviews with managers and experts from nine public organizations. The interviewees represented organizations such as a small municipality, a medium-sized town, a ministry, a regional environment centre, the traffic sector, a large university, and a government agency. In addition, the interviewees estimated the maturity of their organizations on the basis of the GIS maturity scale. The managers and experts were easily able to position their organization on the right maturity level. The results of the survey justified further research on the GIS maturity of organizations. The paper also considers how systems intelligent behavior appears in the utilization of spatial information.

Papers V and VI concentrate on the methodological challenges of maturity assessment. They describe how the theoretical and experimental results of Articles I-IV are implemented as a process: the development of the maturity model, the maturity assessment, and the presentation of the results.

Paper V focuses on a general GIS maturity model that was developed in the SDI utilization working group of the Finnish National Inspire Network. The members of the working group represented organizations such as the cities of Helsinki, Espoo, Vantaa, Tampere, Turku, Hyvinkää, and Naantali, the Finnish Transport Agency, Geological Survey of Finland, Finnish Environment Institute, Ministry of the Interior, National Consumer Research Centre, CSC – IT Centre for Science, National Land Survey of Finland, and Aalto University. The author of this dissertation acted as the chair of the working group. The working group organized an open GIS maturity workshop and open meetings where the content of the model was drafted and discussed, and carried out a survey which studied the current status of spatial data utilization in the public administration in Finland. The eighty-six organizations that took part in the survey listed success factors that enable or would enable spatial information to be utilized comprehensively in their organizations. Three large cities, a state institute, and a private company evaluated the new GIS maturity model and the maturity assessment process. They assessed their GIS maturities and reported the quantitative maturity values in a formal and structured questionnaire. SWOT analyses were used to verify the results of the maturity assessments.

Paper VI describes the development processes of the two customized maturity models and quick maturity assessments of disaster management organizations in the SAR 2010 exercise, where a temporary SAR organization was established to manage an aviation accident, and in a large national ICT exercise where preparedness for disturbances in information systems and networks was trained. In both cases, a literature study on international maturity models that have been developed for crisis management and emergency management operations, the results from Articles II and V, the goals of the exercises, and interviews were used to create the content of the maturity models, formal and structured questionnaires to collect quantitative data during the exercises, and graphical presentation to report the results of the maturity assessments. In the one-day SAR exercise the data for the maturity assessment were collected at the end of the day. A total of 35 human agents – 16 from the CCRRS, 15 from the Command Body of Supporting Services (CBSS), and four from the Command Body of the Area of Operation (CBAO) – answered a questionnaire in which they assessed the maturity level of each sub-area. For each sub-area is a mean maturity was calculated from the single maturity values given by the human agents. For the data analysis, each respondent filled out a form dealing with background information such as the field of operation, the command body during the exercise, and his/her role in the command body. In the two-day ICT exercise the steering and evaluation group conducted a maturity pre-assessment before the exercise and the participants assessed the maturity of cooperation twice: late in the first day and at the end of the second day. The numbers of respondents varied between four and ten. For each sub-area the participants chose the maturity level which, from their perspective, was reflected in what happened in the exercise. The respondents filled in background information, such as their organizations and their roles in the exercise – top management, middle management, or expert – as well. Thus the data that were collected could be analyzed on the basis of organizations, administrative areas of ministries, or roles.

Papers I, II, III, and IV answer the first research question, Papers II and VI the second research question, Papers IV and V the third research question, and Papers V and VI the fourth research question.

4. Research results

This chapter summarizes the main results of the appended papers. The first research question, the role of systems intelligence in maturity, is answered in Chapter 4.1. Chapters 4.2.1 and 4.3.1 answer the second research question by presenting the indicators of SSA for situation-aware disaster management organizations and information about the maturities of two disaster management organizations revealed by the indicators. Chapters 4.2.2 and 4.3.2 answer the third research question by presenting the indicators for a spatially aware organization and information about the maturities of five organizations that use spatial information proposed by the indicators. The results with regard to the process for the development and use of a customized maturity model are summarized in Chapter 4.2.3.

4.1 Role of systems intelligence in maturity

This chapter outlines the meaning of systems intelligent behavior in human agents' roles and the components that seem to be relevant when trust is created. These were studied in the context of disaster management. Some examples of systems intelligent behavior from the case studies are presented as well.

4.1.1 Role layers of a human agent

Paper II identified that in addition to core professional skills, a human agent should possess abilities that promote interagency collaboration. Figure 3 presents the three role layers of a human agent that are essential in disaster management.

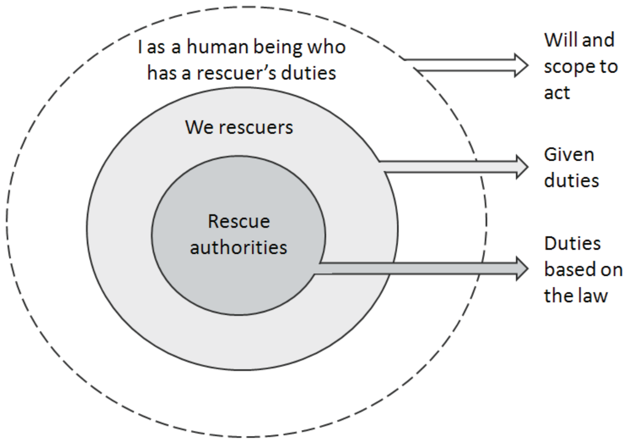

Figure 3. The three role layers of a human agent – a rescuer as an example (adapted from Paper II).

