HELSINKI METROPOLIA UNIVERSITY OF APPLIED SCIENCES

Master’s Degree in Business Informatics

Master’s Thesis

SHARED SERVICE CENTER AS A NEW COOPERATION MODEL FOR NORDIC WEATHER PREDICTION SYSTEMS

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PREFACE

This Thesis has been a good professional opportunity to investigate the possibilities for using different service models in the meteorological field. The studying of new service models has opened up my mind and gave rise to new thoughts about the business that has seemed so familiar for years before. Having the chance to do research on a real life business problem made this project very pleasing, as its results can be used to solve actual challenges in my daily work.

I would like to thank my employer and my colleagues at FMI and other Nordic meteorological institutes who helped me with this work and shared their valuable ideas. I would also like to thank my instructor Dr Thomas Rohweder for excellent supervision, Zinaida for language comments and my classmates at Metropolia University of Applied Sciences for their support in writing this Thesis.

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ABSTRACT

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This Master's Thesis aims to increase the cost efficiency of the meteorological weather prediction system in the Nordic countries. To improve the cost efficiency, this study examines and presents a proposal for model of a new cooperative shared service center for weather prediction systems.

The objective of this study is to investigate a way to create an effective cooperative model for a limited area weather modelling and prediction system based on a shared service center concept. The key component in the proposed cooperation is numerical weather modelling and high performance computing which is also known as supercomputing. The outcome of this work develops a model for potential institutional participants for a shared service center based on a common weather prediction system that includes several countries.

The research process is based on a theoretical study of the shared service center concept and the examination of benchmarks of successful implementations of shared service centers by using case studies from a similar work field. After these research steps, a proposal for the model of the new cooperative shared service center is developed to suit the specific need of meteorological organizations in weather prediction systems.

Key words	Shared service center, information system, weather prediction system, high performance computing.

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ABBREVIATIONS/ACRONYMS

COST	Framework for European Cooperation in Science and Technology
CSC	IT Center for Science Ltd.
ECMWF	European Center for Medium-Range Weather Forecasts
ECOMET	Economic Interest Grouping between the Meteorological and Hydrological Services in Europe
EPS	Ensemble Prediction System
EUMETNET	Network of European National Meteorological Services
EUMETSAT	European Organization for the Exploitation of Meteorological Satellites
FMI	Finnish Meteorological Institute
Funet	Finnish University and Research Network
GNI	Gross National Income
GTS	Global Telecommunication System
HPC	High Performance Computing
HPCF	High Performance Computing Facility
ICT	Information and Communication Technology
IS	Information System
IT	Information Technology
LAM	Limited Area Modelling
LAMEPS	Limited Area Modelling Ensemble Prediction System
met.no	Norwegian Meteorological Institute
MI	Managerial Implications
NMS	National Meteorological Service
NORDUnet	Nordic Infrastructure for Research & Education Network
NOSC	NORDMET Steering Committee
NWP	Numerical Weather Prediction
OG	Operations Group
OM	Operations Manager
RMDCN	Regional Meteorological Data Communication Network
SC	Steering Committee
SG	Steering Group
SMHI	Swedish Meteorological and Hydrological Institute
SSC	Shared Service Center
SWOT	Strengths, Weaknesses, Opportunities and Threats Analysis
WMO	World Meteorological Organization

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1 INTRODUCTION

This Master's Thesis aims to increase the cost efficiency of the meteorological weather prediction system especially in the Nordic countries. To improve the cost efficiency, this Master's Thesis examines and presents a proposal for a new cooperative shared service center model for weather prediction systems.

1.1 Case Organization and Its Work Field

The case organization of this study is the Finnish Meteorological Institute (FMI), a research and service institute and a subordinate to the Ministry of Transport and Communications. FMI is acting in weather services and research fields of work, and its work mostly consists of different weather forecasting products and research activities.

Since weather is a global phenomenon, weather prediction information systems and weather models are usually developed within an international cooperation. In line with this trend, FMI has established close connections with several meteorological institutes around the world which became its partners in several international development projects.

Internally, the mission of FMI is to produce high-quality services and scientific know-how on the atmosphere and the seas. The institute sees itself as a service oriented organization and uses its expertise to provide services that promote public safety and enhance wellbeing of the people and environment (FMI 2012). The full description of FMI mission and service areas can be found in Appendix 1.

The FMI priorities focus on predicting and responding quickly to changes in the environment as well as the changing expectations of society. For the planning period 2012-2015 (FMI 2012), FMI has defined a list of priorities and challenges that society is currently facing (Appendix 1). To deal with these issues, FMI currently employs 680 people (Appendix 2).

Organizational structure of the Finnish Meteorological Institute

FMI has an organization model that comprises two main divisions and two administrative functions. One division is responsible for weather and safety services and the other one for research and development activities. The administrative functions are executed by the office of Managing Director and Administration. The overall organizational structure of FMI is illustrated in Figure 1.

Figure 1. Organization chart of the FMI (FMI 2012).

As shown in Figure 1, Weather and Safety Division is sub-divided into five units: Weather and Safety Center, Commercial Services, Development of Services, Information Management Services and Observation Services. This division is responsible for the safety and security support of the meteorological services, commercial weather services, the implementation of meteorological production systems and their development, and the infrastructure of atmospheric observation systems.

FMI also has a separate division responsible for research and development which are conducted in meteorology, oceanography, air quality, climate change, Arctic region, space physics and remote sensing areas. As FMI is a national weather service that is responsible for improving the quality of life and safety of the people in Finland, FMI observes the physical state and chemical composition of the atmosphere and the seas, and conducts international scientific research in the air, physical oceanography, polar research and the near space. High-quality observations and research data are then utilized in the development of services for the benefit of the people in their everyday life. The productivity and other performance measurements of FMI are presented in Appendix 3.

FMI funding

The funding in the basic weather services in Finland mostly comes from the state budget. Every year, however, there has been a growing trend for increased cost savings in public funding. In the weather service operations, the need for savings in public funding is also visible, and it affects daily work of FMI and its future planning. On the European level, there have been some plans to integrate different weather services of different countries towards acting together, but these plans have so far been quite difficult to implement as weather services are considered to be related to safety and are usually tightly connected to security and military actions. As an opposite trend, there have also existed some plans to open up more services to competition, for example, in flight weather services.

Presently, weather service markets can be divided into two different segments. The first segment includes the production of the actual weather data and related products. The second segment includes weather services. To produce the data needed for creating the actual weather services, national meteorological institutes are typically responsible for their own national weather observation networks. Private weather services companies usually purchase or use freely the weather data produced by the national publicly funded institutes. In Finland, for example, domestic commercial markets are somehow limited, but international business markets are now rapidly developing.

As for the FMI financing, it consists of the basic operations funded from the state budget and the incomes coming from commercial activities, as well as the sources from jointly funded research and development activities. The structure of the funding for 2010 is shown in Figure 3.

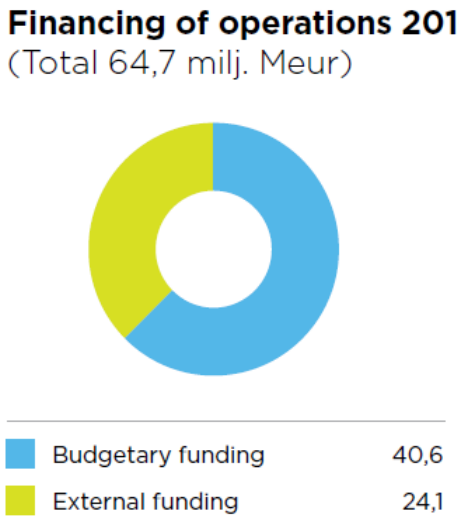

Figure 2. Financing of FMI operations in 2010 (FMI 2012).

As seen from Figure 3, in 2010 the state budget funding covered 62 % of the FMI expenditure, which amounted to 40.6 ml Euros. Although in 2010 FMI has a major part of its financing coming from the governmental funding, about one third came from the external funding, which in 2010 equaled 24.1 ml Euros. This external funding is essential for FMI since it provides some level of independency compared to the actors funded from the state budget sources only.

Presently, FMI is a governmental organization acting in weather services and research field that is actively developing its services and innovative ways of work. This Thesis work is part of this development process.

1.2 Supercomputing in Weather Services

As sensitivity to the weather in society has continued to grow, it increasingly affects such functions as roads, railways, airways and maritime transport, energy supply, rescue services, as well as a number of other business segments. Climate change, population growth, urbanization and globalization of society all increase the sensitivity to climatic events and natural phenomena. As a result, the need is constantly growing for information and services to enhance public safety and ensure that weather-related economic losses are minimized. A special strength of the national weather services is the ability to function in near real time operation conditions, at least in exceptional circumstances. The ability to provide 24/7 safety services, on the other hand, requires sufficient human resources and state-of-the-art, well-maintained IT and other infrastructure. Operational IT environment is a central component in this weather service, and the high performance computing environment, in which weather forecasts are produced, is its key component. (FMI 2010)

Currently, weather predictions based on modeling based on two different scales: first, these are global weather models run by bigger countries by themselves; the other model is the so-called limited area weather predictions which mean the use of a smaller forecasting area usually from part of a country to a continent level. These limited models are usually run by meteorological institutions in different countries.

The Finnish national weather model system is based on using a limited area model, which can be done at a higher resolution than the global system can currently perform. Because of the more accurate resolution, the limited area models are able to describe the small-scale phenomena (e.g., wind conditions near the coast, areas around the lakes and mountains), and thus can provide added value in relation to global models. As part of an international consortium, FMI has been at the forefront of km-scale weather prediction systems HIRLAM and HARMONIE. The future supercomputing capacity, for internationally co-developed km-scale model, can be used at full capacity as part of the daily operational weather forecasting activities. Increasing the computing capacity is vital to secure the FMI research status in weather model development activities on the international level. (FMI 2010)

The FMI service production and delivery system is one of the most modern in its field, which has been a goal and priority of FMI for years. The FMI's aim is to ensure that both research and operational services have the needed IT systems in use. High performance computing is also socially important for the dispersion model use, for example, in case of nuclear accident, chemical accident and in ash emission situations. In the previous procurement in 2009, the supercomputer capacity was increased approximately 19 times compared to the earlier 2005 purchased equipment. Although the investments in high performance computing have grown in all industries in recent years, the sums of investment in relation to the obtained benefits can still be considered very reasonable. A more detailed description of the need for supercomputing for FMI activities can be found in Appendix 4.

1.3 Business Problem

The main business challenge investigated in this study is the improvement of cost efficiency of the meteorological production system and the high performance computing solutions, in particular. The current trend in computing systems in all industries is marked by the increase in costs of technological solutions. So far, FMI has been able to get the funding for its computing systems, but in the future it can be more difficult to secure the needed computing capacity required by the new weather services. Therefore, new ways of cooperation are needed to address these challenges. One of the possible solutions may be found in an increased international cooperation, which can start from cooperation in the Nordic region.

In the current situation, the whole meteorological production system in the Nordic countries is disorganized, which means that the countries act by themselves. Every meteorological organization has their own systems, including supercomputing facilities for weather model calculations. As there is no existing, already implemented cooperation in this field, the supercomputing backup systems are also handled nationally, separately by every country. The expenses of these systems are becoming ever more difficult to sustain, and a cooperation model would be needed to find a solution to this problem.

Sweden and Norway have already started to plan and implement some co-operative production systems for their limited area numerical weather models and the high performance computing systems. So far, however, this co-operation is planned to include only two participants sharing their resources. But since there is an interest also from Finland, this plan for cooperation could be further developed to include an additional participant. This Thesis concentrates on finding a solution to the challenge of developing such operation in weather services.

1.4 Objective of the Study

If further refined, the business problem presented in the previous sub-section would stress the importance of cost efficiency in weather prediction systems and set it as the main study goal. If taken on a general level, this study aims to increase the cost efficiency and cooperation in the meteorological weather prediction system in the Nordic countries, including possible other participants with similar needs in limited area weather model calculations. If described on a more detailed level, the objective of this research is to propose a more effective cooperative weather predictions system compared to the current state by using a Shared Service Center (SSC) concept. As the outcome of this study, the Thesis develops a model for the case organization for creating a Nordic SSC for weather prediction system.

Based on the current situation, with the systems developed and maintained by each country separately, there is a strong argument in favor of planning and developing the meteorological production system in a cooperative way. As described earlier, such plans already exist, but a wider cooperation model is needed, as there is a clear urge to build up an arrangement for more than two participants sharing their resources. At a minimum, this cooperation incentive should join forces in supercomputing, which is a major investment for all meteorological organizations. Additionally, some other parts of the production system can be considered for possible sharing such as data, pre- and post-processing, and archiving solution.

If developed, such cooperation would mean a solution for a shared super-computing system for participants, thus backing up the resources of each country and reducing the expenses for every single participant. The cost reduction can be achieved through the increased computing power as separate backup systems would not be needed anymore on a national level. In this cooperation model, each country could buy a new computer system every four years and, as a result, a new cooperative shared computer could be upgraded every two years. The newest computer could then be used as the operational one, and the other could act as the backup computer. Eventually, as it would be possible to get more computing power with the same amount of money every two years, there would be no need for the nationally duplicated solutions for backup. As a result, this faster cycle could significantly increase the computing power available for operational model calculations, thus considerably reducing the expenses for each participating country.

The cooperation model that is investigated in this Thesis could work for three or more countries as a model supporting a proposed SSC that all the participating countries would invest in and use as shared resources for production of their meteorological services.

1.5 Structure and Scope of the Thesis

This Thesis is written in seven sections. Section 1 is an introduction to the FMI as a case organization and its field of work, including general information about the meteorological production systems. This section also presents the business problem and research objective of the study. Section 2 overviews the research method, data collection and analysis methods used.

Section 3 analyzes the SSC concept based on a literature review and best practices found in the current markets. This section also suggests a model for the successful SSC implementation requirements built on the literature review findings.

Section 4 of this Thesis examines two case examples of similar services that have been using a shared service model successfully. These case examples are derived from the benchmarking organizations remarkable for their SSCs in this meteorological cooperation situation. In this section, a model for the successful SSC implementation and its requirements are suggested and compared to the case examples to examine the requirements reliability.

Section 5 presents the current situation in the Nordic countries and their meteorological institutes, as well as introduces the meteorological production systems in general.

Section 6 presents a new service model proposal for operating in cooperation. The new service model is based on the SSC model and includes some key components of the weather predictions systems.

Section 7 of the Thesis presents the discussion and conclusions summarizing the work and proposals developed for cooperation in weather services.

As for the scope of this Thesis, it is limited to investigating the possibilities of improving cost efficiency of the weather prediction systems in the Nordic countries. It means, first, that this Thesis does not examine cooperation models other than a SSC. Although cost efficiency of the weather prediction system could be developed through applying other different models too, in this work, the focus is placed on the SSC concept.

Secondly, this Thesis concentrates mostly on the situation in three Nordic countries instead of building a model for all five Northern countries or even more participants. The countries included in this study are Finland, Norway and Sweden. The other two countries, Denmark and Iceland, can also utilize the solution proposed in this study, but a more detailed investigation is needed to be conclusive about the model which could also include these countries.

2 METHOD AND MATERIAL

This section discusses the research method, research process and research material used in this study. It also presents the data used in this Thesis and overviews the methods of data collection and analysis. Reliability and validity of this research are discussed at the end of this section.

2.1 Research Approach

This study is based on using the qualitative research methods, and the research approach utilized in this Thesis is a multiple case study.

Case Study Method

According to Yin (2003), the case study can be defined as an empirical inquiry that investigates a phenomenon in its real life context, in a certain period of time, when the boundaries between the phenomenon and the context are not clearly evident. Yin (2003) also stresses that the case study can manage technically distinctive situations where many different variables point to the same result. Such inquiries usually rely on several sources of evidence to converge the data in a triangulating fashion, thus strengthening reliability of the obtained results. Importantly, data collection and analysis in these inquiries, according to Yin (2003), should utilize a prior development of theoretical propositions and specify the chosen research methods.

In case study research, there can be one or several cases studied analyzed. According to Yin (2003), multiple cases support the trustworthiness of the study, as in this case the study can become more compelling and robust. The cases are recommended to be selected for theoretical reasons, since statistical reasons cannot be considered equally important for drawing conclusions (Eisenhardt 1989: 537). In this study, the analyzed cases are successful implementations of SSCs by investigating the organizations working in similar fields as benchmarks. The research process is based on a theoretical study of the SSC solutions to identify the key elements of a new SSC to be able to implement it successfully. After these steps, a shared service cooperation model is built to suit the specific needs of meteorological organizations in weather prediction systems.

Methods for Interviewing in Qualitative Research

Interviews are a widespread tool in qualitative research. A research process based on qualitative interviews can be divided into the following steps: 1) Thematizing and formulating research questions, 2) Designing the study to address the research questions, 3) Interviewing, 4) Transcribing, 5) Analyzing, 6) Verifying, and 7) Reporting (Kvale 1996: 14).

According to Turner (2010), qualitative interviews can include informal conversational interviews, general interview guide approach and standardized open-ended interviews. Marshall et al. (1998) distinguish three interview methods that are *structured*, *semi-structured* and *unstructured*.

After the data from the interviews are collected, Kvale (1996) suggests employing five main approaches to analyze the meaning of the interviews. These are: *condensation, categorization, narrative structuring, interpretation* and *ad hoc* methods (Kvale 1996: 191). In this research, generating meaning through *ad hoc* methods as an eclectic method is used applied to the semi-structured and, in some cases, unstructured interview types.

The basic method of qualitative interview analysis is the content analysis which includes the following steps: 1) Deciding the level of analysis; 2) Deciding how many concepts to code for; 3) Deciding whether to code for existence or frequency of a concept; 4) Deciding on how to distinguish among concepts; 5) Develop rules for coding your texts; 6) Deciding what to do with "irrelevant" information; 7) Code the texts; 8) Analyzing the results. (Kvale 1996: 191)

2.2 Data Collection and Analysis Methods

In this study, the research data are collected from the following sources: 1) research and business literature on the SSCs and best practices of successful services center implementations; 2) two case examples from benchmarking organizations working in a similar area and using SSCs; 3) analysis of the current situation in the case company and in potentially participating Nordic meteorological organizations based on: a) the scrutiny of internal and inter-organizational documentation, b) interviews, discussions, brainstorming sessions on the needs and prospects of weather prediction systems, complemented with the researcher's participant-observations.

Findings from the literature review on the concept and various models of the SSCs and their implementation requirements are made by utilizing library search and best practices analysis.

Study of the two case examples is based on the material provided by the benchmarking organizations as well as publications on their service centers and interviews with their representatives. The researcher's own observations are also used for the benchmarks analysis, since the benchmarking organizations are well-known to the researcher from his practical work as partner organizations providing service to FMI for several decades now. The cases examples studied as benchmarking organizations in this Thesis are: 1) CSC - IT Center for Science Ltd.; and 2) ECMWF - European Center for Medium-Range Weather Forecasts. Other meteorological institutes overviewed for the current state analysis and possible current cooperation plans include: 1) 1) met.no - Norwegian Meteorological Institute; and 2) SMHI - Swedish Meteorological and Hydrological Institute.

Analysis of the current situation in the case company and in potential Nordic partner organizations is done by scrutinizing the internal and inter-organizational documentation and the extensive use of interviews, discussions and brainstorming sessions. This Thesis mostly applies *semi-structured* and additionally also *unstructured* interviews, as well as discussions, and brainstorming sessions, which were prepared by creating lists of questions (Appendices 5-10). The obtained data were then processed by analyzing the collected material before being included in the study. The transcribing in this Thesis work is mostly reduced to creating field notes which are subsequently processed by applying the content analysis. The internal documents which supplement the interviews, discussions and brainstorming sessions are comprise of cooperation reports; published and open company documents, such as web-material, research publications, and annual reports and plans; and also include emails as documentation.