The first and innermost layer describes the core duties of rescue authorities, which are based on the law. The second or middle layer is task-specific and covers duties that depend on the type and the location of the disaster. These two inner layers are professional role layers in which the role behavior is mostly based on the human agent's training and experience and predefined duties that have to be performed. The third and outermost layer embodies a human agent's personal will and commitment to the collaboration and his/her readiness to use the scope he/she devotes to realizing the common goals. This framework of the role layers was one of the key results of this research. The framework is based on the Finnish legislation and regulations on rescue administration and services and on Senge's principles for building a shared vision. It demonstrates that core professional skills form the basis of all disaster management activities and that the systems intelligent behavior of human agents is a prerequisite for successful collaboration. Therefore, a person's will and proactive behavior regarding the success of a system was chosen as one of the key abilities in the development of SSA, and can be used as an indicator in the assessment of maturity. This ability should be evaluated and developed systematically in disaster management organizations.

4.1.2 Components of system trust

The framework of system trust is based on the theories of trust and Luhmann's definition (Luhmann, 1979) that system trust is built up by positive experiences with using the system. The framework also takes into consideration the components of collaboration, such as common processes, that have been identified as essential in the SAR organization. The suggestion that system trust is build both on given trust and deserved trust originates from the research of Harrè (2001), who has defined that trust can be a pre-given or earned property. Figure 4 illustrates the components that promote the creation of trust in an SAR organization.

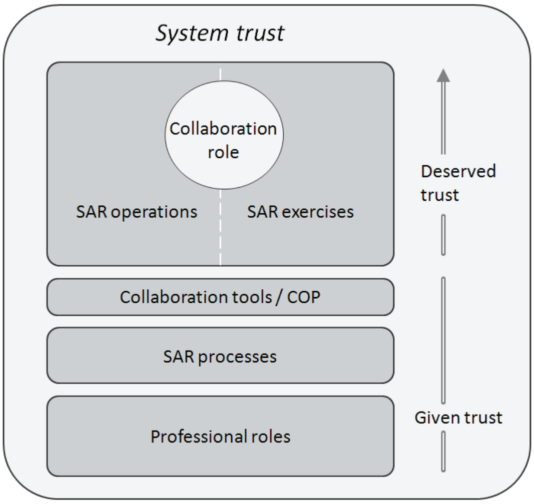

Figure 4. The components of system trust (adapted from Paper II).

Paper II introduces system trust as a whole which comprises the components of given trust and deserved trust. The given trust is formed from the core professional skills of human agents, common processes, and the availability of reliable interoperable collaboration tools that facilitate the creation of a common operation picture. Deserved trust is created in social interaction and is achieved through systems intelligent behavior. This corresponds to the human agent's personal will and commitment to the collaboration, the outermost role layer of a human agent. Given trust creates the basis for interorganizational trust in collaboration, and situation-specific deserved trust facilitates open communication and the sharing of critical information between human agents. The components of system trust can be used as a basis for the definition of the trust-based indicators of the development of SSA.

4.1.3 Systems intelligent behavior in the case studies

In this study it was discovered that systems intelligent behavior is a key human ability both in disaster management organizations and in organizations that use spatial information. The case studies highlighted, on the one hand, examples of systems intelligent behavior that promote the flourishing of the organization and, on the other hand, examples of collaboration where systems intelligence has not yet emerged. One essential part of disaster management is communications to the media and public, and press briefings have to be practiced as well. The success of the disaster management organization is, among other things, evaluated on the basis of the rate and relevance of information about the disaster and its management and the consistency of the communications of the actors. Paper II describes how the agent who coordinated the press briefing ensured personally that each responsible agent had the best possible SA in his/her own field and the agents together were able to act as an SAR organization in front of the media.

Political champions and role models are a prerequisite for spatially enabled organizations. Paper V describes how the city mayor's genuine interest in the possibilities offered by spatial information in City3 and his personal commitment to the development of the use of spatial information has facilitated the change of unused possibilities into organization-wide competencies to utilize spatial information. Paper V also describes how the GIS maturity assessment process in an organization can act at its best as a systems intelligent intervention. In City2, the maturity assessment process enabled organization-wide discussions to take place about the possibilities and benefits of spatial information, even with top management. According to the coordinator, the process may even commit the managers to the future development of competence.

In contrast to the above encouraging case examples, Paper III describes the difficulties that exist in multi-national collaboration even if National Mapping and Cadastral Agencies (NMCAs) have the will to collaborate. The NMCAs that own EuroDEM, a digital representation of the ground surface topography of Europe, have a shared vision of the significance and success of the product in the commercial market for example in the military and insurance sectors. They have had the will to harmonize their national digital elevation models (DEM) and produce a unified geographic information product for the European market. The ownership and decision making of EuroDEM is decentralized and therefore all the owners must accept changes to the current pricing and licensing principles. The real commercialization of EuroDEM needs more user-friendly pricing and licensing models and therefore better commitment to the shared vision and even political champions from all the NMCAs are required.

4.2 A customized maturity model

Two customized maturity models were developed for disaster management organizations, and the models were used and evaluated in the SAR and ICT exercises. These are explained in Chapter 4.2.1. The third customized maturity model, the GIS maturity model was developed for and evaluated by organizations that use spatial information. The content of the GIS maturity model is explained in Chapter 4.2.2. The customized maturity models are built on the essential key areas and indicators, also called subareas. As the final result, a generic process for developing and using a customized maturity model was defined.

4.2.1 Indicators of a situation-aware disaster management organization

Indicators in the SAR maturity model
Paper II aggregates and categorizes the factors of SSA identified during the SAR exercises during 2007-2008. These factors were recognized as being the ones that should be developed in this research. The factors are: 1) the accessibility of the required information, 2) open communication, and 3) the creation of trust. The awareness of these factors, the objectives of the exercise, and a literature review on maturity models and collaboration in disaster and crisis management directed the definition of the indicators of the maturity model developed for the SAR 2010 exercise. Paper VI introduces the six key areas of the SAR maturity model and the indicators of one key area: common ground and tools. The indicators of the five other key areas are complemented here by the unpublished analysis report of the SAR2010 exercise (Seppänen et al., 2011). The six key areas and their indicators are listed below.

1. *Roles and structures*
    - Clarity and functionality of actors' roles
    - Speed of formation of an SAR organization
2. *Processes and practices*
    - Level of collaboration processes
    - Actors' courses of action to support collaboration
3. *Common ground and tools*
    - Information requirements
    - Availability of information between actors
    - Communication tools and application in use
    - Creation of common situation picture

- Information system that supports the creation and maintenance of SSA

4. *Communication and interaction*
   - Communication of critical information to other actors
   - Interaction between human agents to increase trust
   - Communications to the media
5. *Competence*
   - Competence to use communication and other tools
   - Team's internal competence to collaborate
   - Team's competence to collaborate with other teams
6. *General goal*
   - Specification and clarity of the goals of collaboration
   - Actors' vision of the SAR exercise
   - Management's support for the exercise

Figure 5 illustrates the indicators of a situation-aware disaster management organization. The indicators of role competence are visualized by dotted lines and the indicators of system trust are visualized by dashed lines.

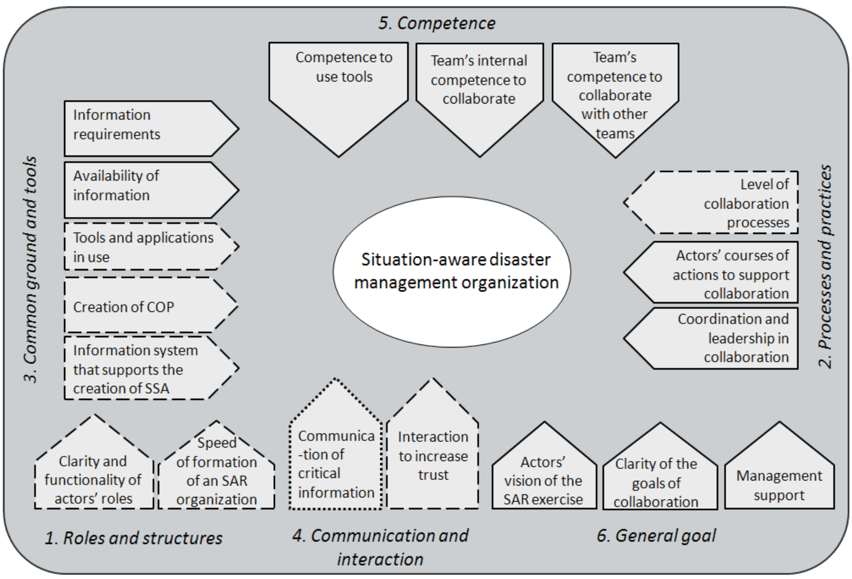

Figure 5. Key areas and indicators of a situation-aware disaster management organization.

Indicators in the ICT maturity model

Paper VI describes how the key areas and indicators of the ICT maturity model are based on the main goals and principles of the Security Strategy for Society, which underlines a comprehensive and intersectoral approach to disaster management. One of the main goals of the Strategy is the existence of appropriate situation picture systems that support the relevant and rapid situation awareness of decision makers at national, regional, and local levels. In addition to the strategic goals, both the public and private organizations that played the main roles in the ICT exercise highlighted capabilities that, from their point of view, were critical in the intersectoral collaboration. They emphasized the sharing of information, interaction between organizations, and the agility of organizations as critical success factors. Social media were also recognized as an important data source. In conclusion, the indicators of the key area *creation of situational awareness* are listed below.

- Definition and communication of information requirements between administrative sectors
- Definition and communication of information requirements between authorities and the private sector
- Coordination of the compilation of a situation picture
- Utilization of social media
- Timely sharing of information
- Coverage of shared information
- Interaction between people to increase trust
- Human agents' will to develop a comprehensive SA
- Prerequisites of organizations to develop a comprehensive SA
- Collection, analysis, and sharing of information

The indicators highlight the definition and communication of information requirements between the public and private sectors and actions to share information and increase trust. In the ICT exercise the role of information systems received minor attention but it is partly included in the indicator prerequisites of organizations. Figure 6 illustrates the indicators for the creation of situational awareness. The indicators of role competence are visualized by dotted lines and the indicators of system trust are visualized by dashed lines.