The list of informants and other details of the data collected from the interviews, discussions and brainstorming sessions are summarized is Table 1.

	Informant	Date	Type of event	Topic, question lists	Document
1	Director (A), IT Directors (A and B) and Specialists (5 FMI specialists in IT and weather modelling)	2011-2012 (5 meetings during that time)	Interviews and discussions	Nordic HPC cooperation (Appendix 5); FMI's needs in cooperation (Appendix 6); FMI current state analysis (Appendix 10)	Field notes
2	Customers of the benchmarking organizations: Case 1: 3 FMI IT experts (Head of Group A and B, System Specialist A) Case 2 3 FMI IT experts (Head of Group A and B, system specialist A)	Spring and summer 2012 (2 meetings)	Interviews 4 hours	Topic about services provided by the case SSCs and their success in service production. Also discussion about the needs for these services discussed in more detail. (Appendix 5)	Field notes
3	IT Directors (A and B) and Specialists (6 persons)	5.9.2011	Brainstorming session 6 hours	Nordic IT cooperation (Appendix 7)	Field notes
4	IT Director (A)	1.-3.11.2011	Discussion 1 hour	Nordic HPC cooperation - current plans and possibilities for cooperation (Appendix 7)	Field notes
5	IT Directors (A and B)	25.-27.4.2012	Email discussion	Nordic HPC cooperation - possibilities for cooperation (Appendix 7)	Emails
6	Director (A) and FMI experts (Head of Group A and B, system specialist A)	Spring 2012 (2 meetings)	Interviews	Interview Questions for the New Shared Service Model (Appendix 9)	Field notes
7	FMI IT experts (Head of Group A	Winter and spring 2012	Interviews	Current state analysis at FMI	Field

	and B, system specialist A)	(2 meetings)		(Appendix 10)	notes
8	IT Experts and Managers (Head of Group A, B and C)	15.6.2012	Brain-storming session 3 hours	Validation with experts of the draft proposal (Appendix 11)	Field notes

Table 1. List of informants and other details in the data collection.

The empirical research in this Thesis is based on collecting and analyzing the data from the interviews, discussions, and brainstorming sessions. The collected data are then analyzed using the content analysis which is applied as widely as possible; though it need to be noted that some of the interviews were conducted as an informal discussion which makes the content analysis more difficult.

The seven steps presented by Kvale are followed in this Thesis (thematizing and formulating research questions; designing the study; interviewing; transcribing; analyzing; verifying, and reporting) (Kvale 1996: 14), taking into consideration the realities of the work. The questions for the interviews, discussions and brainstorming sessions were prepared based on the literature review of the research topic. After this step, the questions and interview designs are formulated. The collected data are then analyzed and reported according to the outcomes of the interviews. The data verification is made according to the considerations discussed in Section 2.4 Reliability and Validity.

The study also widely used a number of official documents, such as published plans and cooperation reports in the area of this Thesis. These materials are analyzed in a similar way as the interviews, by applying the content analysis, as is done with all the qualitative research data in this Thesis.

2.3 Research Design

This research was carried out as illustrated in Figure 3. To solve the business problem and answer the research question presented in step 1, the following steps were taken: a) First, in step 2 the literature review was made on the concept and models of the shared service centre; b) Second, two benchmark cases were studied in step 3 to identify the ways of working and providing services in cooperation. The information and data for the case studies were collected from studying the published documentation and from interviewing representatives of these organizations in step 4; c) Then, the current state analysis of the case company (FMI) and the potential partner meteorological organizations was carried out (based on the cooperation plans, annual reports and various published and internal documentation) in steps 4 and 5; d) finally, based on the study findings, in step 6 a model was proposed for setting up a shared services center in the meteorological field for the potential Nordic participants.

This research design is presented in Figure 3.

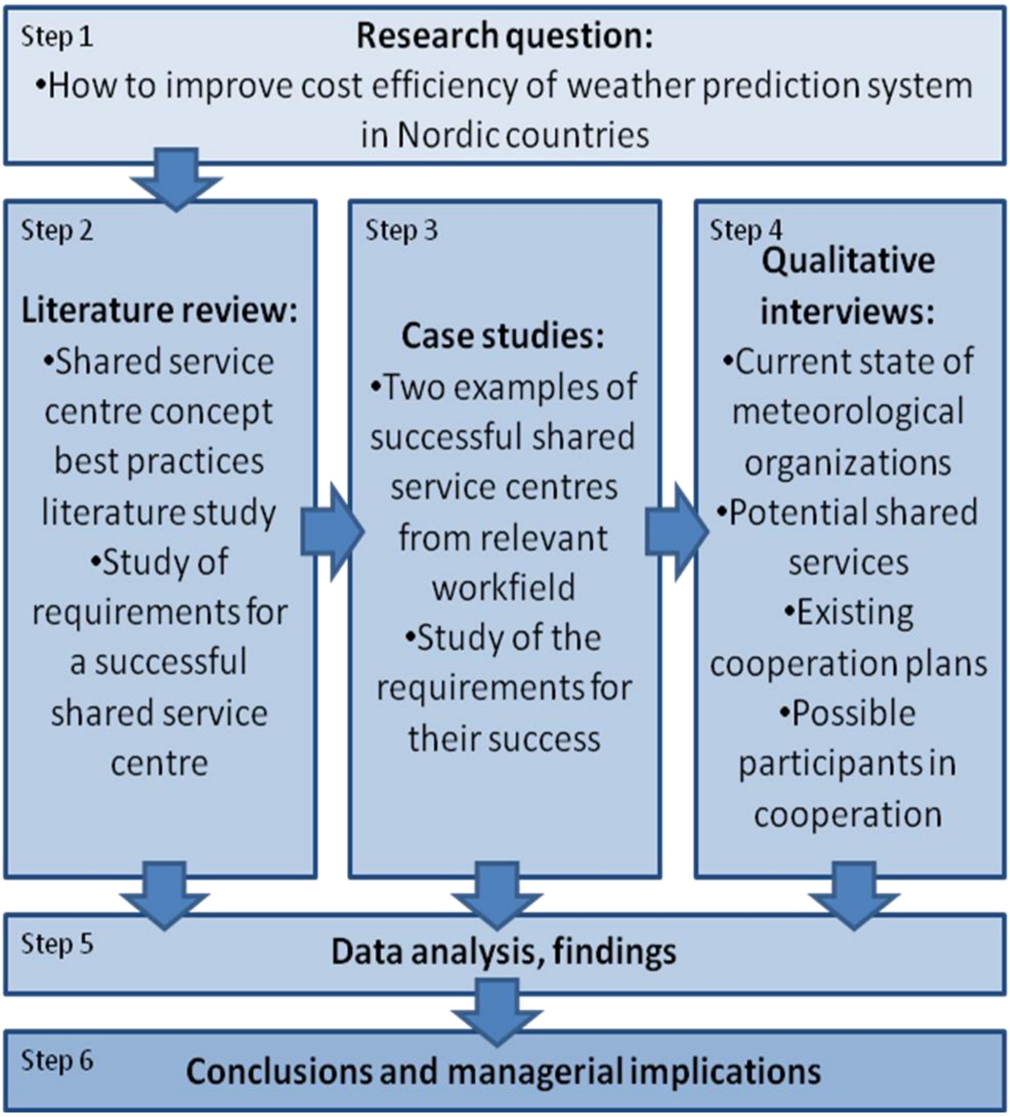

Figure 3. Research design.

As can be seen in Figure 3, the research design includes the following steps typical of qualitative research: 1) defining the research question; 2) literature review; 3) case studies; 4) qualitative interviews; 5) data analysis; 6) reporting the conclusions, formulating the research outcome and suggesting managerial implications.

As for the research process, the study flow roughly corresponds to the typical research flow often divided into three different phases (Yin 2003): 1) planning the study (defining and design); 2) conducting the study; 3) making analysis and conclusions.

In this study, the research process consisted of the following steps: 1) theoretical study of the SSC concept, models and requirements for its successful implementation; 2) identifying the key components for setting up a successful SSC, based on the theoretical study; 3) analyzing the case examples of successful SSC implementations in benchmarking organizations in a similar working area; 4) comparing the case examples to the requirements model for the SSC developed from the theoretical research; 5) studying the current situations of potential participants from the Nordic meteorological organizations and their weather prediction systems; 6) comparing the current situations in the potential Nordic meteorological cooperation (FMI plus two Nordic participants) to the requirements model of the SSC; 7) developing a final cooperative service model for the SSC for the meteorological cooperation in weather prediction systems.

Figure 4 specifies the research process implemented in this Thesis.

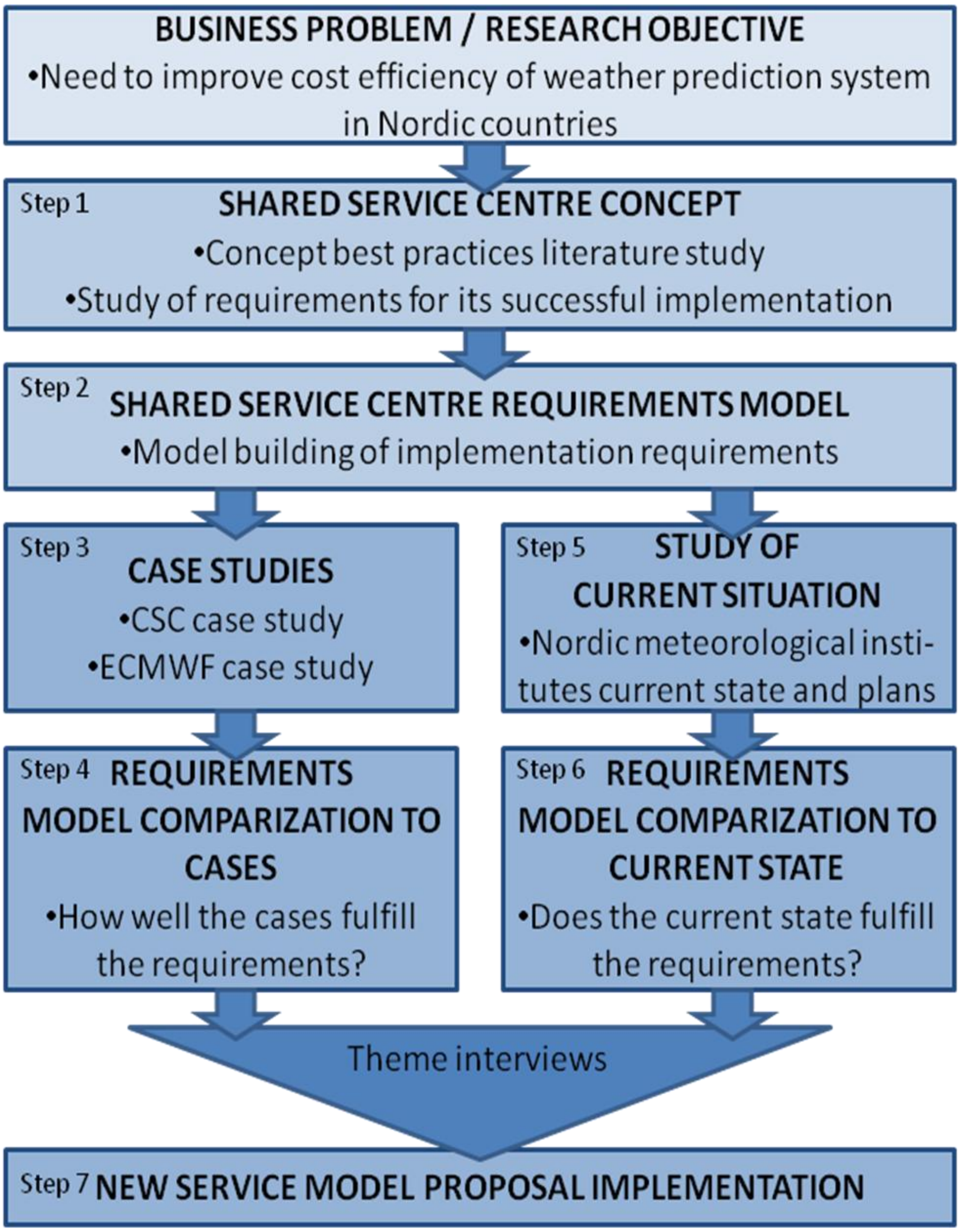

Figure 4. Research process of this study.

The outcome of the study is a shared services center model proposed to the case company and based on: a) theoretical study of existing successful service center solutions, b) knowledge increased through the two case studies, c) by investigating the existing cooperation reports, and d) also by extensive intervening, discussing and brainstorming the topic of this Thesis with the researchers, colleagues and experts from partner organization. The proposed model suggests how to create a more efficient weather prediction system in a possible cooperation with the Nordic countries, focusing on a solution for supercomputing in weather model calculations, data pre- and post-processing and archiving solution.

2.4 Reliability and Validity

In case study research, the reliability and validity of the study needs to be opened up for the readers in such way that they can estimate these by themselves (Baxter and Jack 2008). The quality can be enhanced by writing the research question clearly, by reflecting the research question in the research design, by collecting the data systematically and by analyzing the data correctly. (Baxter and Jack: 556)

Reliability

The reliability of the research implies the researcher’s intention to minimize the possibility of misleading the readers of the research work and giving as true image of the reality as possible. The reliability of the research also means consistency of the research findings and implies that the research is conducted and documented in such a manner that the study can be repeated by following the indicated steps and arriving at similar results. (Kvale 1996: 235)

Qualitative research is sometimes criticized for being unreliable and subjective. One of these critics, Patton (1990), argues that qualitative research often lacks objective quantitative data. He also points to a possible bias caused by the researcher’s subjectivity as for the research object. To address these challenges, Patton recommends creating a more reliable research process by carefully documenting all the research procedures, thus giving others a possibility to access the bias in the research work. (Patton 1990: 482)

Validity

The validity in research data means that the findings truly represent the phenomenon the researcher is claiming to measure. There are several possibilities to improve the data validity and to reduce the possibility that the findings are invalidated.

According to Yin (2003), the validity of results in the case study is improved by investigating several case examples in the research field, as well as by establishing a chain of evidence and by gathering stakeholders’ views on the draft of the research report, among other means. Yin (2003) argues that any case study finding or conclusion will be more convincing and accurate if based on several sources of evidence.

3 SHARED SERVICE CENTER CONCEPT

This section discusses the SSC concept and the change from the in-house IT services to an outsourced production model. Additionally, implementation requirements for the SSC are analyzed, and a model is built for successful implementation requirements for a SSC.

3.1 Outsourcing vs. Small IT Units as ICT Service Providers

Information systems (IS), which are widespread in modern business practice, are basically intended to create the best possible benefits for the company business processes. Presently, there are plenty service models for providing the needed IT services available (see, for example, Janssen et al. 2010). The most common models are two which use either the company's own IT capabilities for providing the necessary services, or utilize outsourced IT services.

As for the first type, it is still quite common that IT services are provided by small IT units inside an organization as is the situation in the case company FMI in this research. The challenge with these small IT units is that they do not necessarily have enough size to have the scale advantage in their service production; and it is usually more difficult and expensive to keep all the needed knowledge inside in these small units. However, the most significant strengths of these small IT units are their capability for quick moves based on the customer needs as small inner organizational actors. These smaller units can also better fulfill the customer tailored needs as their processes are not so fixed and tight.

How fast the IT unit gets the critical mass in it to be efficient in its actions depends much on the size of an organization and its IT needs. Too small units have difficulties in getting all the required knowledge inside; they also typically have a small number of users who need a wide variety of services. In this case, the smaller units do not necessarily operate very efficiently. In case of a larger corporation size, the IT unit often reaches the critical mass to achieve the scale advantage and can operate very efficiently cost and quality wise. In these cases, the decision to outsource is more on strategic level than just a matter of trying to save costs.

As for the second option, the trend has currently been to outsource IT services, and this development keeps on growing (Herbert et al. 2008: 38). Within this second option, in many cases, there may also be another possibility available, namely to join forces in IT service providing by setting up service centers for various service areas. These centers can be shared with organizations from the same working field or by organizations with similar service needs.

Business practitioners have different opinions on the cost efficiency of possible solutions and service models in IT service providing. Sometimes it is argued that outsourcing is cost efficient; but only too often the IT costs seem to rise, especially after several years of outsourcing relationships, when the organization has lost its skills in the IT area. It is also argued that even more efficient IT services could be provided, if a larger scale advantage is arranged. The next subsection discusses one possible solution to create a scale advantage in an efficient way.

3.2 Shared Service Center Concept

A SSC is often used as a solution to provide services for several customers with similar interests and needs. Krause et al. (2010: 267) defines the term "shared services" as the resource concentration of the company in performing activities in order to service multiple internal or other partners. This usually comes along with the standardization and consolidation of redundant information processes.

Herbert et al. (2008: 38) agrees that, in the past two decades, there has been an increasing trend for replacing the traditional IT service model of organizing service activities in-house with an outsourced model. There are several arguments for closing down one's own IT services and replacing them with an outsourced or other different service model. For the outsourcing model, the most important reason has always been an opportunity to focus on the core activities. It is this model that allows the company to concentrate on the field of its expertise and leaves the IT business for those that are professionals in this area. Secondly, cost savings have also been argued to be achievable in outsourcing. In many cases, however, there has been no consideration of any alternative solutions, one of which is the SSC service model.

According to Herbert et al. (2008: 38), a SSC solution is a model that exists in between the traditional in-house service model and outsourcing. It is a solution that gives the organization a possibility to get benefits of both, in-house model and outsourcing. This model allows companies to focus on their core activities while still leaving them a chance to retain control of the targeted services. One important fact is that a SSC solution also makes possible to avoid significant workload of negotiating and monitoring external contracts. It also gives an advantage of the partly in-house approach in the sense that those activities that would have been let out to others often turn out to be much more significant than was expected originally; and by using the shared service solution this vital knowledge can still be retained in the company for the future.

For the SSC to become successful, it has to meet a long list of specific requirements. Among other considerations, when thinking about a SSC, it is important to select the location very carefully when setting it up. Many of the companies that were early adopters of business process outsourcing have found that the expense of leaving an unsuitable location once a SSC is launched can become a challenge. That is why business practitioners recommend (Herbert et al. 2008: 38), first and foremost, to take a strong approach when selecting a destination for the center in order to minimize the risks and maximize the long-term savings. The method for choosing the site location should include the geographical, business and financial aspects. Other vital requirements for the SSC to become successful are discussed in Section 3.5. The following sub-section discusses the topic of possible SSC benefits compared to in-house IT services or an outsourced model.

3.3 Shared Service Center Benefits

In business and research literature, there are traditionally several reasons distinguished for choosing a shared service model. Usually, cost reduction and customer satisfaction are placed on top of this list for shared services implementers as they work to support their businesses. Herbert et al. (2008: 38) argues that, in most cases, cost savings is the main reason behind a decision to change the existing current service model to a SSC. Studies by Mangano (2010: 7) also confirm that the satisfaction with the SSCs is mostly attributed to their cost efficiency. But there are also other benefits in this service model that can be considered essential for the company's success in a longer lifespan.

Herbert et al. (2008: 39) point out that, apart from cost savings, SSCs have another considerable advantage in retaining and protecting the company's valuable expertise. This has a strong appeal for many companies in adopting a SSC model, even if they may not realize that expertise is critical to their competitive advantage. This advantage is based on the well-known fact that, once a company loses its IT skills, they are really hard to build up again; and this often leads to a situation when a company becomes fully dependent on its IT service provider.

Another advantage is that by centralizing activities into a SSC the participating companies can execute these activities much more efficiently and specifically; so that there is a feasible chance to maintain a critical mass of resource, skill, education and recruitment to turn such a center into a center of excellence. In this case, such centers of excellence could be very helpful in creating and maintaining even more advanced technology services that would fully, and pointedly, support the companies' critical business processes. According to Wilson (2004: 41), one aspect to consider here is for the companies to concentrate and agree on determining the best possible implementation approach for their shared center, which is not a simple matter.

Finally, the SSC leads to numerous benefits for the organizations through a wide area of cooperation that this model is based on. Once the cooperation between different actors is established, further cooperation usually emerges, also in other areas, going beyond the originally planned IT cooperation. This can help to produce even more cost efficient solutions and help new services or service models to be designed.

Therefore, it can be concluded that a shared service model contains a range of opportunities for positive impact on the company's business. These benefits make the shared service model competitive compared to traditional outsourcing of IT services.

Before discussing the requirements for setting up a SCC, it is necessary to overview also potential weaknesses of the SSC model, as compared to in-house IT services or an outsourced model. This overview is done in the following sub-section.

3.4 Shared Service Center Weaknesses

Among the SSC weaknesses, the shared service solution seems, first of all, to be tightly tied to some specific persons in an organization. Research by Krause et al. (2010: 268) points out that, in their case studies, the central persons (key actors) in SSCs prove to have special importance for the success of the model. Their studies show that, without this kind of key actors, it is unlikely that shared service services would have started at all. Their research also reveals that these key actors typically have no special functional importance in the business, but rather hold political or other significant positions in their organizations. This research suggests that, for the success of the shared service solution, it is vital to have such active actors existing in the organization, if a SCC is planned.

Additionally, Krause et al. (2010: 268-269) argue that another organizational condition is important to decide whether the SSC cooperation would succeed or fail. This condition is the existence of a preceding cooperation. In the case studies by Krause et al. (2010: 271), these two conditions – the above mentioned existence of the key actors and the existence of a preceding co-operation – were present in all the shared service cases and played an important role for launching and success of the studied SSCs.

Among other potential deficiencies, Janssen et al. (2010: 241) states that the SSC model has a disadvantage in achieving the economies of scale and scope being restricted by the limitations of the internal organization. Moreover, SSCs are often limited by their governing organizations and not allowed to serve external clients, thus being unable to enhance their cost effectiveness. This somewhat explains why implementation of new technologies is often strategically associated with outsourcing as a more feasible option, rather than SSC arrangements.

Finally, when setting up a SSC, internal resistance to change can become a challenge also, as in any development project. In the SSC case, however, this resistance may be even more difficult than, for example, in case of outsourcing, as the same existing staff is usually used also in the developed SSC service. Business practitioner warn that the bottom-up integration usually do not happen, unless the organization has a clear execution model for setting up its services.

Therefore, potential weaknesses of the SSC solution, if compared to in-house IT services or an outsourced model, need to be carefully considered when planning the IT shared service model in an organization. But it should be stressed that many of the weaknesses overviewed in this sub-section would not threaten the shared service model, if considered well in advance, and they are not core or crucial to the business that is planning the change.

To further analyze the concept of a SSC, there are many requirements that need to be fulfilled in order to make this model successful. The requirements for the SSC are investigated in more detail in the following sub-sections.

3.5 Shared Service Center Requirements

Based on the literature search, this sub-section, first, discusses the operational and organizational requirements for setting up a SSC; then, it separately overviews its technical requirements; and finally, suggests a summary of the requirements for the sheared service center to be successful.

3.5.1 Operational and Organizational Requirements

For setting up a SSC, there are several operational and organizational requirements that need to be considered. As already discussed, the first requirement identified by Krause et al. (2010: 268) points to the need for key actors. Without these persons, it seems unlikely that SSCs can even be established. The presence of key actors can, therefore, be considered as an important general requirement for the emergence of shared service cooperation. Further on, these actors would take active part in the development of networks, so that the shared center can continue functioning successfully.

A second requirement is the need for the previous cooperation between the participating organizations (Krause et al. 2010: 269). Quite often, it is also the results of the activities of the key actors on an individual or organizational level. The absence of such previous cooperation could become a significant barrier for, or could potentially slow down, effective establishing of a SSC model.

SSCs can also have considerable advantages in retaining and protecting valuable expertise. If expertise is seen as a critical factor to be protected, this can motivate organizations towards setting up a SSC instead of, for example, outsourcing. The SSC can also help organizations create centers of excellence thus helping them in creating and maintaining high quality of their services and supporting pointedly the company's critical business processes.

Staff relocation is also one aspect to consider, since it is common that at least part of the existing staff would be used also in the new service model. Moreover, this staff should possess the whole spectrum of the knowledge and expertise for servicing the customers in the future.

3.5.2 Technical and Economic Requirements

A SSC solution also requires various technical aspects to consider. For example, the services to be provided are often geographically more distant than in-house services, and this calls for efficient telecommunications systems. Therefore, technical requirements need to be considered carefully, because there will be new, additional kinds of considerations compared to the in-house service model. In this sub-section, two major kinds of technical requirements for a service center solution are identified and discussed – technical and economical.

In the technical requirements area, telecommunications will, first of all, play a vital role in the shared service solution, as fast and efficient telecommunications are required for successful service production. To serve the communications needs of the SSC, there are two possibilities, and these are either connections bought from a telecommunication operator or the use of the Internet. Service practitioners believe that the best functionality and cost combination can be achieved by using a suitable combination of these two. The research by Weis (2010: 430) argues that, as the Internet evolves, the segments of the Internet have demonstrated their ability to serve the changing and dramatically growing demand for online services quite well. In many cases, organizations can combine their development and production needs successfully just by using the Internet. These organizations have proven their ability to provide leading-edge services to their customers while simultaneously achieving economies of scale brought to their customers by the evolving Internet.

The other major technical requirement is risk management which is a crucial factor when setting up IT services outside the organization. In risk management, research by Kenney et al. (2002: 57) defines such constituents as policies, procedures, and mechanisms to manage and respond to identifiable risks. An effective program also has a comprehensive scope and includes regular audits, tested responses and strategies, built-in redundancies, and openly available, assigned responsibilities. To be effectively implemented, this risk management program should be known and understood both within the organization and by relevant stakeholders. If an organization takes care of making its risk management program known to all the participants, they become aware of the risks and thus can manage them better. Finally, (Kenney et al. 2002: 57), in order to reach its purpose, the risk management program should balance the value of assets with the direct and indirect costs of preventing or recovering from damage or loss.

As for the economical requirements, cost savings are in most cases the main reason behind a decision to change the current in-house service model to a SSC. Without the forcing need to achieve cost savings, there most likely does not exist enough motivation for the planned change to be implemented successfully.

Cost savings are usually achieved mostly by scale advantage. The services that are provided using the SSC model need to be such services that do really support scale advantage. This Thesis, for example, is mostly about high performance computing and data archiving services and these services are most likely benefiting of scale advantage. There exists also different kind of services that do not support scale advantage so well and the required savings cannot necessarily be achieved by this solution.

In the next section, the SSC requirements are summarized and a model of the SSC requirements is presented.

3.6 Summary of the Requirements for the Shared Service Center

This sub-section summarizes the requirements that need to be fulfilled for the SSC to be successful. These requirements are identified based on the literature review and presented as a model for setting the SSC in Figure 5.

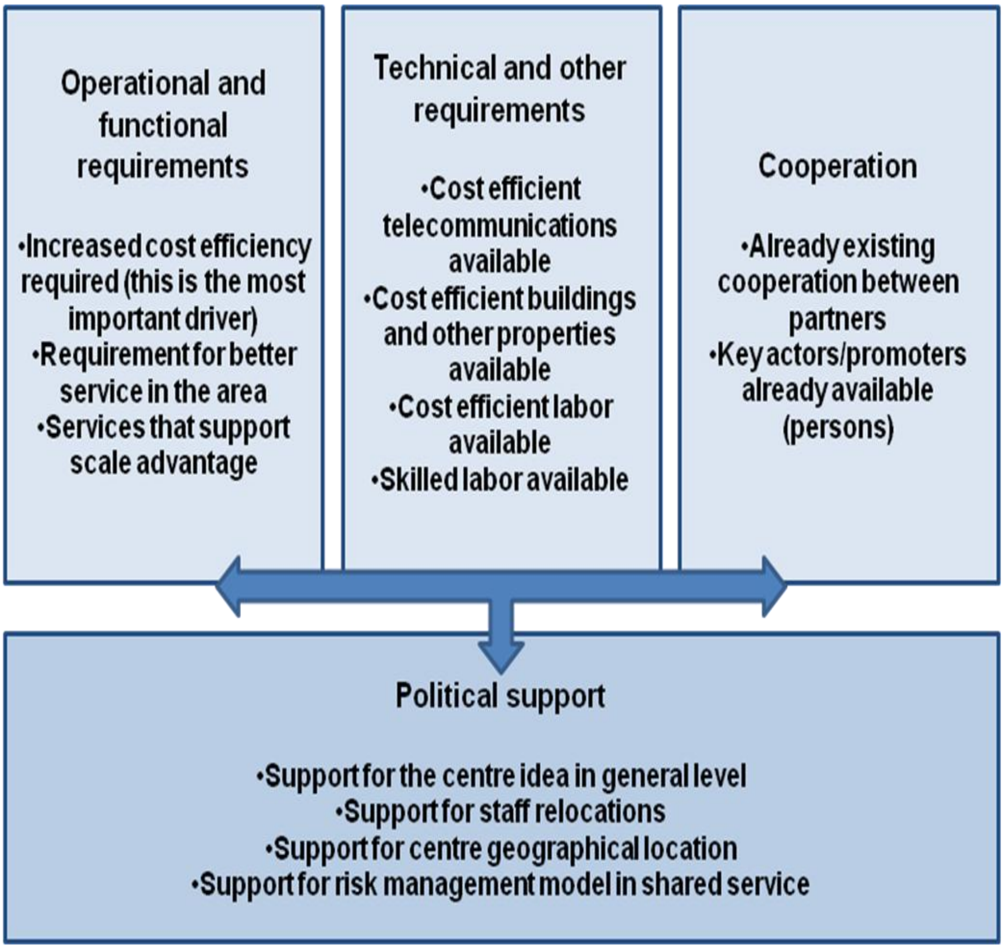

Figure 5. Requirements for successful SSC.

As seen in figure 5, the requirements for setting the SSC are divided into four requirements areas. The first area, operational and functional requirements, includes factors of cost efficiency and a requirement for services that support the use of a larger scale in service production. The costs of new information systems need to be considered carefully because there will be new different kind of costs compared to the in-house service model.

The second area, technical and other requirements, comprises of cost efficiency from technical point of view. Telecommunications plays a vital role also in the shared service solution as fast and efficient telecommunications are required in service production. Also the need for high skill to be available for the SSC is presented.

The third area, cooperation, consists of the need for existing cooperation in the planned service area and also presents the need for the key promoter persons existence already at the beginning of the service development. The presence of key actors is identified as a basic organizational requirement, both for the emergence of the shared service cooperation and for further development of its networks. Without these key persons, the barriers to establish an efficient cooperation are considerably higher. The need for existing cooperation between the participating organizations is also considered essential as this cooperation is seen as a foundation for the emerging new cooperation.

Finally, in order to be successful, all the areas need political support which is therefore distinguished as a separate area of requirements. Even promising plans do not succeed without proper support on a political level and this is actually the most important requirement to be fulfilled in order to get the cooperative solution actually implemented. Some particular issues, such as selection of the location and staff relocation also need to be considered when planning a SSC. It is common that at least part of the existing staff is employed in this new service solution, and it is vital to choose a good location before launching the SSC.

Summing up, this sub-section discussed the SSC requirements and made it obvious that there are many aspects to be considered when setting up a SSC. The resulting model will be used in the coming sections for comparison of the existing SSC situation to various implementations of SSCs in case examples.

Here it also need to be noticed that, since the identified requirements may be easier for some companies to meet than for some others, it indicates that the usefulness of the SSC solution may be different for different companies. Therefore, this model should be treated with caution, as a general outline of requirements which in every case needs to be analyzed and adjusted to a particular situation. In this paper, the model is developed for analysis of the existing conditions in the case company and for analysis of case examples of successful SSC implementations by other companies. This analysis in presented in the subsequent section.

4 CASE EXAMPLES OF SUCCESSFUL SHARED SERVICE CENTERS

This section presents two benchmarks of successful SSCs in similar organizations. The analysis of these benchmarked in based on the results of the interviews with informants from the case organizations 1 and 2, as well as studying their public documents and discussions with external experts. These case examples are studied to investigate the possibility for the successful shared service implementation using a similar model in weather prediction systems.

4.1 Case Example 1: CSC – IT Center for Science

Case 1 is represented by a Finnish IT Center for Science Ltd. (CSC). It is national organization administered by the Ministry of Education, Science and Culture.

4.1.1 Organization Background

CSC is a non-profit organization providing IT support and resources for academia, research institutes and companies. Today, its services consist of modeling, computing and information services. Currently, CSC provides Finland's widest selection of scientific software and databases and is the owner of the Finnish most powerful supercomputing environment. Its computing services are provided to researchers via the Funet network which is also maintained and developed by CSC. CSC has been in computational and network services since 1971, and in more than 40 years of CSC's history it has changed ten different names (Ahonen 2011).

Finnish researchers have had access to national computing services for decades now. The first mainframe computer, a Univac 1108, was installed on the premises of the Finnish State Computer Center in 1971. That new computer was bought with the financial support of the Finnish National Fund for

Research and Development (Sitra), and was then the fastest computer type in all Europe of its time (Ahonen 2011: 17).

Later, CSC's activities expanded to go beyond mere computing services and switched to providing telecommunication services to universities. In 1984, a new network, the Finnish University and Research Network (Funet), was established. This new Funet network also included the international network connecting participants, first, via Earn and later via the Internet in cooperation with Nordic university and research network NORDUnet (Ahonen 2011: 94). From the beginning, CSC was a leading actor in this cooperation.

The use of CSC's services has risen rapidly in past years, and CSC has grown in size lately, for example, in the number of its staff. Figures 9 and 10 demonstrate the increase of the staff numbers.

Key indicators	2010	2009	2008	2007
Number of staff	210	191	166	152
Permanent	191	175	150	131
Fixed term	19	16	16	21
Men	74%	77%	78%	79%
Women	26%	23%	22%	21%
Age distribution				
< 30	11%	12%	16%	10%
30-39	44%	44%	36 %	41%
40-49	32%	32%	36%	37%
>50	13%	12%	12%	12%
Average age	40	39	39	40
Education				
Basic and vocational 21%				
University of applied sciences 11%				
University 45%				
Post-graduate degrees 23%				

Figure 9. Development of staff numbers 2007-2010 (CSC 2011).

As can be seen from Figure 9, the number of staff has risen from 152 people employed in 2007 to 210 specialist working for CSC in 2010. Key financial indicators have also demonstrated growth in the same years.

Key indicators	2010	2009	2008	2007
Operating profit (%)	0,09 %	0,12 %	0,49 %	0,19 %
Return on equity	2,45 %	3,10 %	18,00 %	13,91 %
Return on invested capital	3,61 %	4,57 %	24,85 %	19,59 %
Quick ratio	2,6	2,5	1,9	2,2
Equity ratio	24,95 %	24,60 %	22,78 %	27,56 %

Figure 10. Key financial indicators (CSC 2011).

As can be seen in Figure 9, CSC has shown growth on return on equity, return on investment, and other financial ratios, though the operating profit stayed close to almost zero as required for a non-profit organization.

4.1.2 Services and Customers

Today, CSC – the Finnish IT Center for Science Ltd. – provides computing services, communication and data storage services as well as scientific expertise in its working field for the whole research community of Finland (CSC 2012). CSC provides the following services for its customers.

Data services for science and culture

CSC offers a wide area of solutions for data storage, management and analysis needs. These services cover, for example, long term data storage, databases, data mining, analysis and visualization. Backup and archive services form the core of CSC's data management. CSC has also tailored its special services for different scientific areas such as biosciences, chemistry and linguistics. Various other organizations, for example, the Finnish academic library systems, are also managed in CSC's service environment (CSC 2012).

Funet network services

CSC maintains and develops Funet, and provides fast research and education network services based on this network. Funet is a high capacity data communication network which connects most of the Finnish universities, polytechnics and research institutions providing national and international communications services for research and education. Funet has a large number of users, amounting to approximately 350,000. Today, Funet is considered to be one of the most advanced research networks in the world which has provided reliable services for its users for years (CSC 2012).

Figure 6 shows the rise in the Funet international network traffic in the past decade.

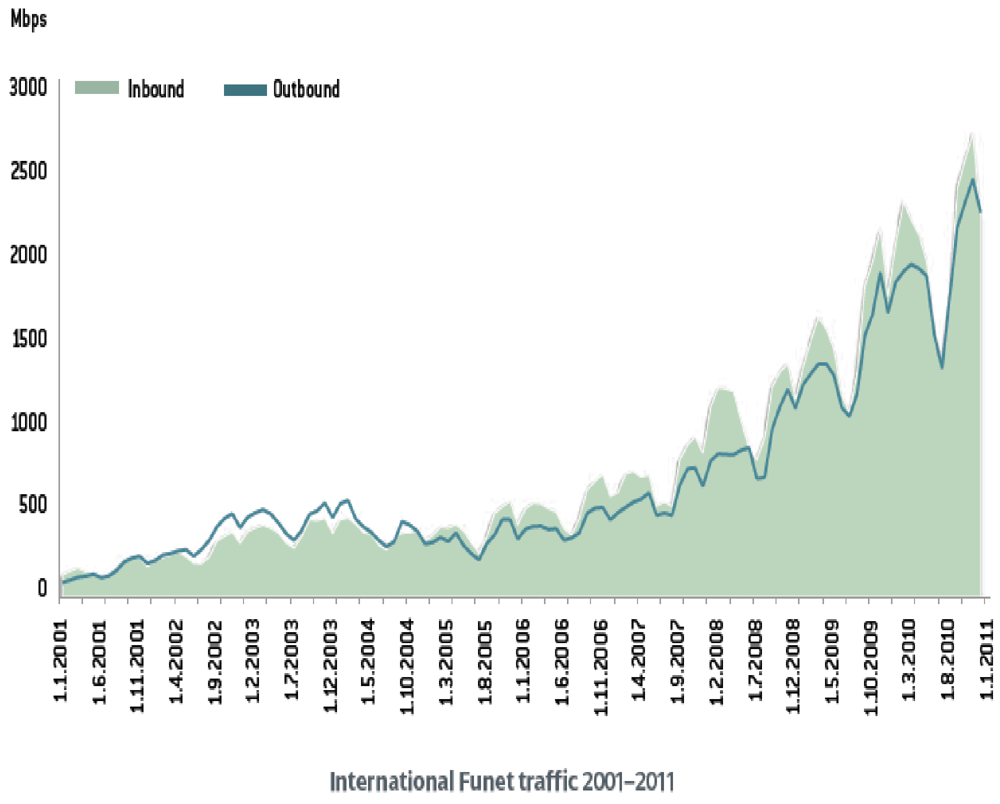

Figure 6. International Funet traffic 2001-2011 (CSC 2011).

The Funet network is connected to the pan-Nordic NORDUnet network that provides access to all international services and links Finland to global research networks (CSC 2012). The pan-Nordic NORDUnet network cooperation builds a foundation to the research cooperation between the Nordic countries and provides high capacity telecommunications services for the researchers to other actors abroad.

Figure 7 illustrates the NORDUnet network connection in the current network setup.

Figure 7. International NORDUnet network (NORDUnet 2012).

As can be seen in Figure 7, the NORDUnet network covers the Nordic countries providing connections between Helsinki, Stockholm, Oslo and Copenhagen, among other cooperation participants.

Computing services

The Nordic research community has a growing need for high performance computing services. In Finland, CSC is the actor to provide these resources at the highest technical level measured in computing power. Some customers require especially large amounts of computing power, and CSC can provide it massively in parallel systems. In addition to computing systems, one important service by CSC is the provision of scientific applications and databases for use by the research community (CSC 2012).

CSC's supercomputing environment is designed to be able to run even the most demanding parallel programs as efficiently as possible, technologically wise. Currently, the most powerful of CSC's current computers, a Cray XT4/XT5 system called Louhi, has a theoretical peak performance of more than 100,000 billion of floating point operations per second (CSC 2012).