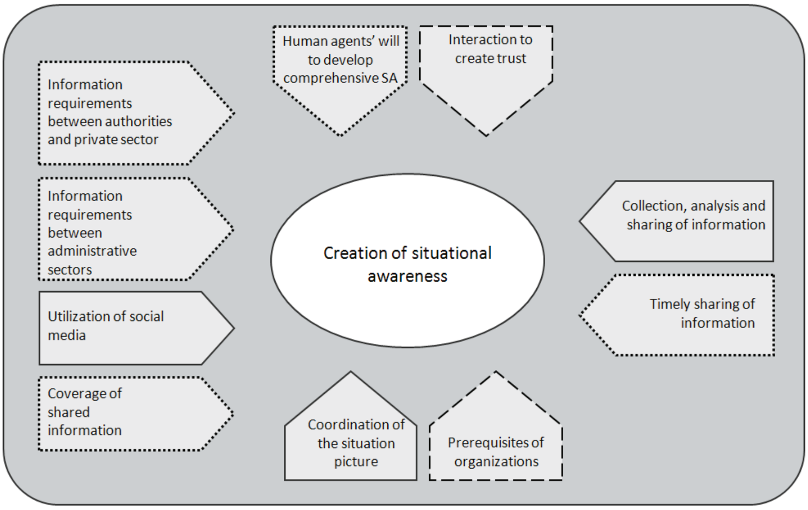

Figure 6. Indicators of the key area *creation of situational awareness* in the ICT maturity model.

4.2.2 Indicators of a spatially enabled organization

In Paper IV there is discussion about the role and importance of a GIS maturity model in the enhancement of the comprehensive utilization of spatial data. When the model takes into account aspects of human competence, as well as the technical infrastructure, working processes, and relationships with customers and stakeholders, it also supports the setting of the strategic goals of competence management in the organization. Aspects that should be included into a GIS maturity model and are not covered in the existing models were identified. The implementation of the strategy, communication of the possibilities of spatial data, and the level of commitment of people in an organization are important in the development of the utilization of spatial information. Paper V describes how the SDI utilization working group of the Finnish Inspire Network was involved in the specification of the indicators. The studies emphasized that the model should take into account the four viewpoints of an integrated information systems architecture: the functional entity of information, information systems, technology and business processes. The integrated information systems architecture is used to direct the planning of processes and information systems and it enhances the interoperability between the organization's internal SDI and business solutions, as well as external eGovernment services such as network services of an NSDI. Furthermore, the studies revealed that the success factors which really ensure the comprehensive utilization of spatial information in organizations are leadership and organizational culture, including the commitment of management, the motivation and competence of staff, the improvement of communication, and coordination. In conclusion, the fifteen indicators that are essential in the assessment of GIS maturity and their grouping into three key areas are listed below.

1. *Architectures*
    - Acquisition and management of spatial data sets
    - Discovery and evaluation of fitness for use of spatial data sets
    - Accessibility of spatial data sets
    - GIS software and applications
    - Technologies that support the use of spatial data
2. *Services and processes*
    - Spatial data in customer services and solutions
    - Spatial data in internal core processes
    - Spatial data in support processes and services
3. *Capabilities*
    - Leadership
    - Personnel resources
    - Communication of spatial information
    - Internal cooperation
    - Individuals' technical competence to use spatial data
    - Individuals' role competence
    - Organization's external networking capability

The key area *architectures* takes into account data acquisition and management, discovery and evaluation of fitness for use, and the accessibility of spatial data sets to potential users, which are the indicators of the organization's SDI. Thus the level of SDI is assessed as a part of GIS maturity. An individual's role competence highlights the systems intelligent behavior of all individuals, both managers and employees. Role competence means, on the one hand, the proactive development of personal competencies, and, on the other hand, the will to share one's own knowledge of the use of spatial information. The external environments of the organization, such as the possibilities offered by an NSDI, are considered in the maturity model as well. The model emphasizes the importance of collaboration between the public administration, universities, and private companies and the choices of strategic partners. Collaboration enables resources to be shared and useful research results to be put into practice.

Paper V did not explicitly discuss the role of trust in spatially enabled organizations. However, some of the barriers to the utilization of spatial information in Figure 2 in Paper V can be interpreted as expressions of a lack of trust. Barriers such as 'unawareness of available spatial data sets', ' holding back knowledge on spatial data usage', 'no training', 'no coordinated support', and 'no competence to use GIS' indicate that individuals do not trust their organization to be able to support them in the use of spatial information. The indicators of GIS maturity were not developed to assess trust but Figure 7, which illustrates the indicators of a spatially aware organization, visualizes, in addition to the indicator role competence (dotted line), the possible indicators of trust, which are also listed in the caption.

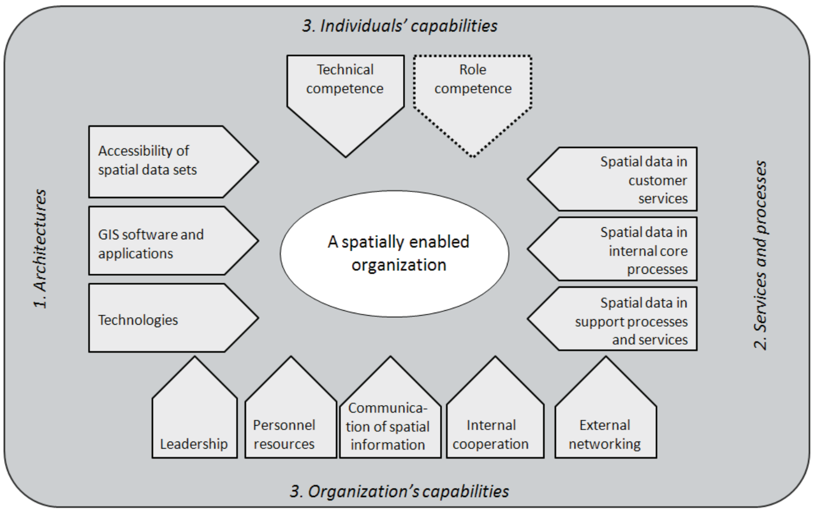

Figure 7. The indicators of a spatially enabled organization. In this figure there are some indicators that can be interpreted as describing trust. These indicators are: technical competence, communication of spatial information, internal cooperation, personnel resources, and leadership.