CSC also provides its customers with consultations in scientific computing and information technology. FMI, for example, is a customer of CSC in this consultation area (CSC 2012).

CSC is an active member in different cooperation bodies in supercomputing nationally and internationally. For example, the Partnership for Advanced Computing in Europe (PRACE), a pan-European Research Infrastructure for High-Performance Computing, is one of them; and CSC represents Finland in the European Grid Infrastructure (EGI.eu) organization (CSC 2012).

Figure 8 shows the development of logins and batch jobs 2006-2010 on CSC's servers.

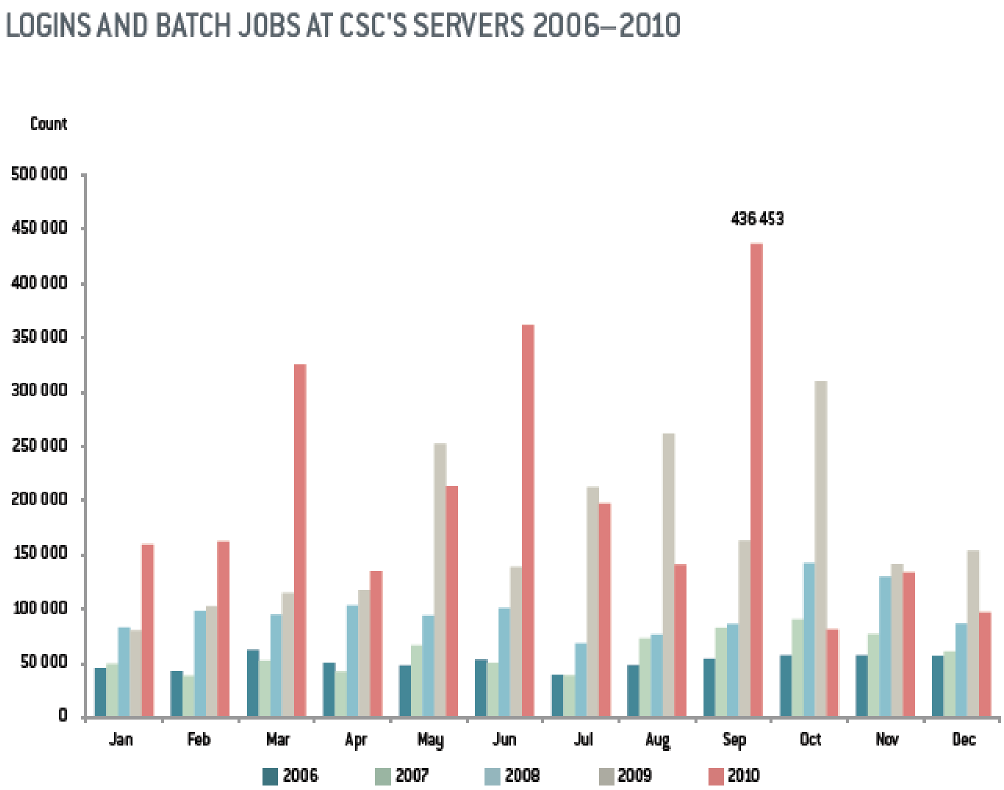

Figure 8. Logins and batch jobs development 2006-2010 (CSC 2011).

As can be seen in Figure 8, the development of logins and batch jobs 2006-2010 at CSC's servers has increased rapidly during the past years showing the increased need for CSC's shared services.

Application services

CSC also maintains several programs and services in its application services. CSC has Finland's widest software selection for scientific and engineering research. This software selection consists of around 200 scientific programs. Additionally, CSC provides consultancy services for these scientific programs. CSC is also active also in open-source software development (CSC 2012).

In the CSC software library, researchers can find different programs relating to various research areas including chemistry, physics, biosciences, environmental sciences and geosciences, mathematics, statistics and nanoscience, computational fluid dynamics and structural analysis. The CSC software library has both, freely distributable academic programs and commercial programs that are subjected to a license fee (CSC 2012). CSC’s customers can have remote access to CSC's computers, databases and scientific programs through the CSC maintained Funet network.

Other information management services

CSC maintains and develops various cost-effective, centralized information technology services, especially for governmental actors in education and science. These services cover, for example, centralized data management services, maintenance and development of the information systems, user identification systems and consultancy services for higher education (CSC 2012). Consultancy services are offered to CSC’s customers on IT projects and development needs (CSC 2012).

Overall, CSC provides a wide range of services many of which are maintained and developed in cooperation with other institutions, as a shared services solution.

4.1.3 CSC Services Compared to the Needs of a Meteorological Shared Service Center

CSC provides a number of services that are very similar to the needs of the meteorological organizations in the weather services and prediction area. For example, the achieved service implementation and production by the CSC using a shared service solution is one of them. The services which are similar to the needs of meteorological organizations are overviewed below.

A. Computing services

First, CSC provides high performance computing services for its customers. Meteorological organizations, in their turn, also provide similar services for their customers in part of weather model calculations, which creates a possibility for successful shared services in this area. Second, in past years, CSC has been a service provider for FMI in weather model calculation services, which proves a possibility of establishing a SSC to provide these kinds of services together. Although the weather model calculations were made only for a single country so far, similar services could most likely be provided in a similar way for several participants, too. Importantly, CSC's computing services also proved to be able to reach the scale advantage in supercomputing area.

B. Data storage services

First, CSC provides data storage services for its customers. These services are also needed in the Nordic meteorological organizations as shared service needs; moreover, the data storage and archiving is currently one of the most challenging areas of IT work that meteorological organizations have in this area. The amounts of data are large; and a shared service could benefit the meteorological organizations as the weather data would only be stored once instead of several times. Second, CSC provides centralized services to various organizations. For example, Finnish governmental actors benefit a lot from this kind of services in their daily work, which proves the data storage services a success by using a cooperative, shared service solution in such services production.

C. Technical consulting

CSC provides different kind of technical consultancy services in its field. CSC offers, for example, consulting services in code optimizing area, with different scientific codes. Potentially, the knowledge gathering in a SSC can be used for the meteorological organizations too. For meteorological cooperation, the knowledge gathering in the weather model development area is similar in nature to the development model used by CSC, for example, for scientific code consultancy services. Eventually, knowledge sharing will lead to creating a center of excellence in the future.

D. Telecommunication services

CSC has established a telecommunications network for a group of actors with similar needs. This network has proven to be highly available technically and able to provide reliable service for its customers in a cost efficient way. The successful telecommunication network services of CSC (especially Funet) have become part of the NORDUnet network. If a similar meteorological cooperation were established together with CSC, these services would be used by meteorological organizations too, as NORDUnet covers all the Nordic countries and is the most cost efficient solution of today to produce high bandwidth telecommunications services between the meteorological offices. The Funet network service is a good example of possible cooperation, as it fits directly to the needs of the Nordic meteorological services.

Overall, a range of shared services in high computing and related services by CSC gives a good example of providing scientific services in a shared manner, which has been in use for decades, and supports a possibility of setting up a similar center for meteorological needs, too. Additionally, the CSC example points to a possibility to build up such services in a cost efficient and highly reliable way.

4.1.4 Value of CSC's Shared Services for Its Customers

CSC has built a SSC for a wide range of services and has been using it for decades. Based on the literature research and also the interviews with the FMI informants (Head of Group A and B, System Specialist A) the added value for its customers can be summarized as follows (Table 2).

Added value for customers of CSC's services
• Cost efficiency from the scale advantage in telecommunications services and in general (Informant Head of Group A and B)
• Cost efficiency and higher expertise from the scale advantage in su-

percomputing services (Informants Head of Group A and B)
• Higher quality services are achieved by creating a center of excellence through getting the critical amount of resources together in the service centre (Informant Head of Group A and B, System Specialist A)
• Possibility for Finnish scientists to use higher computing capacity that would not be possible without a SSC (Informant Head of Group A and B, System Specialist A)
• Cost efficiency and higher expertise from the scale advantage in software development work (Informants Head of Group A and B, System Specialist A)
• Cost efficiency from the scale advantage in other supporting IT systems administered by CSC (Informant Head of Group A and B)
• High skills in consultancy on the specific areas of knowledge (Informants Head of Group A and B, System Specialist A)
• Enhanced cooperation between the Finnish and international research communities (Informants Head of Group A and B)

Table 2. The added value for customers of CSC's services.

As can be seen in Table 2, CSC has managed to provide shared services that offer a range of unique benefits to its customers, thus adding value and making CSC's services attractive for the customers. The range of these benefits is most likely even wide, since Table 2 lists only those benefits which came out most often in the interviews with the informants in this study.

Overall, CSC can be said to create added value for its customers in several directions, especially in terms of cost efficiency derived from the scale advantage of providing services to a group of similar users, and higher expertise in its specific areas of knowledge. Eventually, providing these kinds of services led to the development of CSC into a center of excellence, backed up by strong cooperation network additionally benefiting its customers.

4.2 Case Example 2: ECMWF – European Center for Medium-Range Weather Forecasts

Case 2 is presented by the European Center for Medium-Range Weather Forecasts (ECMWF). ECMWF is a weather modeling organization that works in the field of meteorology close to the subject of this Thesis work, which makes it a valuable benchmark for this Thesis.

4.2.1 Organization Background

ECMWF is a global Numerical Weather Prediction (NWP) center. NWP is a technique used to forecast the weather by using computers to make predictions from the present situation up to several days ahead. ECMWF's objective today is to operationally forecast the weather up to 15 days ahead by employing its research and development activities (ECMWF 2012). Figure 14 illustrates a comparison of ECMWF forecasts with other institutes in global weather model forecasting results.

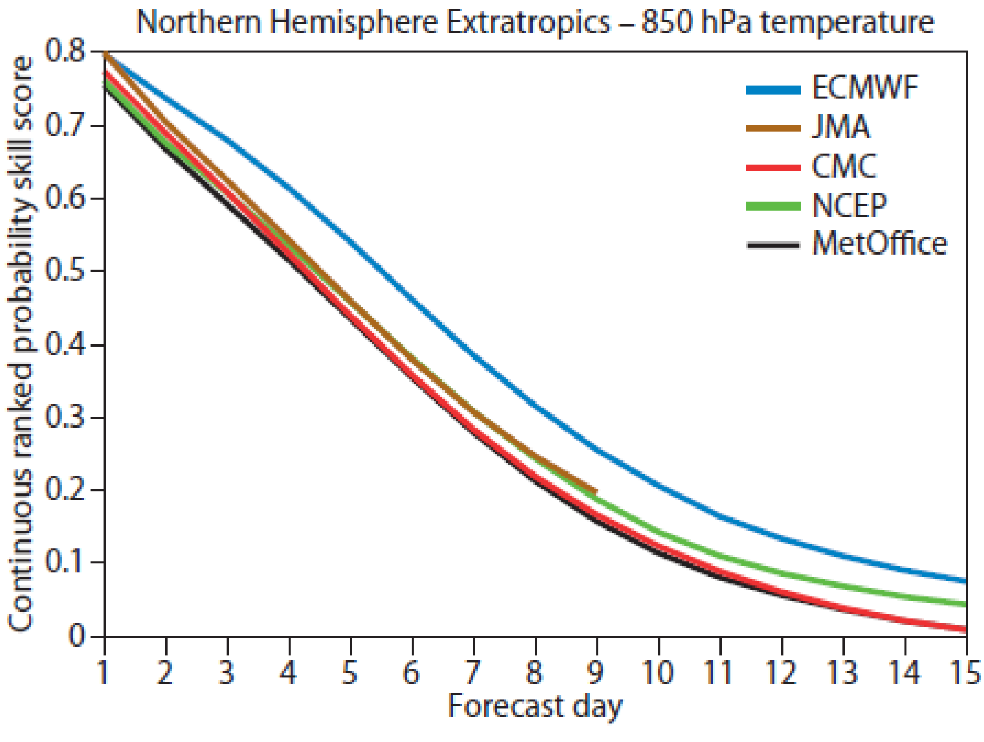

Figure 14. Comparison of the ECMWF Ensemble Prediction System (EPS) scores with other centers' results (ECMWF 2011).

As can be seen in Figure 14, the ECMWF has the best forecasting expertise in its working field. In this comparison, ECMWF is the only SSC, while the others are national weather services or other institutions.

ECMWF was established when the European governments agreed to combine their individual resources and set up an intergovernmental organization that had the goal of developing, improving and operationally producing up to 10 days medium-range weather forecasts, the European Center for Medium-Range Weather Forecasts (ECMWF 2012). A Convention established ECMWF which came into force on 1 November 1975. ECMWF's first real-time medium-range forecast was made in June 1979, and it has been producing operationally medium-range weather forecasts since 1 August 1979 (ECMWF 2012). Since then, ECMWF has grown rapidly and today more than 30 States support and finance ECMWF.

ECMWF is one of the world leaders in global medium-range numerical weather prediction (NWP). ECMWF is responsible for the development and operation of global models and data-assimilation systems, and for collection and storage of appropriate data. ECMWF is preparing forecasts by means of numerical methods and providing initial conditions for the forecasts. ECMWF assists in implementing programs of the World Meteorological Organization and provides advanced training to the scientific staff of the Member and Co-operating States in the field of numerical weather prediction (ECMWF 2012). ECMWF also makes the data in its extensive archives available to outside bodies.

As for funding of ECMWF, in 2012, the Member States and Co-operating States will contribute £40,409,900 to the ECMWF budget. The scale of each State's contribution corresponds to their Gross National Income (GNI). Figure 11 shows the percentages of each member's contribution to the budget in 2012 (ECMWF 2012).

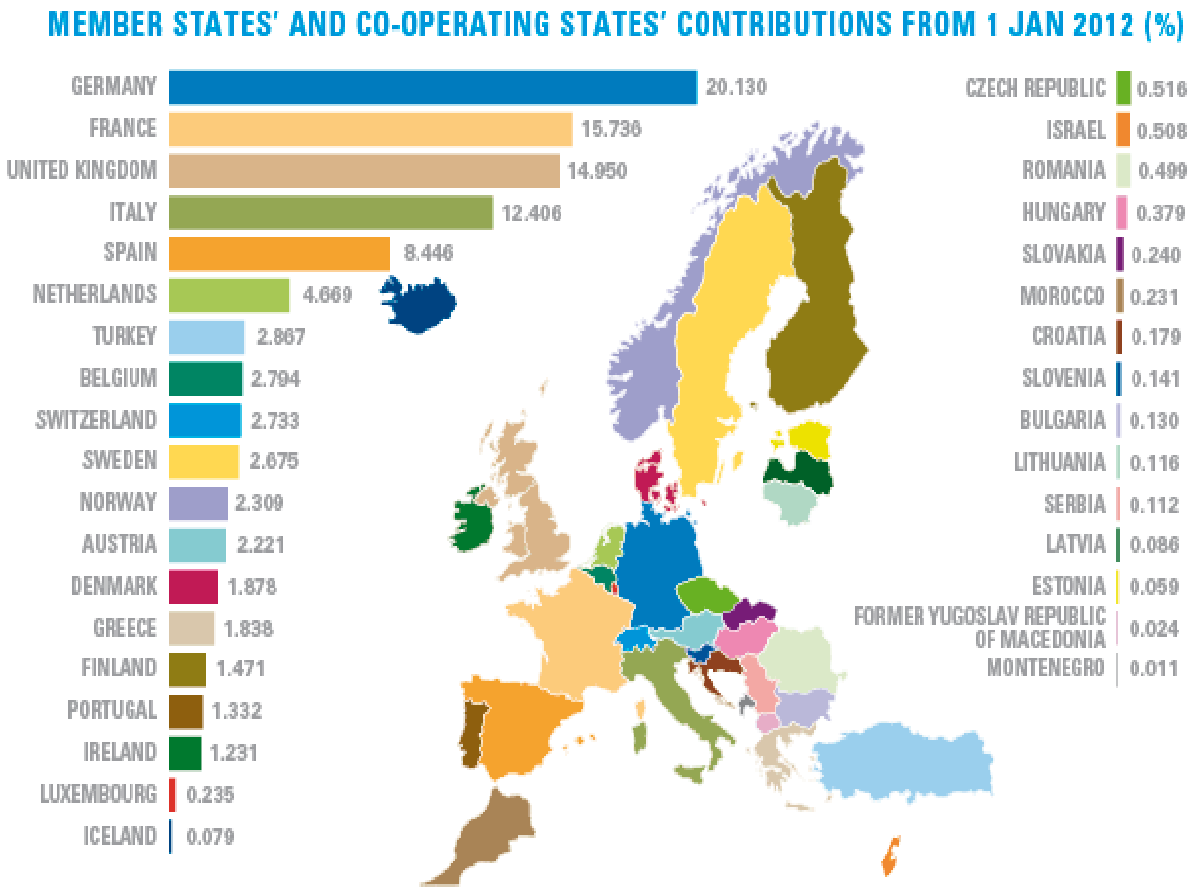

Figure 11. ECMWF funding in 2012 (ECMWF 2012).

Figure 11 shows that the biggest contribution is made by the biggest European states, Germany and France, while Finland only comes the fifteenth on this list, preceded by Sweden (10th), Norway (11th) and followed by Iceland (19th). This distribution of member states contributions proves the possibility for economies of different size to successfully participate in cooperative solutions.

4.2.2 Services and Customers

ECMWF predicts the behavior of the atmosphere in the medium-range up to ten days ahead. ECMWF does also seasonal forecasting which is a developing field of work currently. The ECMWF customers consist mostly of national meteorological services (NMSs) (ECMWF 2012).

Weather prediction services

The behavior of the atmosphere is governed by a set of physical laws. These physical laws can be expressed as mathematical equations. Computers can be used to calculate these changes; however, these equations are complex. As there is no exact solution that can give the exact future values, numerical modelling techniques are used to provide approximate solutions (ECMWF 2012).

ECMWF predicts the behavior of the atmosphere using these numerical modelling techniques up to ten days ahead. In this time period the future state of the atmosphere at any point can be influenced by phenomena at very distant geographical locations. Many applications for this kind of forecasting, for example, ship routing, or pollution dispersion, are not limited to certain areas of the globe. This is why the whole global atmosphere must be included in the model. ECMFS's weather prediction services include these global forecasts (ECMWF 2012).

Computing services

The ability to provide high availability 24/7 weather services requires sufficient human resources and operational well maintained IT infrastructure. Operational IT environment is a central component in this weather service system and the high performance computing environment, in which weather forecasts are produced, is its key component. Also for the supported research activities the information technology components and specially the high performance computing and archiving systems are the key components that make these actions possible.

The amount of needed high performance computing capacity is described by the needs of the new weather models. The computing capacity needs have increased rapidly in resents years and this development seems to go further in coming years also. More powerful computers allow using finer grids in weather modelling. Figure 12 shows the High Performance Computing Facility (HPCF) used in ECMWF.