4.3 Interpretation of the results from the case studies

The usability of the customized maturity models was evaluated by two disaster management organizations and five organizations that use spatial information. The results give information about the maturities of the case organizations and the relevance of the indicators that had been defined.

4.3.1 Maturity of disaster management organizations

Paper VI presents the results from the maturity assessments in the disaster management exercises. The quick maturity assessment was first used in the SAR exercise and here Figure 8 summarizes the maturity values given by human agents in the three command bodies.

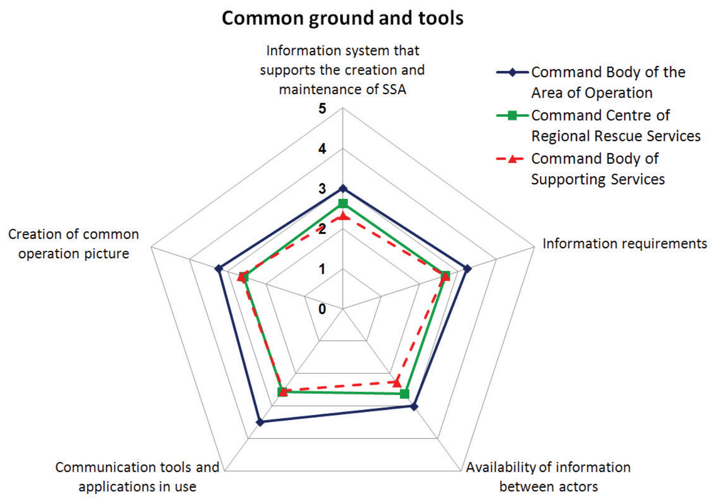

Figure 8. A radar chart showing the maturity values on a scale of one to five given by the three Command Bodies in the SAR 2010 exercise (adapted from Paper VI).

According to the human agents in the CBAO, the total maturity of the key area *common ground and tools* was on level three, whereas the human agents in both the CCRRS and the CBSS assessed the key area as being on maturity level two. Furthermore, the human agents in the CBSS scored the lowest maturity values. The biggest differences between the maturity values given by the three bodies are in two sub-areas: the availability of information between actors and communication tools and applications in use. The availability of information got the lowest maturity values of all indicators. The results indicate that an information gap exists between the command bodies and it does most to hinder the development of SSA in the Supporting Services. The results show the known fact that the collaboration, sharing of information, and creation of a common situation picture are more mature in the CBAO than in the two other bodies. This is due to the continuous collaboration of the rescue authorities, police, and medical care services in everyday emergency operations.

Figure 9 summarizes the results from the ICT exercise. The pre-assessment of the steering and evaluation group encompasses the overall maturity and concerns all the participating organizations. The maturity values from the first- and second-day assessments represent the opinions of human agents from all the administrative levels of one ministry.

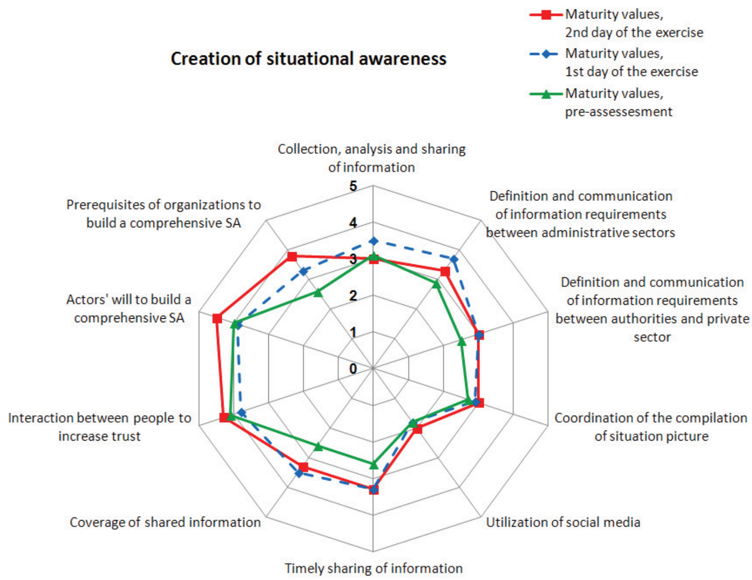

Figure 9. A radar chart showing the maturity values on a scale of one to five from the pre-assessment of the steering and evaluation group and the first- and the second-day maturity assessments of the human agents in the ICT exercise (adapted from Paper VI).

The human agents scored a value of three or higher in almost all the subareas. The values demonstrate that the creation of situational awareness is coordinated but not yet agile. As expected, the utilization of social media is at a low level. During the exercise, as the number of disturbances increased and they became more complicated, the organizations' capabilities to collect, analyze, and share information decreased. The communication of information requirements between administrative sectors decreased, whereas the private sector and the authorities were able to maintain the same level of communication. Figure 9 shows that the strengths in collaboration are the actors' will to build SA and interaction to increase trust. These sub-areas matured from level three to level four during the exercise. In sum, the two-phased assessment gives information about the agility of the collaboration, which has been defined as a key capability in a complex disaster situation. The maturity values of the pre-assessment show that the steering and evaluation group expected the capabilities of the organizations to be less mature, for example, in the sharing of information. However, the assessments during the exercise show that the organizations performed better than expected.