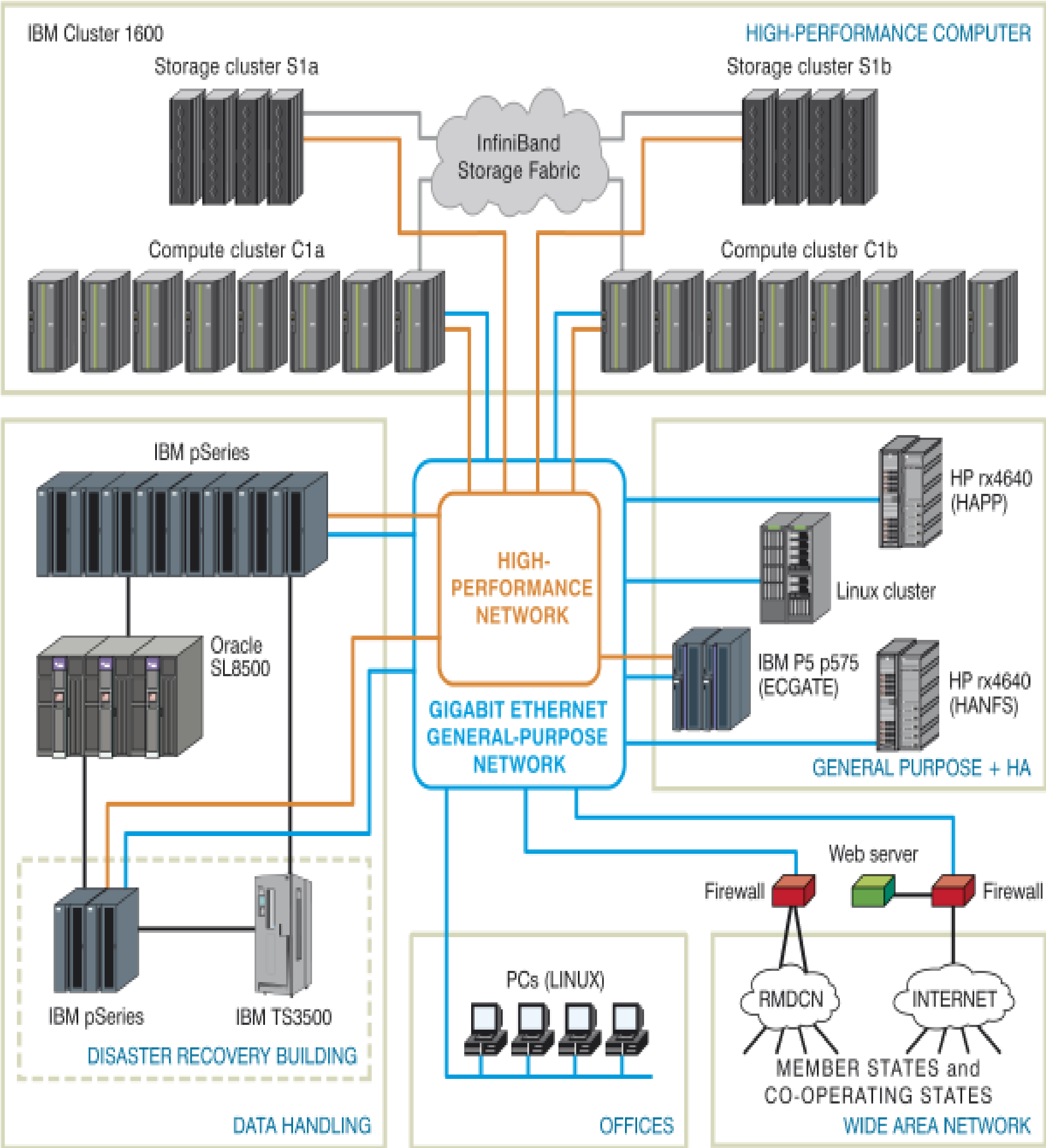

Figure 12. ECMWF computer system (ECMWF 2012).

As illustrated in Figure 12, ECMWF's High Performance Computing Facility (HPCF) comprises two identical but independent IBM Cluster 1600 supercomputer systems. Computer system needs to be duplicated for high availability in services that are considered to be part of governmental safety actions (ECMWF 2012).

As there are two computing systems and the backup computer is free most of the time for other tasks these powerful computing systems are used also for other needs of the member states. For example, different research activities can be fulfilled using the ECMWF provided capacity (ECMWF 2012).

Archiving services

Archiving services are one of the largest information systems that ECMWF has in its possession. ECMWF produces and gathers large amount of data in its actions. ECMWF is one of the world’s biggest data warehouses having a multi petabytes storage environment. Most of the data is archived and provided for the use of ECMWF’s customers in operational or research needs (ECMWF 2012).

Application services

ECMWF produces also different programs for member states use. , for example, meteorological production scheduling programs and archiving systems has been developed that can be freely used by the member states. Also different user interface programs have been developed for the use of the meteorological services (ECMWF 2012).

Weather model development

ECMWF is developing its own weather models but this activity also helps other institutes in their own model development. In many cases other weather models have same components developed in the ECMWF or in cooperation ECMWF included (ECMWF 2012).

Telecommunications services

ECMWF is responsible for maintaining and developing the Regional Meteorological Data Communication Network (RMDCN) which is part of the larger meteorological network Global Telecommunications System (GTS). Each Member State organization has dedicated network access to ECMWF over RMDCN network as the connection is part of the membership package as shown in figure 13 (ECMWF 2012).

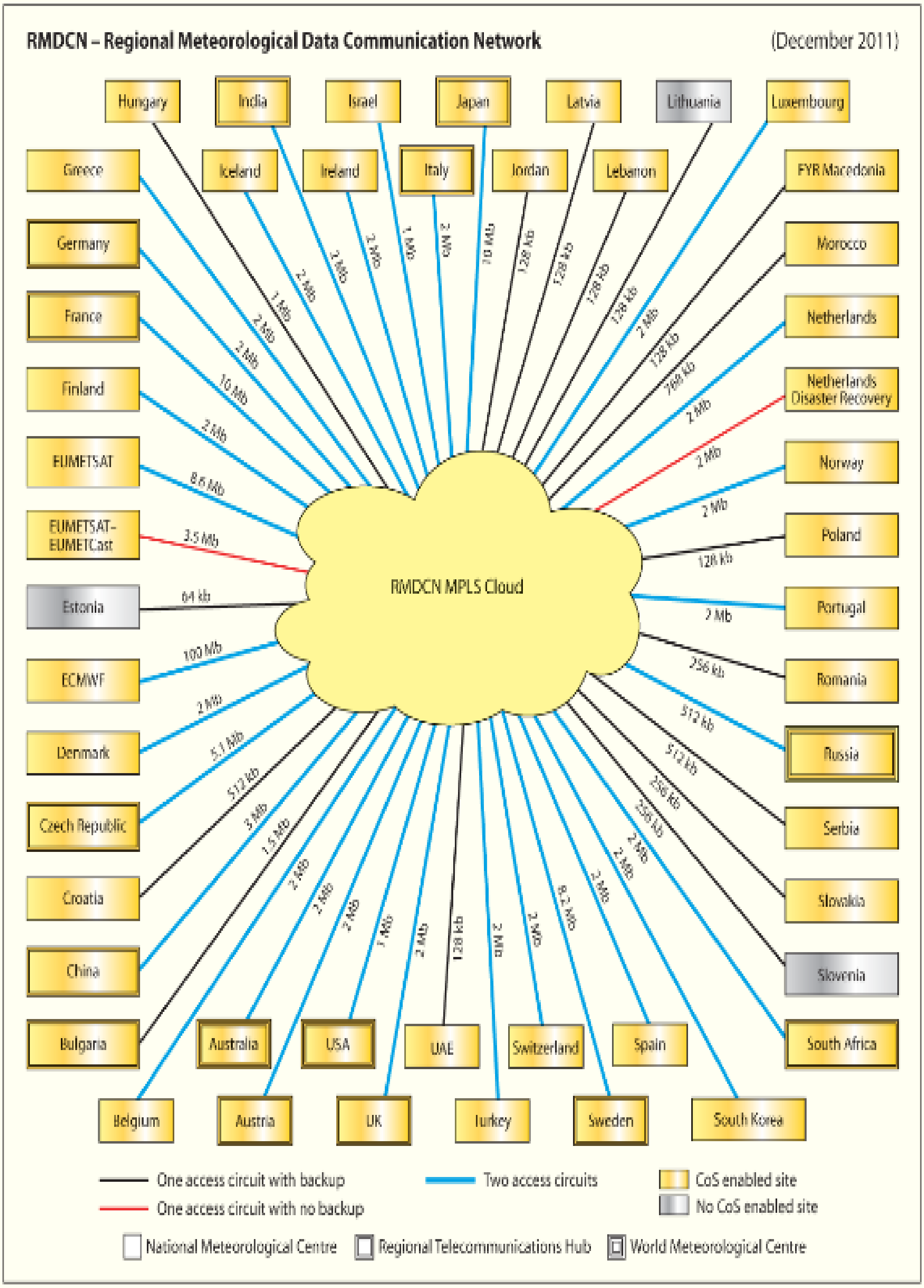

Figure 13. ECMWF administered RMDCN network (ECMWF 2012).]

Figure 13 shows the amount of telecommunications connections connected to the service administered by the ECMWF. This presents a good example of a shared telecommunications service in the field of meteorology.

Trainings

ECMWF provides also different kind of trainings for its customers. As there is lot of high research and development skill centered in the ECMWF it is useful to share the knowledge to the members in these trainings (ECMWF 2012).

ECMWF has a wide selection of services for their meteorological customers. The ECMWF seem to benefit from scale advantage very well in their services and has mostly pleased customers for their services.

4.2.3 ECMWF Services Compared to the Needs of a Meteorological Shared Service Center

ECMWF provides many services that are very similar with the needs of the case organizations in their limited area weather services. The successful implementation of global modelling using shared service model encourages the plans also in Nordic limited area weather modelling services area.

A. Weather model services

ECMWF's global weather prediction model has been proven useful for several countries and is a good example of successful shared service. Based on this success, that kind of service model could most likely be successfully used in limited area modelling also.

B. Weather model development

ECMWF is developing its global model using the resources that have been gathered from different meteorological organizations and is at the moment in its area a center of excellence in the world. This kind of development model is already used also in limited area weather models in national weather service's although the organization model is not as fixed but more as an open approach using collaboration model.

C. Computing services

ECMWF provides high performance computing services in global weather modelling as its main task of working. As the computing system is duplicated for safety and high availability reasons there exists most of the time free capacity of weather model calculations. This free capacity is provided by the ECMWF for its customers to other scientific purposes and special projects. Meteorological organizations in single countries are also providing these almost exactly similar services. ECMWF's computing services do also prove that scale advance possibility exists in supercomputing working area in general.

D. Data storage and archiving services

ECMWF also provides data storage services for its customers. These data services are also one possible service in the SSC development in the Nordic meteorological organizations. This kind of service can also be proved to be a possible success by this case example using the shared service model.

E. Technical consultation services

ECMWF provides also consulting in its specific working area and the knowledge gathered in a center in this kind of specific area can be seen very useful. This would be the case also in meteorological cooperation if a SSC would be implemented in the Nordic countries.

F. Telecommunications services

ECMWF has proven its capability in establishing a telecommunications network for a group of actors with similar interests in an efficient way. The network has also proven to be highly available and able to provide reliable service for its customers.

Overall, ECMWF provides several services that are very similar with the needs of the case organizations in their limited area weather services. Additionally, the services provided by the ECMWF act as a good example of a possibility for successful cooperative development also in the Nordic countries.

4.2.4 Value of the Center for its Customers

The customers of ECMWF had a common need for global weather prediction services. Some of the larger countries do calculate their own global weather models currently but for most of the countries this is too expensive to be done alone. Also for the larger countries the common interest in this shared service is the weather model development that benefits all of the member countries including also the ones with own global model run by themselves.

Based on the literature research and also the interviews with the FMI informants (Head of Group A and B, System Specialist A) the added value for its customers can be summarized as follows (Table 4).

The added values for customers of ECMWF's services
• Possibility to get global weather forecasts that would be too expensive to be produced on their own for smaller countries (Informants Head of Group A and B, System Specialist A)
• ECMWF has created a center of excellence by getting the critical amount of resources together in the service center (Informants Head of Group A and B, System Specialist A)
• Exceptional level of skill in this specific weather modelling area that produces world's best global forecasts (Informants Head of Group A and B, System Specialist A)
• Exceptional level of skill in supercomputing systems and procurements in this area (Informants Head of Group A and B, System Specialist A)
• Cost efficiency from scale advance in weather model running in global models (Informants Head of Group A and B)
• Cost efficiency from scale advance in weather model development research work (Informants Head of Group A and B)
• Cost efficiency from scale advance in other supporting IT systems governed by the center (Informants Head of Group A and B)
• Increased cooperation between national meteorological services (Informants Head of Group A and B)

Table 4. The added values for customers of ECMWF's services.

As can be seen in the Table 4 ECMWF has created shared services that provide several benefits for its customers. It is needed to note that ECMWF provides most likely also other different benefits for its customers that did not come out in this study.

Overall, ECMWF creates added value for its customers effectively and their work has been appreciated for decades by its customers. These kind of effective global centers of excellence provide good examples of the strength of cooperation when implemented properly in proper working field.

4.3 Requirements for the Shared Service Center in Case Examples 1 and 2

In this sub-section, requirements for setting up a SSC are compared for Cases 1 and 2 according to the same method of comparison developed in Section 3.5. The model suggested for such comparison includes four areas of requirements areas that would need to be fulfilled for establishing a successful SSC.

4.3.1 Comparison of the Case 1 and 2 Requirements

The requirements model for a successful SSC applied for this comparison is formulated in this Thesis based on the literature review conducted in Section 3 and summarized in Figure 5, page 38. This requirements model is then applied for the analysis of Cases 1 and 2 to investigate if the conditions defined are present in the existing case examples from real life. The information for comparison is based on the interviews with the informants X-Z from the case organizations and external experts in the field; for cooperation questions, the information was obtained form the relevant published research in this field.

The summary of comparison of Cases 1 and 2 against the requirements model divided into four requirements areas are presented below.

Requirements Comparison with Case 1: CSC

The requirements model for setting up a successful SSC developed in Section 3.5 is applied to Case 1 CSC example with the following results.

I.	*Operational and functional requirements*	
1	Need for increased cost efficiency	*Service center is built to achieve cost savings in services that benefit from the scale advantage. Before CSC was established, there were several actors providing services on a smaller scale, but these services proved to be more effective when provided on a larger scale, both cost and quality wise.*
2	Need for better service in the area	*The services provided by CSC are very specific and require high differentiation and deep knowledge of the working area. This kind of special services and skills proved to be more effective when gathered in one place to reach the necessary service level in this area.*
3	Services that support the scale advantage	*Most of the services provided by CSC seem to support the scale advantage. Computing services, data archiving and storage, telecommunication, knowledge sharing by consultation and also more basic IT services are successfully provided with more cost efficiency that keeps the customers satisfied year after year, so that even more services are currently gathered together by CSC.*

Table 5. Operational and functional requirements met by CSC.

The requirements shown in Table 5 (operational and functional requirements for setting up a successful SSC) are fulfilled in the CSC case. Cost efficiency of the services is achieving by using the scale advantage. Higher quality services are achieved by creating a center of excellence through getting the critical amount of resources together in the service centre.

II.	*Technical and economic requirements*	
1	Cost efficient telecommunications	*Own telecommunications network was established by CSC which has proven to be cost efficient for its customers including for example FMI.*
2	Cost efficient buildings and other	*This cost was typical of Finland and was not a special issue in this development pro-*

	properties	*ject.*
3	Cost efficient labor available	*This cost was typical of Finland and was not a special issue in this development project.*
4	Skilled labor available	*Skilled labor is available in Finnish Helsinki Metropolitan area. The center also works in close collaboration with the Helsinki Technical University (now Aalto University) which gives a good opportunity for recruiting skilled labor.*

Table 6. Technical and economic requirements met by CSC.

As seen from Table 6, the requirements in technical and economic area are also fulfilled in Case 1. The costs are typical of Finnish organizations, and no visible effort for cost savings to be achieved by getting services from cheaper labor cost countries. Cost efficient telecommunications are arranged by the case organization own network which has proven successful.

III. *Cooperation requirements*		
1	Already existing cooperation	*Universities have had existing cooperation already before the service center was established. But this technical cooperation was a new type of creating common services which deepened the existing cooperation* (Ahonen 2011: 12).
2	Key actors and promoters already available (persons)	*Key actors were available to get the governmental support for the center, although at the starting phase there was a lot of work to be done and also resistance existed* (Ahonen 2011: 12).

Table 7. Cooperation requirements met by CSC.

The cooperation requirements summarized in Table 7 are also fulfilled in Case 1. Cooperation already existed before the establishment of CSC and key actors helped to develop this model.

IV. *Political support*		
1	Support for the center idea in general level	*CSC received political support from the Finnish governmental when it was set up* (Ahonen 2011: 25).

2	Support for staff relocations	*There was no need for massive staff relocations when CSC was established, so this was not a major issue in this case.*
3	Support for center geographical location	*Geographical location was chosen in the Helsinki Metropolitan area which was supported.*
4	Support for risk management model in shared services	*Risks in this kind of research activities were not an issue as producing services was done inside Finland and there was common trust between participants and security was at a satisfactory level. Additionally, at the time of launching CSC, the data security was not such an important issue as it became later on.*

Table 8. Political support requirements met by CSC.

The requirements for political support overviewed in Table 8 are also fulfilled in Case 1. The idea of setting up CSC received the necessary support; no major staff relocation from Finland was needed; the geographical location was supported, and the risks were also on an acceptable level as the data security issues were not raised at the time of its development.

In general, the CSC case fulfills most of the identified requirements as comparison between the developed model and Case example 1 shows. The results can also be considered to support the developed requirements model as an example of a successful shared services center meets them all.

Requirements Comparison Applied to the ECMWF Case

The requirements are fulfilled as presented in the following tables in this ECMWF case organization.

I.	*Operational and functional requirements*	
1	Need for increased cost efficiency	*Service center is built to achieve cost savings compared to a solution where services would be set up by each country on their own. In global forecasting it is usual that one nation do not have enough resources to be able to create this kind of services so*

		increased cost efficiency makes it possible in general.
2	Need for better service in the area	*There was need for global weather forecasting products. These services provided by the ECMWF are very specific and require high differentiation and deep knowledge of the working area. This is why this kind of special services and skill need to be gathered in one place or to some other collaboration to achieve enough knowledge in this area.*
3	Services that support scale advantage	*Most of the services provided by the ECMWF seem to support scale advantage very well. Weather modelling, computing services, data archiving and storage, telecommunication, knowledge sharing by consultation and training services are successfully provided with cost efficiency that keeps the customers satisfied year after year.*

Table 9. Operational and functional requirements met by ECMWF.

The requirements in Table 9 are fulfilled very well in the ECMWF case. Cost efficiency of the services is required and this is fulfilled by achieving the scale advantage. Higher quality services are required and this is achieved by creating a center of excellence by getting the critical amount of resources together in the service center.

II.	*Technical and other requirements*	
1	Cost efficient telecommunications	*Telecommunications network RMDCN was established to provide the telecommunications services to member countries. The cost efficiency in this international network has been in quite typical level although it has been very reliable in its operations.*
2	Cost efficient buildings and other properties	*The building costs has been in a typical level but in this kind of center arrangements governments are usually willing to provide assistance in locating the center as it is seen important to get these center's to one's own countries.*
3	Cost efficient labor available	*Salary level in the center is quite high but staff has to have exceptional skills so the*

		salary level has not been the place to make the savings.
4	Skilled labor available	*The labor for the ECMWF has not been hired from the typical market. The weather model business area requires very specific skills that are usually achieved in years of working experience that has been received after university education of a certain area (meteorology or physics typically).* *It has been possible to get the skilled labor to ECMWF from meteorological institutes that are the members of the center. ECMWF has had a flexible rule of having people hired from different countries so that the member countries are presented in the number of staff in the same percentage that the funding is from that member country. This has been more of a guideline and not to be exactly followed.* *In the ECMWF case skilled labor has always been available as the center has a high reputation. Therefore researchers and other operational staff from meteorological organizations have been willing to apply for this center which is known as a workplace of motivated and highly skilled people making world leading products for its customers.*

Table 10. Technical and other requirements met by ECMWF.

The requirements in Table 10 are fulfilled in this case in an average level. Costs are at typical western European level and no cost savings are received by getting the services from cheap laboring cost countries. As these are high skill services it is most likely needed to concentrate the resources the way these are at the moment. Skilled labor is available by staff exchange in the international meteorological cooperation.