4.3.2 Maturity of organizations using spatial information

Paper V presents the results from the detailed maturity assessments of three large cities, a state institute, and a large private company. Table 2 in Paper V illustrates the elaborate quantitative results, as well as the areas that perform well and the areas that need to be reinforced. Here the results of the detailed assessment have been summed up into the maturities of the three key areas (Figure 10).

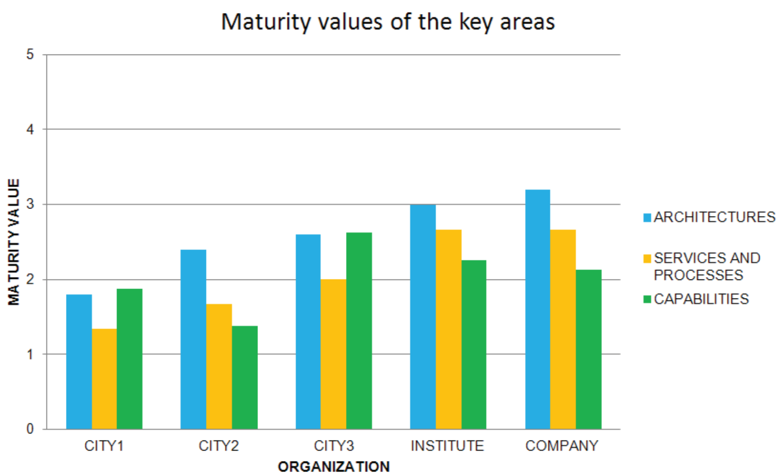

Figure 10. Results from the detailed GIS maturity assessments of the five organizations are summed up into the maturity values of the three key areas.

The maturity values in Figure 10 reveal some key findings from all three key areas: architectures, services and processes, and capabilities. The Institute's maturity value of 3 and the Company's maturity value of 3.2 in the key area of *architectures* show that they both have an internal SDI that supports the easy accessibility of spatial data. City2 and City3 have also invested in technical infrastructure but spatial data management and sharing services do not yet support all the branches in the organization. When the maturities of the three key areas are in balance, the organization is able to get the greatest benefits from the internal SDI. The low maturity values in the key area *services and processes* in Figure 10 show unused potential in the use of spatial information in all the organizations. As Paper V describes, none of the organizations had identified and documented those central customer services and solutions where spatial data could be utilized, which is a prerequisite for the attainment of maturity level three. However, opportunities exist to enhance the utilization of spatial information and City3 is a good example. The investment in competence development is illustrated in Figure 10 as the highest maturity value of *capabilities*. Paper V shows how systematic development of resources, cooperation between branches, the coordination of spatial information issues, employees' competence to use spatial information, and communications have improved the use of spatial information in the city. The low maturity value in the area of *capabilities* in City2 is due to a lack of competence in other than technical branches. The results of the SWOT analyses in Table 3 in Paper V reveal that the GIS maturity model contains requirements that the organizations did not find important. They did not find strengths or weaknesses in *services and processes*, even if this key area seems to be essential from the point of view of the organization's productivity.

4.4 Process for the development and use of a customized maturity model

Paper VI describes the development processes, contents, and use of the SAR and ICT maturity models. These models were used for quick maturity assessments in the disaster management exercises and therefore the content of the models was condensed. Tables 1 and 2 in Paper VI show the maturity levels and the key definitions that best describe the characteristics of each level. In addition, the importance of the visualization of the results is highlighted and a radar chart as a graphic method for displaying the results of maturity assessments is recommended.

Correspondingly, Paper V describes the development process and content of a detailed GIS maturity model. The process was open to all interested organizations. Paper V explains the series of steps that were taken in order to develop and evaluate the usability of the GIS maturity model (in Figure 1). It also shows the structure and detailed content of the model (Table 1) and provides evidence about the reliability of the detailed and quick maturity assessments. Figure 11 illustrates how the stages of the development processes of the SAR, ICT and GIS maturity models were combined, and as a result a formalized process for the development and use of a customized maturity model was created.

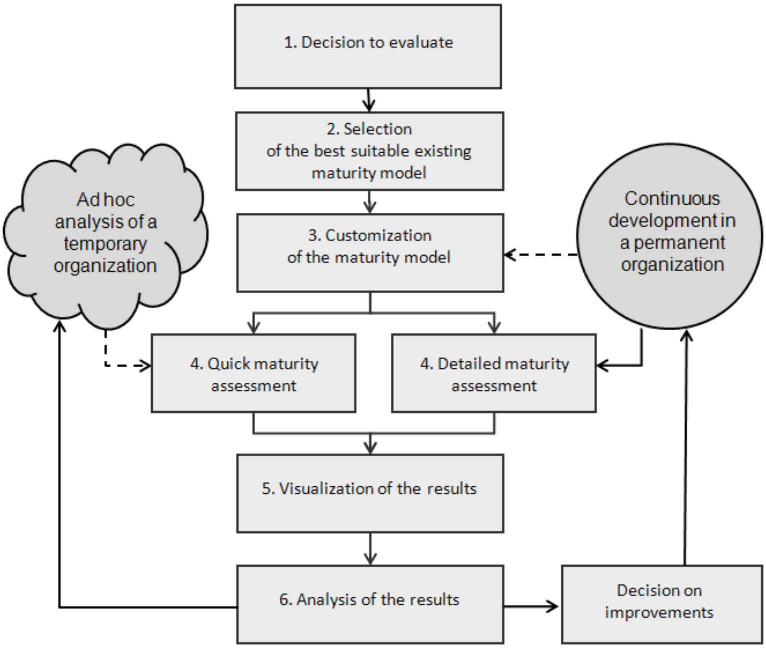

Figure 11. Steps in the development and use of a customized maturity model.