III. *Cooperation*		
1	Already existing cooperation	*Meteorological institutes have had lot of existing cooperation already before the service center was established. Weather business in general level is a global working area and different kind of international cooperation is typical for it. Scientists that*

		were the ones to start the cooperation in global forecasting had already existing co-operation in other areas.
2	Key actors and promoters already available (persons)	*Key actors were available to get the needed support in the meteorological services for the center establishing. The establishment was a result of the scientist's vision was that European governments did agree to combine their individual resources. These scientists established an intergovernmental organization that had the goal of developing, improving and operationally producing up to 10 days medium-range weather forecasts and this ended up in ECMWF establishment (ECMWF, 2012).*

Table 11. Cooperation requirements met by ECMWF.

The requirements in Table 11 are fulfilled very well. Cooperation already existed in the meteorological community before the establishment of the center and scientific key actors were available to develop this model.

IV.	*Political support*	
1	Support for the center idea in general level	*ECMWF did get the political support from all the participating countries when it was established. This was a result of the scientist's strong vision that European governments did agree to combine their individual resources (ECMWF, 2012).*
2	Support for staff relocations	*No actual staff relocations were needed in this establishment as the center was a totally new site and new staff was recruited. Although the staff was mostly hired from meteorological organizations but these scientists applied for the open positions in the center as it works still today.*
3	Support for center geographical location	*Geographical location in UK/Reading was supported. Usually in these international shared center establishments there are several countries interested in positioning the center to their countries and for this the final location is not so easy to find.*
4	Support for risk management model in shared service	*Risks in this kind of new activity were acceptable as the center needed to be located in one of the member countries. All the*

		meteorological services including the UK office were dependent on working telecommunications to get the services, although UK benefitted the safety of the center been in its geographical area.

Table 12. Political support requirements met by ECMWF.

The requirements in Table 12 are fulfilled fairly well. Center idea got wide support, staff relocations were supported as needed, the geographical location was finally supported and the risks were also on an acceptable level as actually data security issues were not raised at the time of this development.

In general the ECMWF case also fulfills most of the presented requirements very well and also support the model of the requirements for successful SSC as providing a successful example of the shared services. Both of the case examples are actually very similar in fulfilling the requirements.

4.3.2 Learning from Case Examples 1 and 2

In this study, two case examples were identified and analyzed of the successful implementation of SSCs in a similar work area. These cases demonstrate the shared service efficiency for meteorological weather prediction development work. As shown in Section 4.1 and 4.2, Case 1 (CSC) provides its services mostly to the research community in Finland, and Case 1 (ECMWF) performs weather prediction work in a shared model on a larger, global scale.

Case 1, CSC, has proven itself successful, cost efficient and customer-oriented in its services as a national organization. CSC has gathered exceptional level of specialized skill and has earned international reputation within its work field. The Finnish research community has benefited from the CSC services for more than 40 years. The level of CSC's services has risen rapidly in past years, and CSC has grown in size, for example, in the number of its staff.

Case 2, ECMWF, has proven its success in global weather modeling, having been acknowledged as a leading international weather prediction institution worldwide. Its SSC has also proven to be customer-oriented in all its actions. As a result, ECMWF has reached exceptional level of its specialized skills and has been recognized internationally. Smaller service units would hardly have been able to earn such international recognition or reach similar level of services. In comparison with other institutes in global weather model forecasting, ECMWF is the only international SSC, with others being national weather service centers or other types of institutions.

Both organizations have been active in their fields for several decades; and their actions are heavily based on high performance computing, which is a targeted area in this Thesis work. Based on the collected data and organizational information, these cases vote in favor of the SSC model and prove that its application for weather prediction systems can be beneficial in the following areas.

First, these examples demonstrate cost efficiency of a SSC when sharing resources in high performance computing for the user groups with similar needs. This also points to a good possibility for scale advantage in hardware solutions and knowledge sharing for research and development work.

Second, these examples also demonstrate the possibility to achieve better service meaning the higher quality products when gathering resources together to work towards the common goal.

Third, these examples prove the possibility for cost efficient telecommunications solutions in the shared use.

Fourth, these examples also show the possibility for increasing cooperation. In the beginning the cooperation has been started with some part of these final services and after years of development the number of efficient shared services has increased in both cases.

Overall, the SSCs in Cases 1 and 2 prove a good possibility to achieve results that are not possible on a single organization or a single country level, but bring success for shared services on an international level, for decades.

When the requirements for a successful SSC identified from the literature review are compared to the conditions existing in Case examples 1 and 2, the identified requirements seem to be relevant for the case analysis and can be considered as a possible tool for the SSC requirements analysis. In both case examples, the requirements list was fully met by the organizations; and in both cases, the SSC implementation was successful. It allows us to conclude that the fulfillment of these requirements can potentially lead to building a successful SSC model, and a possibility for a successful SSC in the weather prediction field does exist.

Summing up form looking at these two case examples, it can be argued that, in the shared aspects that are relevant to the meteorological cooperation in weather prediction systems, and in high performance computing, the SSC model can be beneficial in operational, functional, organizational, economic and some other aspects. It also suggests that the list of requirements applied for the analysis of these benchmark cases can also be effective in the design of an SSC model for the topic of this Thesis.

The next section analyzes the current situations in the case organization (FMI) and possible participants in the SSC in weather prediction cooperation, and defines possible services that could be included in such a SSC model.

5 CURRENT SERVICE SOLUTIONS AND COOPERATION PLANS IN THE NORDIC COUNTRIES

This section discusses the current situation in weather prediction systems in the Nordic countries. Currently, these systems in the Nordic countries are mostly separated, so that the countries act by themselves. Although there is a lot of cooperation between these countries, they do not share computing systems so far.

5.1 Current State of Systems and Cooperation

International cooperation is a typical way of working in the meteorological field, and it plays an important role in the weather services area worldwide. There is a long history in sharing observations globally, as well as developing different shared services for common use. The case organization of this Thesis, FMI, has established a close cooperation with several meteorological institutes around the world which became its partners in several international development projects. There exists also many other organizations or collaboration groups in the working field that FMI has also developed cooperation with.

Computer systems

Currently, every major meteorological organization in each country typically has its own IT systems including supercomputing facilities for weather model calculations. It is quite unusual that the meteorological production systems would be outsourced but there are also existing examples of outsourcing in the world. In the Nordic countries, all the systems are currently handled by the countries themselves. As an example of how countries do it independently, Figure 16 shows the architecture and data flows (generalized) of the on FMI weather production system.

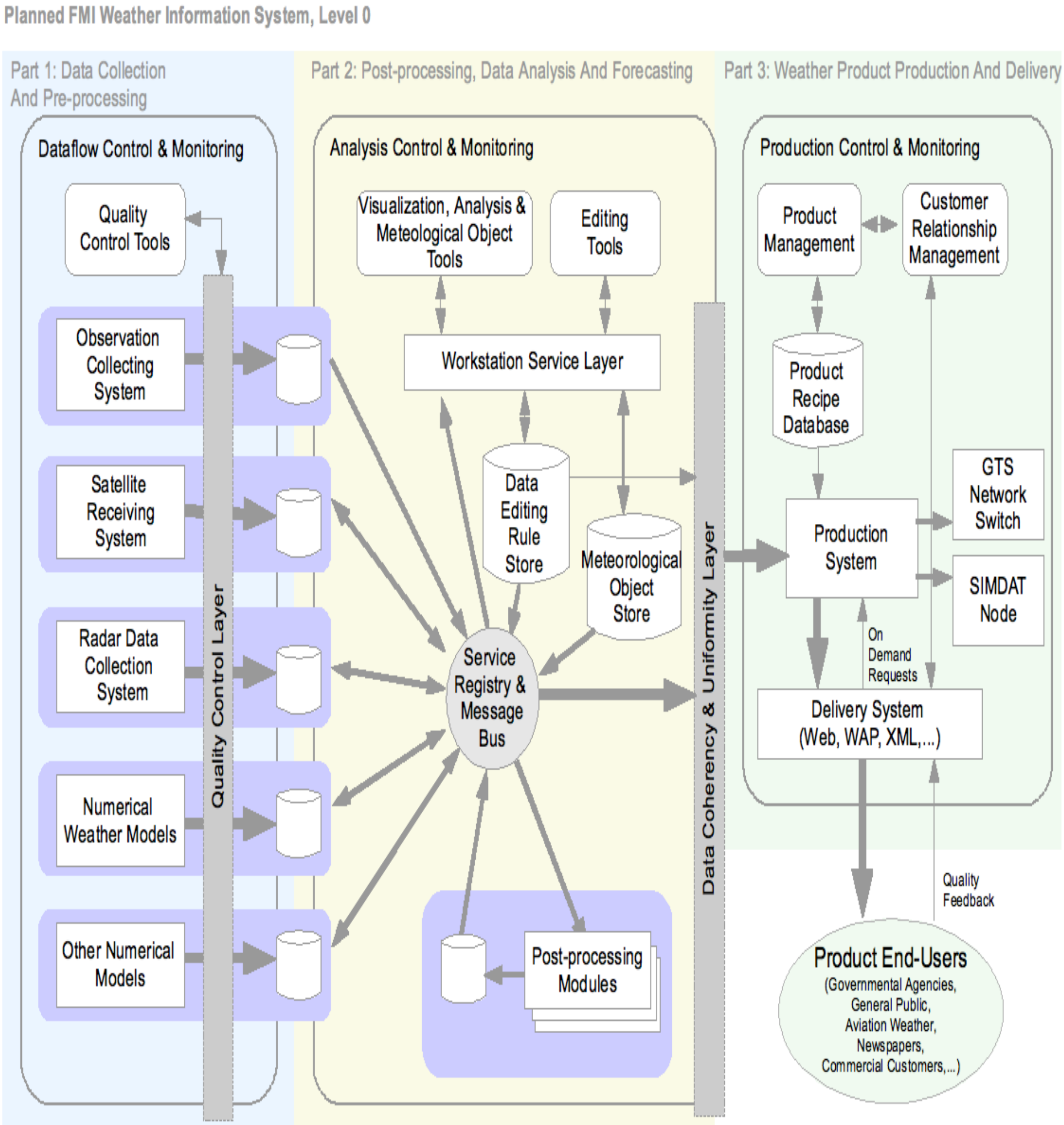

Figure 16. FMI weather production system (FMI 2011).

As can be seen in Figure 16, the FMI production system includes several data sources and different processing layers to generate the final product. It is also visible that IT systems play a vital role in the generation of the products.

As there is no already implemented cooperation in the field weather prediction systems in the Nordic countries, the supercomputing systems and needed backup systems has to be handled nationally by every country on their own. The expenses of these systems are becoming harder to handle by the single meteorological organizations by themselves, and a shared cooperative model would be a possible solution for this issue.

Table 13 sums up cost dynamics in the high performance computing procurements made by the FMI in the previous years. There is also an estimation of the next procurement 2013 according to the costs in the current procurement plans.

High performance computing system costs per procurement	***Procurement costs***
Year 2005	1,25 Million Euros
Year 2009	2,5 Million Euros
Year 2013 (estimate)	3-4 Million Euros

Table 13. Dynamics of costs in the high performance computing system procurements at FMI in 2005-2013 (with 2013 as an estimate).

As can be seen from Table 13, the cost dynamics is showing a rapid growth in the cost of the system. The system requirements are decided by the needs of weather modeling as the weather products benefit from the increased computing power. But even if the weather product quality does improve, it does not remove the current problem of financing the computing procurements as the funding does not increase.

To address this challenge, Sweden and Norway has already started to plan and implement their cooperative production systems in high performance computing to increase the cost efficiency of their services. Now there is an increasing interest to study a possible solution that would also include Finland in this cooperation, as Finland is interested to improve the cost efficiency of its solutions, too. So far, Finland most likely has a possibility to finance the next generation of its supercomputers in 2013; but the subsequent generation would definitely benefit from cooperation.

Weather model development and other cooperation

There exist many different kinds of cooperation between the Nordic countries. For example, weather models HIRLAM and HARMONIE are developed in consortiums that include the Nordic countries as their active members. Nordic cooperation also exists in weather radar projects consisting of data sharing in this area. There are also various other research projects that the Nordic countries participate in together.

Steering in the Nordic meteorological cooperation

Nordic cooperation in the meteorological infrastructure area is guided by the NORDMET Steering Committee (NOSC). The aim of this cooperation is to reduce costs and enhance cooperation activities in the following areas: observations, data management, research, product development, meteorological production and training. This cooperation agreement was signed in 1998. The Danish Meteorological Institute joined this cooperation as a last Nordic country in 2001.

The NORDMET cooperation has the management board as the highest decision making body. The management board meets at least once a year, usually in late summer, to decide on issues raised by the NORDMET Steering Committee (NOSC). The management board also decides on the possibility to initiate new activities, and appoints the members of the steering committee. (FMI, 2012) Any possible shared service cooperation in weather prediction systems will also be decided by the NOSC.

5.2 Cooperation Plans in the Nordic Countries

The Nordic countries made a plan for the cooperation development in the weather prediction systems in past years. These plans have the goal of sharing resources to achieve increased cost efficiency and higher skills in their specific working area. If cost efficiency is necessary to achieve enough capacity for developing services from the computing side, increased skills would help smaller countries with smaller meteorological institutes to create new innovative services and to develop the existing systems to the highest professional level. Enhanced cooperation between the countries also tend to create additional positive effects that currently are not even planned. Therefore, it is advisable to invest in such cooperation to make the future better for all the participating organizations.

Numerical weather prediction cooperation

In December 2009, Swedish Metrological and Hydrological Institute (SMHI) and Norwegian Meteorological Institute (met.no) decided to investigate a possibility for a joint production system in numerical weather prediction (NWP). The result of this investigation is the Report on Operational Cooperation between SMHI and met.no on NWP from 2010-05-31 (Internal document). The vision for this collaboration was to provide its participants with an efficient and cost effective operational NWP system for a short and very short prediction range. In this report it was concluded that, to get the full benefits of the common computer platform, SMHI and met.no should choose to run a common non-hydrostatic model for high resolution deterministic forecasts and ensemble forecasts. The common NWP production between SMHI and met.no was planned to begin in 2013 or 2014.

As a starting point for this cooperation, both met.no and SMHI have their own model systems with their own model domains suited for their specific needs. Figure 17 shows the current SMHI model domains in blue and met.no model domains in red (SMHI and met.no 2010).

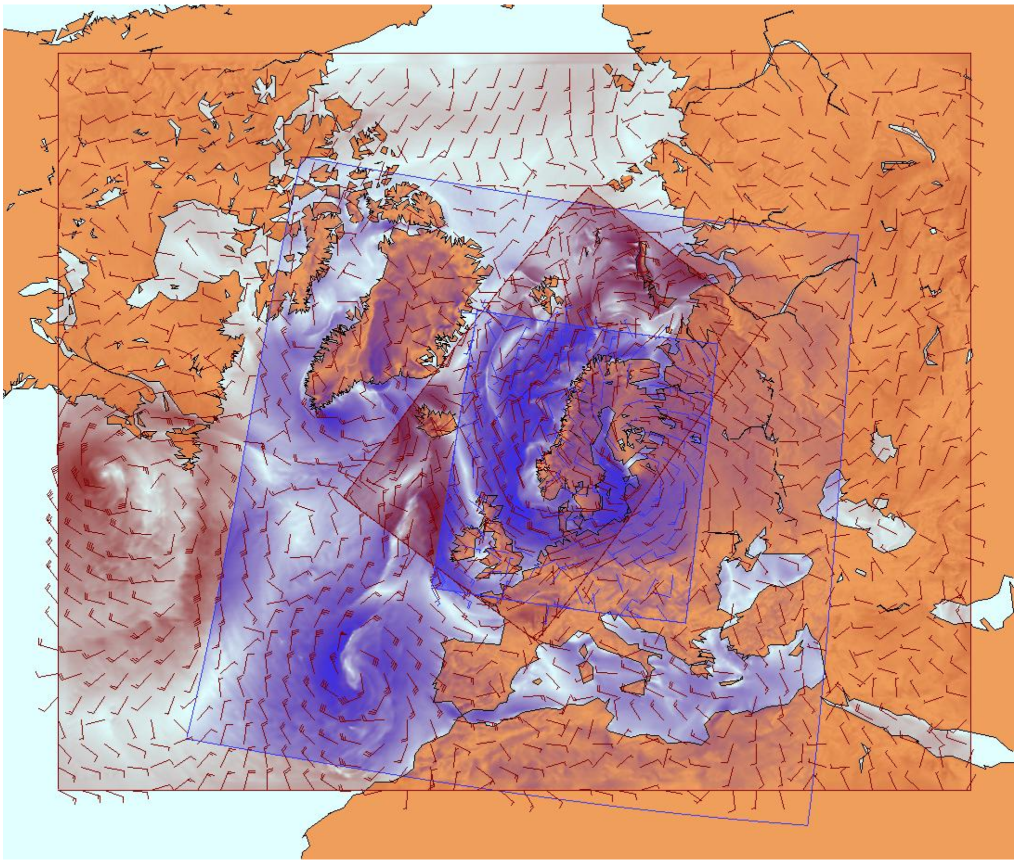

Figure 17. Current SMHI model domains (blue) and met.no model domains (red) (SMHI and met.no 2010).

Figure 17 shows the plans made by met.no and SMHI for their future common production model domains. As can be seen in Figure 17, most of the areas are covered twice in the existing model domains of met.no and SMHI. Meanwhile, the smaller domains with higher model resolution and the larger ones with lower resolution can be suited to two-model domains that have suitable areas for both of the countries.

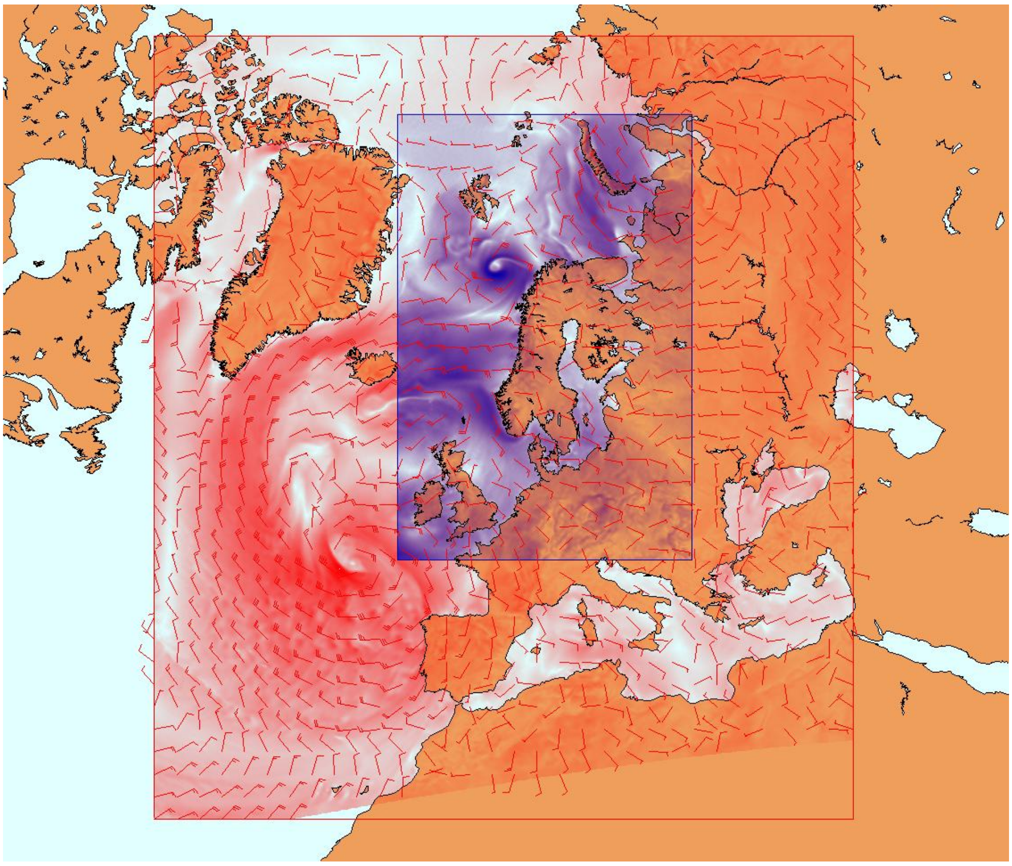

Figure 18. Two proposed common model domains for met.no and SMHI (SMHI and met.no 2010).