The formalized process has the following steps.

1. *Decision*

   Identification of the needs for development and a decision to assess the organization's competence to utilize information.

2. *Selection*

   A pre-study of the national and international maturity models that has been developed for the same application domain.
   A decision on the maturity model that will be used as a framework for the customized model.
   Identification of the relevant key areas and subareas that will be used as indicators of maturity from the selected model.

3. *Customization*

   Choice of a detailed or a concise model structure, depending on the purpose of use.
   Consideration of both the national goals and the jointly specified goals.
   Specification of the final key areas and indicators and the description of the maturity levels.
   Incorporation of the following areas into a customized maturity model for disaster management

  - components of trust: common processes, communication tools and information systems that support the creation of a common situation picture
  - human components: interaction with other agents, commitment, and will to collaborate.

Incorporation of the following areas into a customized GIS maturity model

  - internal SDI
  - spatial data in internal core processes and customer services
  - the organization's capabilities, such as leadership
  - communication of the benefits of spatial data
  - internal and external cooperation
  - employees' technical competence to use spatial data
  - systems intelligent behavior of each individual

4. *Assessment*

   Choice of a detailed maturity assessment for strategic and ongoing competence development in permanent organizations.
   Choice of a quick maturity assessment for rapid and cost-effective assessment of present competencies in temporary organizations.
   Evaluation of the reliability of subjective detailed maturity assessments of organizations by SWOT analyses.

5. *Visualization*

   Processing of the quantitative data from the assessment and visualization of the results.

6. *Analysis*

   The analysis of the results and utilization of the analysis, even during the disaster management exercises.

The case studies show that in the selection stage for a customized GIS maturity model both GIS maturity models and IT maturity models are worth studying. Respectively, both civilian and military maturity models for disaster and crisis management should be considered when maturity models for disaster management are being developed. An important part of the customization step is the choice of the right terms. For example, descriptive names for the maturity levels are important. In disaster management they should highlight the actual starting level of collaboration and the highest maturity level that it is realistic to achieve. In the case studies, the names of the maturity levels in the ICT maturity model seem to demonstrate the achievable stages of collaboration better than those in the SAR maturity model. A web tool or corresponding application is most practical for developing a questionnaire and carrying out the maturity assessment. The application facilitates an easy and guided way for the respondents to fill in their background information and choice of maturity level for each subarea. It also enables the results to be analyzed and visualized rapidly. A proper detailed maturity assessment involves all the branches within the organization and needs time and resources. A graphic visualization enables data to be viewed easily and promotes collective discussion and interpretation of the results. For example, a radar chart provides an effective way to compare values and to recognize even small improvements in the capabilities.

5. Discussion

5.1 Theoretical implications

This dissertation is the first study to apply a systems intelligent approach to the development of an organization's maturity. One of the main findings is that systems intelligent behavior is one of the leverages of a maturing organization both in disaster management and in the utilization of spatial information. Other main findings include the formalization of the most significant indicators of a customized maturity model and the customizing process itself.

This research has recognized the importance of human abilities such as professional and technical skills and leadership in the development of an organization's maturity and thus it supports the findings of earlier research (Alberts and Hayes, 2007, Babinsky, 2009, Hof et al., 2010, Kok and van Loenen, 2005, Masser et al., 1996, Somers, 1998). However, this research extends the human abilities that have already been identified with systems intelligent behavior and calls the new cluster of abilities an individual's role competence. Role competence is not a static concept but should include abilities that are important for the application domain. Personal commitment, will to act, and active inquiry and sharing of information are essential both in situation-aware and spatially enabled organizations.

Systems intelligence also shows up as a holistic approach to the defining of indicators. The indicators of a situation-aware SAR organization cover key areas that include common processes, common tools, competence, and communication. They were derived from the experience gained in SAR exercises and also from the suggestions of several researchers (Alberts and Hayes, 2007, Endsley, 2008b, Griffin et al., 2012, Krill and Dzirio-Ayvaz, 2008, Kuusisto, 2008, Nofi, 2000, Valtonen, 2010). This research found that system trust and human agents' collaboration roles are important and suggests that the indicators of these capabilities should be taken into account when the creation of shared situational awareness is being assessed and developed. System trust in disaster management organizations involves trust between human agents, trust between actors, and their trust in the organization. Trust has been recognized as important in disaster management by other research studies as well, but trust often means mutual trust between team members and actors (Alberts et al., 2010, Hof et al., 2010). This study underlines the collaborative role of human agents, core professional skills and commitment, and the will and readiness of a human agent to use his/her potential for the benefit of shared goals, both as such and also as indicators of system trust.

Earlier research (Babinsky, 2009, Masser et al., 1996, Somers, 1998) points out that technical infrastructure, organizational culture, strong management support, and competence are important components in spatially enabled organizations. The findings of this research demonstrate that the indicators of a spatially enabled organization should also highlight communication of the possibilities offered by spatial information and the role of spatial information in an organization's internal core processes and support services and in customer services. During the research a strong impression of the importance of the indicator role competence came up, even if it could not be unambiguously quantified. The role competence should be divided into more specific measures or indicators, as in the SAR and ICT maturity models, so that the reliability of systems intelligent behavior can be better justified.

The customizing process describes in a step-by-step manner the development of a customized maturity model and how the model is used in organizations. It also includes suggestions for the content of maturity models and when quick and detailed maturity assessments should be performed. The detailed description of the fundamentals of indicators and the process for the development and use of the customized model in this research tries to fill the gap that has been pointed out by Kohlegger et al. (2009) and Mettler and Rehner (2009).