In Figure 18, it is clearly visible that Finland itself and other important areas for Finland are well covered in the planned SMHI-met.no cooperation domains, which means that there would most likely be achievable a scale advantage, if an increased cooperation for the model calculations through a shared solution is arranged. To better compare the plans by SMHI-met.no, it is needed to point to similar plans and the current state of FMI's weather model domains.

Currently, Finland shares a similar situation with SMHI and met.no as these institutes use HIRLAM and HARMONIE models for their operative limited area weather prediction models. In all of these countries, the future development is also planned to happen mostly based on the HARMONIE model. Figure 19 below shows the current and planned model domains by FMI in its operational production use.

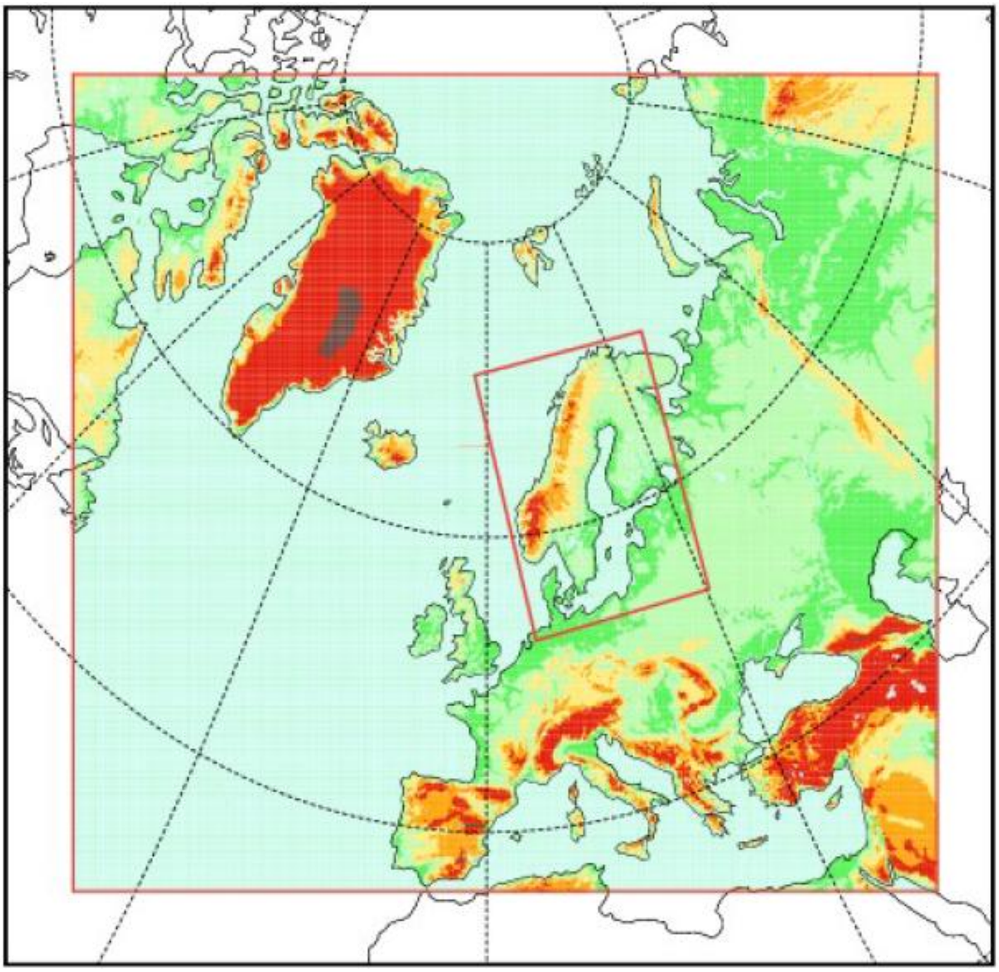

Figure 19. Model domains at FMI including existing larger domain and planned smaller domain (FMI 2012).

In Figure 19, the HIRLAM model is the larger geographical area with lower model resolution, while the HARMONIE model has higher model resolution is the smaller geographical area. Currently, the HARMONIE model domain covers only Finland, but there are plans in FMA for a larger area for the HARMONIE model, which will most likely be in operational use at the end of 2012 or at 2013.

As can be seen from Figures 17, 18 and 19, the current operational models at SMHI, met.no and FMI are focused on working at different resolutions and different domains; therefore, harmonization of production on domains, versions and output will be beneficial for all these organizations. SMHI and met.no are prepared to continue the HIRLAM and ALADIN NWP cooperation, with their future modeling systems based on HARMONIE. These plans suit the FMI plans also very well.

Other possible cooperation areas

The planned joint NWP production by SMHI and met.no (2010) is also considered to result in closer collaboration between SMHI and met.no in other areas of interest, such as meteorological production of pre- and post processing systems and software, forecast production tools and operational IT infrastructure in general. In the planned cooperation, there is also a proposal for having a common long-term archive for the products and data.

Steering and other general aspects of the cooperation

In the SMHI and met.no report (2010), a steering group (SG) is proposed to be the main governing body for the common production collaboration and the daily operational work. The steering group should operate through an operations group (OG) that has members from both SMHI and met.no. It is also proposed that the collaboration should be based on equal sharing of costs when setting up and using the services.

Additionally, the report by the met.no and SMHI (2010) also proposed to set up an agreement for a term of 5 years for the two participants. Unless the contract is cancelled by either party giving at least a two-year notice, the agreement is prolonged each time for an additional period of two years. This type of contract reflects the long term obligations involved in the cooperation.

Further development of cooperation

The met.no and SMHI report (2010) also points to a possibility of a potentially more extensive operational NWP cooperation in Europe in the future. From the FMI point of view, this direction is also very promising.

Concerning the details of further cooperation, the report by met.no and SMHI (2010) tells that there has been interest expressed from other institutes to learn more about the planned cooperation between SMHI and met.no. It is therefore possible that the operational NWP collaboration may be extended at a later stage to include one or more NMSs even beyond the Nordic countries.

An interesting fact also mentioned in the met.no and SHMI report (2010) is that when entering into discussions on future extension of the agreement, the current proposal for the agreement between two neighboring parties would have to be reconsidered in quite a number of aspects. There will be a need, for example, to reconsider at least the impact on communications, governance, HPC resource, cost sharing and similar aspects.

Networks, production and services in the planned cooperation

In the cooperation report by SMHI and met.no (2010), there was a proposal of having two national NMSs, each having one HPC system, with the systems used for common production. If there were more than two countries involved, the national supercomputing centers should be also considered for participation as possible service providers. There are centers for supercomputing in every of these countries, and it might be efficient to put their resources to use in this future development.

The Nordic university networks (Funet, Uninet and Sunet, together called NORDUnet) are considered essential in this possible cooperative solution. Therefore, it is important being active in cooperation with the operators of these university networks to emphasize the national importance of their networks also in this area.

As it was also mentioned in the met.no and SMHI report (2010), there are also relationships planned with the weather prediction systems and national defense forces in each country, as well as some other authorities that require and possibly contribute to NWP production and research. Moreover, the agreements and practices will have to ensure that these national partners or customers receive a continual good service and their specific requirements are taken into account.

Overall, from the point of view of a possible FMI joining the planned cooperation between met.no and SMHI, there should be also no delays in implementing the cooperation plans because of the FMI participation. The new SSC model (with FMI) could be set up at a later time, when met.no and SMHI has already started common production. As for having a common meteorological computing and storage center, it would anyway be needed to consider the possibility of having such a common Nordic center, in case more than two countries are involved in HPC cooperation. It means that a possible FMI participation would not change the initial cooperation plans by met.no and SMHI much, but its participation may be very beneficial for further development of this cooperation.

5.3 Additional Parts That Could Be Included in the New Shared Service Solution

In the weather production systems, there are parts that could possibly be included in a wider shared service solution. Most of these parts have already been considered by SMHI and met.no in their cooperation planning (2010). But as FMI is also interested to be involved in the Nordic cooperation, this wider project could make a natural development of the plans already made by the SMHI and met.no. In this case, FMI can suggest several further possibilities to develop common activities in this direction. These suggestions were collected in the interviews, discussion and brainstorming session in FMI (informants IT Directors A and B), and their summary is presented below.

A. Planning and implementing the future HPC solutions

FMI is potentially interested to further develop the possibility of planning and implementing a common high performance computing (HPC) facility.

Currently, in the cooperation planned by the met.no and SMHI (2010), there are plans to implement a common production system that has one high performance computing system in each country. In this setup, the newer computer is the main computer for the common production and the older one is used for backup and as a platform for research work. However, in a new SSC model, where it is desirable to have more than two countries participating, this cooperative model may not be suitable any more. In case three or more countries are involved, it would rather be needed to have a multi country arrangement for the shared center to use its resources for common production and to invest in. This model could better provide the required scale advantage and create a more cost efficient solution.

B. Common NWP model development

Development of a common NWP model would most likely make one of the first cooperation tasks. In this area, there is already quite a lot of cooperation, but cooperation in production can further be developed, for example, to include common models and model domains for all the participating countries. In this case, the models and model domains would be run only once in a new SSC.

C. Common NWP model production system

The most effective common service could be a common production system implemented for providing its participants with an efficient and cost effective operational NWP system for short and very short prediction range. To get the full benefits of the common computer platform, FMI suggests that the members could run a common non-hydrostatic model for high resolution deterministic forecasts and ensemble forecasts.

D. Common EPS production system

FMI is interested to take part and develop the common EPS production system.

As part of the common EPS production, SMHI and met.no (2010) plan to launch a common limited area modelling ensemble prediction system (LAMEPS), similar to the current met.no setup, but with higher resolution. If FMI or other participant joined this cooperation, it would be natural to build the system on the common operational model, and define the common LAMEPS domain, so that it would coincide with the common deterministic high resolution domain. Common LAMEPS resolution could then be the same as the resolution applied for the deterministic model on the large common domain, as proposed in the SMHI and met.no cooperation report (2010).

E. Meteorological production software development

FMI also sees the importance of common production software development as a shared service, as met.no and SMHI plan in their report (2010).

By now, FMI has an extensive library of high quality software already developed, coupled with technical expertise in this area. Therefore, it might be useful to consider what parts of the production system already available could be involved in this common development work to find a more cost efficient solution.

F. IT infrastructure planning

Finally, FMI sees a possibility to benefit participants form a common IT infrastructure development, as met.no and SMHI suggest in their cooperation report (2010).

There are already several cooperation areas in the IT work that are seen as potentially beneficial for all the countries. But these areas of cooperation could potentially be extended to include, at least, a) development of supercomputing, storage and archiving, b) server systems, and c) web production platforms.

Summing up, the identified additional parts of a possible extended cooperation could include, at least, six areas, starting from common weather modelling system up to more general level cooperation in IT infrastructure planning.

5.4 SWOT Analysis of Cooperation Possibilities

This sub-section discusses the strengths, weaknesses, opportunities and threats of the possible extended cooperation in the Nordic countries in the area of weather prediction systems and their development. These possibilities are estimated within the frame of a SWOT analysis, based on the responses collected in the interviews, discussion and brainstorming session with informants from FMI (informants Director A and Head of Group A and B).

The summary of the SWOT analysis of the potential SSC cooperation is presented below.

Strengths	Weaknesses
• Cost efficient way for producing services • Increasing cooperation that generates more development strength • More computing power achievable which means higher resolution in weather models and results in better weather forecast • Specific knowledge is secured in this model with center of excellence	• Shared management can mean more hierarchy and slower development of services • Services possibly outside Finland and money invested in services abroad • Safety of services reduces if national capacity is lost
Opportunities	**Threats**
• More development resources in common services • More computing power and higher model resolution • Increased cost efficiency • Higher skill when resources are put together in a (logical) center	• Operational risks of availability when services outside Finland • Risk of losing possibilities to influence in the future development

Table 14. SWOT analysis of possible cooperation.

As indicated by the informants, each part of the SWOT analyses of the cooperation possibilities contains a number of aspects.

First, the strengths of the possible cooperation include such benefits as higher cost efficiency in service production, increase of cooperation that generates more development strength, more computing power achievable which means higher resolution in weather models and results in better weather forecast and secures the specific knowledge in this center.

Second, the potential strengths are counterbalanced with a number of identified weaknesses: first of all shared management can mean more hierarchy and lead to slower development of services, then services can possibly be produced outside Finland and money be invested in services abroad, also safety of services reduces if national capacity is lost.

Third, potential threats of the possible cooperation may include operational risks of service availability when services are produced outside Finland, also risk of losing possibilities to influence in the future development is possible.

Finally, the opportunities of the Nordic cooperation may bring at least more development resources in common services, even more computing power and higher model resolution, also more increased cost efficiency and higher skill when resources are put together in a logical or partly physical center.

Summing up, there are a number of possible benefits and prospects identified by the informants in planning and creating common services in a possible extended Nordic cooperation. Although, there also exists a number of potential downsides and threats which such cooperation could bring. All these aspects, therefore, need to be considered carefully when estimating the actual implementation of the SSC.

It is also advisable to note that, since SMHI and met.no are building up their common production system right now, they can provide a unique opportunity to learn more about the common services from their real life experience which they are gathering now, in their current developing cooperation. After this information is made available, there will be more possibility to learn about and predict the details of the future cooperation.

6 PROPOSAL FOR A NEW SERVICE MODEL

This section introduces the proposed new service model. The proposal is based on the literature review on the SSC models; the study of the case examples and the current cooperation arrangements between the potential service partners; and the results of the interviews, discussions and brainstorming sessions with informants in FMI and external experts.

6.1 Suitability of the Shared Service Centre Model to Develop Cooperation in the Current Situation

This sub-section summarizes the discussion about the SSC model for the possible cooperation between FMI and the Nordic countries, from the point of view of the current situation. The goal is to point out how the new SSC model could be implemented to benefit the possible cooperation between FMI and the Nordic countries.

Needs of the case company (FMI) IT services

The case organization (FMI) is a highly technological institution and most of its products are provided electronically. Manufacturing of the products and services is highly automated by using information systems (IS), with high organizational input given to IT services production and development. These aspects explain why it is important to FMI to ensure that ISs and IT services and their development support the business processes of the case company as efficiently as possible.

At the moment, all of the IT services at FMI are provided by an in-house IT unit, and the IT staff and equipment are owned by FMI. Currently, the case company has about 680 employees and relatively large IT systems, which gives FMI some scale advantage for its in-house service providing, but at the same time makes them quire expensive to maintain.

In the future, FMI's IT services could be divided into three different categories. Firstly, there are the general level IT services (user equipment, email etc.) that are already planned to be outsourced from FMI as the Finnish government has plans to centralize them in every governmental organization. Secondly, FMI has a large number of networking equipment, servers, storage systems and other systems that are part of the automated meteorological production systems, which FMI is willing to take care of in-house. The third part of the systems is the supercomputing facility, including the archiving systems for meteorological model calculations. This system is a very expensive investment for FMI, and a cooperative model would be very desirable in this area. Since, at the moment, the Nordic countries are doing a lot of similar work in every country, that part could be unified and produced more efficiently through a common system.

SSC as a cooperation model

For FMI, The SSC could be a suitable model for the common Nordic supercomputing services in weather model calculations. From the IT services point of view, this model would fulfill all the needs of FMI. Therefore, this SSC model needs to be investigated in more detail, and an action plan should be developed and presented to FMI's directors.

Shared service centre requirements: comparison of the requirements model to the possible FMI-Nordic countries cooperation

The requirements model for setting up a successful SSC developed in this work is described in Figure 5, page 37. This requirements model was used next to verify if the conditions existing currently for the possible FMI-Nordic countries cooperation support the establishment of the SSC.

The requirements are analyzed in four requirements areas, including *the operational and functional requirements*, *technical requirements, cooperation aspects* and also *the political support*. The results reveal the possibility to implement a shared services model in cooperation between FMI and the Nordic countries, as seen from the current situation prospect. Tables 15-18 present the results of this analysis.

I.	*Operational and functional requirements*	
1	Need for increased cost efficiency	*There is a need to achieve more computing capacity within the current finances. Since*

	(on both sides)	*there is no possibly to increase the HPC budget, the needed computing power to improve the weather forecasts can only be achieved through improving cost efficiency.*
2	Need for better service in the area *(on both sides)*	*There is a need to improve the model resolution for providing better services. More computing power would mean better services and improved weather forecasts.*
3	Services that support scale advantage *(on both sides)*	*Computing services and weather model development in a SSC model can support the scale advantage very well. (This has been proven by the existing case examples from the similar area).*

Table 15. Operational and functional requirements for a SSC.

Overview of the operational and functional requirements in Table 15 demonstrates that the potential cooperation between FMI and the Nordic countries would meet these requirements fairly well. First, the need for increased cost efficiency exists on both sides. Second, the need for better service, meaning more computing power and higher weather model resolution, exists. Third, the services do support scale advantage which is proven by the case examples.

The next Table 17 presents the results of the technical and economic requirements analysis.

II.	*Technical and economic requirements*	
1	Cost efficient telecommunications *(on both sides)*	*The Nordic university telecommunications network (NORDUnet) has proven to be efficient and could support this service center at very cost efficient level also with acceptable level of reliability. Without this kind of scientific use network the costs of the cooperation would be significantly higher.*
2	Cost efficient buildings and other properties *(on both sides)*	*National institutes are most likely eager to provide premises for this center at very cost efficient level. The current infrastructure is already quite developed and therefore cost efficient buildings and other properties does exist already very well.*

3	Cost efficient labor available	*Basic Finnish and Swedish salary level is relatively cost efficient. In Norway salaries are higher though. Most of the staff would anyway be from the existing contracts in their own institutes so the salary cost would stay mostly in the as is level.*
4	Skilled labor available	*Skilled labor is available in all the possible participating countries and the meteorological institutes can provide already skilled staff for these actions in the future. At the beginning not much new recruitments would be needed and the current staff would be the foundation for the new center also.*

Table 16. Technical and economic requirements for a SSC.

Table 16 presents also supporting information to the centre implementation requirements. First, the efficient telecommunication solution exists at the moment. Second, skilled labor is available from the existing resources in the meteorological institutes. Finally, the other requirements are also met at least in an average level.

The next Table 18 presents the results of the cooperation requirements analysis.

III.	*Cooperation requirements*	
1	Already existing cooperation *(on both sides)*	*Nordic meteorological institutes have had much existing cooperation already in several working areas.*
2	Key actors and promoters already available (persons) *(on both sides)*	*Key actors are at least partly available to get the needed support for the SSC. At Norway and Sweden there are already cooperative solution planned and implementation in progress which proves the existence of that kind of cooperation key promoters. More support would still be needed for the wider political and meteorological support for these plans.*

Table 17. Cooperation requirements for a SSC.

Overview of the cooperation requirements in Table 17 demonstrates that the potential cooperation between FMI and the Nordic countries would meet these requirements fairly well. First, the cooperation is already in a good level. Second, the key actors do exist for creating different cooperative services. Some hesitation is still present for this kind of development but these requirements are also fairly well met.

The next Table 18 presents the results of the political support requirements analysis.