The SAR organization has developed collaboration and preparedness in SAR exercises over several years and can be regarded as a more permanent organization than the ICT organization. The results of the maturity assessments probably indicate that the human agents in the SAR organization expected more from the collaboration and were critical in their assessments. Conversely, the human agents in the ICT exercise perhaps did not have great expectations about the collaboration in advance and were satisfied with the interaction and sharing of information with other human agents. The high maturity values of the indicators on both exercise days do not provide very precise information about the ability of the organization to develop SSA.

The results from the GIS maturity assessments provide evidence that the organizations were motivated to evaluate their utilization of spatial information in a critical way and they were committed to getting concrete information about the competence areas that are worth investing in. The five organizations performed GIS maturity assessments themselves and the results are subjective and the comparison of the maturity values of the organizations is only approximate. But the maturity values serve each organization internally and are comparable when organization’s GIS maturity is assessed in the future.

5.2 Practical implications

The customized maturity models for disaster management can be used as they are by organizations whose structures, processes, and goals are very close to those of the SAR and ICT organizations. However, the models can be used as frameworks when new maturity models for the development of SSA are being developed and customized. The method for developing a concise maturity model and quickly assessing current competencies could also be applicable for a multinational group of producer organizations of spatial data whose goal is to develop common products or services. The customized GIS maturity model is useful for both public organizations and private companies that want to develop their competence to utilize spatial information in all their businesses where spatial information solutions can enhance productivity and innovations and support both strategic and operational decision making. The model enables strengths and areas that should be improved to be identified and thus supports the focusing of competence development in organizations. The detailed GIS maturity model is applicable for individual disaster management organizations such as the police, rescue services, the border guard, and the medical service.

5.3 Recommendations for further research

A concise maturity model was applied to assess the development of SSA in the SAR organization. The SAR organization could benefit from a detailed maturity model, such as the GIS maturity model and maturity assessment, because it shows readiness for a critical evaluation of the organization’s own actions and continuous improvement. A detailed maturity model would enable each actor to assess their capabilities to develop shared situational awareness. The knowledge of capabilities that need special attention before or during the exercise would promote the success of collaboration in the disaster management exercise. The development of a detailed model could also result in more concrete measures to promote system trust and the collaboration role.

Only large organizations assessed their GIS maturities with the new maturity model and evaluated its fitness for use. Further research is needed to evaluate the usability of the GIS maturity model for small organizations. The development of the content of the GIS maturity model might focus on the specification of the measures of role competence and the use of different weightings for indicators. The sustainability of the customized maturity models and how they should evolve along with advances in the information society, such as the opening of public data or the development of collaboration capabilities, such as the interoperability of the information systems of actors in complex disaster situations, needs evaluation in the future. However, human abilities such as systems intelligent behavior are an area that should be maintained in the model.

The research indicates that system trust is a prerequisite for situation-aware disaster management organizations. The role of trust in spatially enabled organizations was not studied in this research. However, some of the barriers to the utilization of spatial information that were presented in Paper V may indicate that employees do not trust their own organization to support them in the better use of spatial information. This subject requires additional study.

One interesting topic that also needs further study is whether the customized GIS maturity model could be used to assess the status and success of the implementation of an NSDI. The NSDI and GIS maturity of user organizations are mutually dependent. Only when the GIS maturity of user organizations is at a high level can they direct their needs to the development of an NSDI and the benefits of the NSDI come true to their full extent. When the maturity assessments of a user organization are repeated at intervals they could function as a measure in the evaluation of the success of the implementation of an NSDI.

6. Conclusions

The main conclusion of the dissertation is that even when the technical infrastructure and common applications exist, the systems intelligent behavior of human beings – the commitment and the will to act for the achievement of common goals – is crucial for the sharing and utilizing of information both in disaster management organizations and in organizations using spatial information. Therefore, the indicators of systems intelligent behavior should be included in the customized maturity models that are created for the evaluation and development of shared situational awareness and comprehensive utilization of spatial information.

This research created a formal process for the development and use of a customized maturity model in both temporary and permanent organizations. The process supports the consideration of the generally identified relevant key areas, as well as specific national and organizational goals, as indicators in the maturity models. A detailed maturity model and maturity assessment are appropriate for strategic and ongoing competence development in permanent organizations, whereas a concise maturity model and quick maturity assessment are suitable for the rapid and cost-effective assessment of the present competencies of temporary organizations.

The studies in two different application areas were challenging from time to time and did not proceed without problems. However, they supported each other and revealed findings that would not have arisen from studies related to only one application area. First, an SAR organization is not necessarily an ordinary temporary disaster management organization that exercises collaboration only because of an obligation. An SAR organization can be motivated to the development of its strategic competencies in the same way as permanent organizations. Accordingly, an SAR organization could benefit from a more detailed maturity model, for instance the GIS maturity model and detailed maturity assessment. Second, GIS maturity models do not emphasize trust in either the customized or the other GIS maturity models. This research indicated that the concept of trust is also important in the assessment of the achievements of spatially enabled organizations. Trust and systems intelligence should be included as indicators of maturity models for spatially enabled organizations.

The approach that was developed and the model that was defined offer the necessary tools for the evaluation of the various types of exercises, experiments, and organizations in which the collaboration of several actor parties is in focus. The method offers an opportunity to compare the results from series of exercises. The development of collaboration can be assessed in detail and the model can be developed when required while keeping the majority of the indicators constant.

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