IV.	*Political support*	
1	Support for the center idea in general level *(on both sides)*	*SSC idea has some support at the moment but no exact opinions in this model exist currently. Some challenges can be seen in getting the support concerning the independency of different countries in their service delivery but these challenges can most likely be solved. There are great opportunities in this shared service cooperative model that can help to provide the political support widely.*
2	Support for staff relocations *(on both sides)*	*No actual staff relocations would be needed in this shared service startup as the center could function with existing staff from meteorological institutes from their place of work. There are of course possibilities also to gather relevant staff also physically together to improve the cooperation and its efficiency. This is still most likely not a critical issue in this development.*
3	Support for center geographical location *(on both sides)*	*Geographical location will be a difficulty as all the participating countries would most likely like to provide a location for the center. One solution to help this challenge is to divide the center to two different physical locations when two countries would get their own sites. The physical setup of the center would have different options that need to be investigated in more detail in future planning.*
4	Support for risk management model in shared service	*Risks in this kind of services are a critical factor as these services are part of the national defense systems in all participat-*

	(on both sides)	*ing countries. Preliminary acceptance has been anyway given in Finland but at least some part of the weather model calculations capacity needs to be secured also on a national level.*

Table 18. Political support requirements for a SSC.

Overview of the political support requirements in Table 18 demonstrates that the political support between FMI and the Nordic countries would meet these requirements fairly well. First, there exists relatively well support for the center idea. Second, the staff relocations are not the central issue in this case as there is no need for those at least in the beginning of the new services. Third, the center location is more difficult as all of the countries would most likely get the center in their countries. Finally, there are also some difficulties with the security point of view as these services are part of the national safety services. It seems that although political support is met in fair level there are many challenges to defeat. There is anyway enough support to keep the discussion on to develop the common services.

As can be seen from the analysis in Tables 15-18, the requirements for setting up a successful SSC model could be fulfilled in case of the possible cooperation between FMI and the Nordic countries. This means that, based on the findings revealed in this study, there exists a possibility to develop cooperation in the Nordic weather prediction systems into a deeper and wider SSC model, as compared to the existing cooperation plans between just two Nordic participants (SMHI and met.no plans dated 2010).

To make final conclusions on the suitability of such a model, the SSC model needs to be further investigated from different angles in a specialized study. So far, the next section discusses some practical suggestions that the FMI informants, external experts and colleagues from Finland, Sweden and Norway pointed out in discussions about the potential SSC.

6.2 Practical Suggestions for a New Service Solution

This list of suggestions aims to further define the new cooperation model and details the need which can surface in the actual planning of the new service model before it is implemented.

The proposed service model that is detailed by these suggestions is a SSC (SSC) for the cooperation in the weather prediction system between FMI and the Nordic countries.

6.2.1 Service Participants

The new service solution is based on the possibility of having several participants in the cooperation. The proposed SSC model should have more than two participating organizations, with three participants as the minimum number for the SSC to be successful. As the requirements for weather modelling domains in the Nordic countries, including Finland and Scandinavia, are quite similar, the cooperation would ideally include all these countries to get the best possible cost efficiency for the shared services.

In the future, there could also be a possibility of extending the cooperation to the Baltic countries. In this case, however, the financing of the new shared service would need to be further investigated to analyze the efficiency of different possible models.

Figure 21 shows the geographical area that could be covered by the weather model cooperation in the proposed SSC.

Figure 21. Map of potential participants in maximum level of cooperation.

As seen in Figure 21, several countries could benefit from the shared services in the limited area weather modeling. Currently, the proposed SSC model suggests the participation of at least three members for the cooperation to be cost efficient.

6.2.2 Service Center Site and Location

The proposed SSC needs to be located in one of the participating countries, in one physical site for the best possible cost effectiveness to be achieved. If it is required by the members, the service center can also be physically located in several places, but its cost efficiency can thus be reduced. There are some advantages of the geographically separated systems, for example, from the safety point of view. In both options, current buildings and computer halls of the existing meteorological institutes can be utilized to accommodate the SSC.

The basic requirement for the multi-site center is the cost efficient high bandwidth telecommunications availability. In the current situation, the efficient way for connecting governmental research institutes can also be achieved by using the NORDUnet network. As for other technical requirements, the Nordic meteorological institutes mostly have modern facilities that can be expanded in electricity and cooling to fulfill the needs of the SSC.

As for the staff relocations, the possible development collaboration, for example, in weather model development and IT infrastructure planning can be made using the existing staff at the research institutes premises; and the locations need not change. This work only needs to be organized so that it encourages more cooperation and interaction between the staff of the institutes.

6.2.3 Service Center Telecommunications Solutions

The SSC in the Nordic area could be connected using the NORDUnet (Nordic academic network collaboration), which coincides with the proposal by SMHI and met.no (2010). NORDUnet is a very cost efficient and high bandwidth international network that connects national research networks together, as shown in Figure 22.

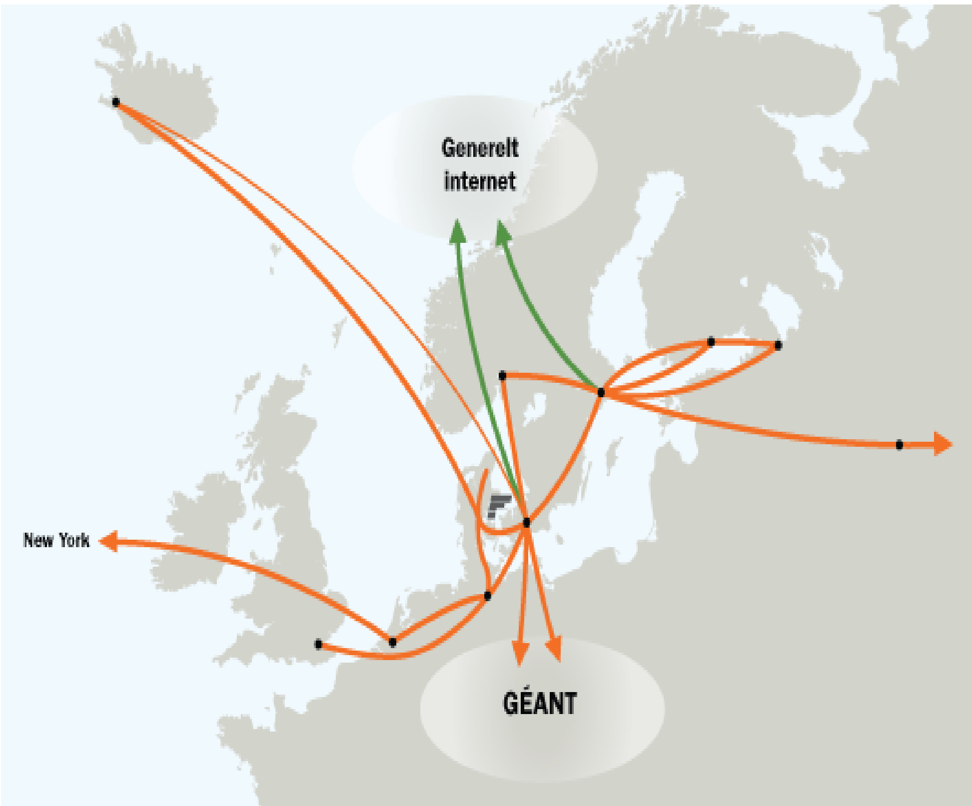

Figure 22. Existing capacity of NORDUnet network (NORDUnet 2012).

Figure 22 shows the international connections provided by the NORDUnet network. Additionally, there also exist national networks in each country: Funet in Finland, Sunet in Sweden, Uninett in Norway, Forskningsnettet in Denmark, and RHnet in Iceland. These networks can be used to connect different locations inside a single country, and subsequently connect them to other participating countries using NORDUnet capabilities available in all Nordic countries.

According to the CSC (2012), the Finnish university network (Funet hybrid backbone network) provides reliable, high-capacity IP services and "light path" for all Funet member organizations in Finland. Funet IP backbone is capable of providing advanced services such as *IPv6* and *IP multicast*. Links between the Funet network and its member organizations range up to 10 Gbps currently. The current configuration of the network based on optical fibers enables up to 40 optical channels, each with the capacity of up to 40 Gbps. This means that the network has a considerable capacity for future development. The optical backbone network also makes it possible to offer "light path" service in major university locations in Finland; and this kind of services could possibly be extended to the NORDUnet members.

Figure 23 shows the Funet connections in Finland and some of its international connections.

Figure 23. Funet network in Finland and some connections abroad (CSC 2012).

As can be seen in Figure 23, all Finland's biggest cities are covered by the Funet network.

There are two important factors in the telecommunications solution: one is the bandwidth of the network for the needed transfer capacity, and the other is the availability of the connections. Weather services are considered as safety services for the society and these services need to be guaranteed for the public in all conditions. This is why the high availability is needed for the telecommunication services and the redundancy of the telecommunications systems is very important. As can be seen in Figure 23, the international connections are duplicated and redundant and the national connections can also be cost effectively duplicated if this is not the case already in the meteorological organizations.

For example, FMI has its connections duplicated with high availability service for several years from the Funet network. The availability rates from the Funet services provided to FMI are presented in Table 19.

Funet connections availability	***Target level***	***Received level***
Year 2011	99,90 %	99,99 %
Year 2010	99,90 %	99,99 %
Year 2009	99,90 %	99,97 %
Year 2008	99,90 %	99,99 %
Average 2008-2011	99,90 %	99,985 %

Table 19. The availability rates of the Funet connections at FMI in past years (FMI 2012).

As can be seen in Table 19, the availability numbers of the FMI Funet connections have been very high and steady, which gives a good possibility to implement the cooperation using the Funet network services. In other Nordic countries, research networks offer similar technologies and services, which can also be seen a good foundation for the cooperation, from telecommunications point of view.

The costs of the needed solutions are mostly already paid by the meteorological offices in their countries. For example, in Finland, Sweden and Norway there exists already 1-10 Gbps level connections from the meteorological institutes to the research networks; and these connections are duplicated. The NORDUnet bandwidth is at 40 Gbps level, and therefore, the capacity between these countries is already on a sufficient level to start the cooperation. Norway has already been using the Uninett network to connect to its HPC system, and has been satisfied with the received service quality (SMHI and met.no 2010).

If the cooperation is extended to the other countries that do not have efficient research networks available in Nordic countries, the data can be delivered through the Internet or by using other, more expensive private connections. In this case, the needed safety level should be negotiated for private connections. However, if the other countries are connected to the shared services using lower capacity telecommunications, or by the Internet, it will make it impossible to locate the service center's sites physically to these countries.

6.2.4 Service Center Cost Sharing Model

Following the framework developed by met.no and SMHI (2010), the collaboration in SSC could be based on equal sharing of the costs for setting up and maintaining the shared services. This could be feasible, if the participants consist of the countries like Finland, Sweden, Norway and Denmark which have similar level of financial capabilities in their meteorological operations.

If other countries are willing to join, for example, Iceland, Estonia, Lithuania of Latvia the cost sharing system would need to be developed so that it would be more tied to the economical and population figures of each country. This model would probably resemble the system described in one of the case organizations studied in this paper, ECMWF (Case 2). In the system used at ECMWF, the scale of each state's contribution corresponds to their Gross National Income (GNI). In this kind of cost sharing model, the costs need to be divided in such a way that producing products could be economically beneficial for participants.

The common costs sharing would mostly be distributed similar to the model proposed by met.no and SMHI (2010). These costs would consist of: a) implementation of the common weather prediction system, b) high performance computing costs for the common weather models and post processing, c) communication costs between the production sites in participating countries, d) governance of the common production, and e) the needed data storage and archiving costs. The computing costs would include all the costs related to the procurement, operations (manpower, energy and infrastructure costs), maintenance and software licenses relevant for common production.

The cost sharing model needs to be planned in more detail, if and when the shared services are implemented as this is always a delicate issue in any kind of development project.

6.2.5 Service Center Service Management

The SSC management could follow the structure suggested by the met.no and SMHI report (2010) which proposes a steering group (SG) as the main governing body to manage the common production collaboration. In SCC, as in the met.no and SMHI report (2010), the steering group would have members from all the participating organizations. The daily operational work would be carried out using an operations group (OG) that also has members from all the participating organizations. This is a model widely used in different service productions that can also be suitable for SSC to start with.

Steering group

In the proposed SSC model, the collaboration should be governed by a steering group (SG). The steering group could consist of 1-3 members from each participating organization, with the chairman rotation between the participating organizations. The term of chair could be stipulated, for example, for two years. Decisions of SG will be taken by consensus. If consensus cannot be reached, the matter could be decided by the Director Generals of the participating organizations. The SG could be responsible for the following matters listed in Table 20.

Responsibilities of the Steering Group
• Establishing the SSC and its necessary groups
• Create a strategy for the SSC
• Establish regular meeting schedule

• Create a yearly activity plan for the shared services
• Deciding on changes to the shared services
• Deciding on investments in the shared service
• Conducting annual review of the collaboration
• Monitor all activities of the shared services
• Responsible for any corrective actions in the shared services

Table 20. Responsibilities of the Steering Group.

In Table 20 the responsibilities are listed for the Steering Group. The main task for this group in to manage the cooperation and make sure in develops towards the common goal that is set up for the cooperation at the beginning. The updating of possibly changing strategy is also the responsibility of this group.

The steering group would also be responsible for the change and development of their responsibilities in the future if ever needed. The steering group and operations groups need to define responsibilities to clarify their fields of work.

Operations group

The daily operational work could be carried out by an operations group (OG) that also has members from all the participating organizations. OGs are typically managed by an Operations Manager (OM). The operations manager responsibility is to ensure smooth operations of common processes. The OG can also be a virtual common group, and should consist of people from each of the participating institutes.

The OG is responsible for delivering and monitoring overall program and service performance and outcomes. The responsibilities of the OG should include at least the points presented in Table 21.

Responsibilities of the Operations Group
• Setting up the common production system

• Facilitate collaborative change management process
• Implement operational aspects of the adopted Memorandum of Understanding
• Promote effective coordination of services planning, program development and delivery
• Technical assistance with 24/7 services needed
• Monitor operations and performance of common services
• Oversee implementation of data, reporting and service quality requirements
• Procurements responsibility of HPC systems

Table 21. Responsibilities of the Operations Group.

In Table 21 the responsibilities are listed for the Operations Group. The main task for this group in to start up the actual system for the coming cooperation and make sure in keeps up to date in an operational level during coming years. The service quality in the running production system is also one of the main responsibilities of this group.

As for the work distribution, in the shared services within similar sized Nordic countries each organization should contribute to the work of the SG and OG with equal amount of workload. The amount and complexity of work could be decided by the SG on a yearly basis.

For the national administration, the report by SMHI and met.no (2010) proposes that each organization should appoint a local manager for the common shared service. They also propose that local managers should be present as observers at the SG meetings. It is also proposed that one of the local managers may serve as the Operations Manager. These suggestions can also be applied for the possible FMI-Nordic cooperation SSC.

6.2.6 Potential Shared Services in the Service Center

The SSC could provide some of all of the following services.

A. Planning and implementing future HPC solutions

A shared service could include planning and implementing a common high performance computing (HPC). In the cooperation planned by met.no and SMHI (2010), there are plans to implement a common production system that has one high performance computing system in each country. In this setup, the newer computer is the main computer for the common production and the older one is the backup solution and a platform for the research work. In the SSC case where it is desirable to have more than two countries participating, this cooperative model is not suitable any more. In the case of three countries or more it is needed to have a center to invest in and use its resources for the common production. This model provides the required scale advantage and creates the most cost efficient solution.

B. Common NWP model development

Common NWP model development could most likely be also one of the first cooperation services by the SSC. In this area there exists already quite a lot of cooperation but this could be developed , for example, to include common model domains for all the participating countries so that these models would be run only once in a SSC. The actual model development responsibility, for example, at FMI, rests with the research and development division and this shared service would be more like a closer cooperation within this collaboration and no actual physical service center is needed to be implemented for this working field. This model development work would anyhow use the shared computing resources in their daily work from the SSC.

C. Common NWP model production system

The SSC would provide common system to its participants as an efficient and cost effective operational short- and very short-range numerical weather prediction (NWP) system. To get the full benefits of the common computer platform it is needed that all participating members choose to run a common non-hydrostatic model for high resolution deterministic forecasts and ensemble forecasts. The proposition for the common model domains could be in this phase the ones presented in the met.no and SMHI report (2010). The final model domains for the shared service can be discussed further if the shared services are actually created. Figure 24 shows these two proposed common model domains for met.no and SMHI (SMHI and met.no 2010).

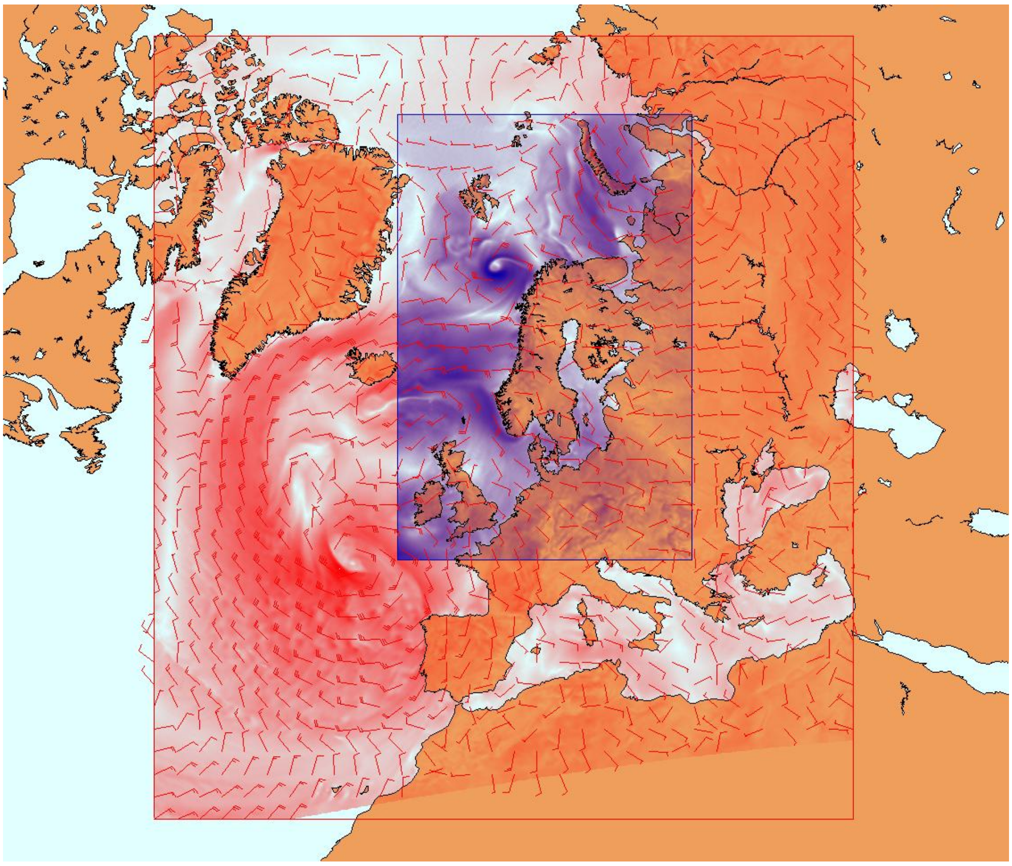

Figure 24. Two proposed common model domains for met.no and SMHI (SMHI and met.no 2010).

As shown in Figure 24, the model domains meet the needs of Finland, Sweden and Norway, with other north European countries also covered for the needs of limited area weather modelling fairly well.

D. Common EPS production system

The common ensemble prediction system (EPS) is one possibility also to widen the cooperation in this possible SSC development. In the cooperation between SMHI and met.no (2010) it is proposed that a common limited area modelling ensemble prediction system (LAMEPS) system, similar to the current met.no setup but at higher resolution, is implemented as part of the common production. It would be natural to build the system on the common operational model, and to define the common LAMEPS domain to be the same as the common deterministic high resolution domain. Common

LAMEPS resolution could be the same as the resolution applied for the deterministic model on the large common domain as proposed in the SMHI and met.no cooperation report. FMI is also interested to develop and take part in this common EPS production system. This common EPS production system could also be one of the services provided by the SSC solution.

E. Meteorological production software development

FMI also sees it important to include common production software development with the shared service in cooperation as do met.no and SMHI in their report. FMI has several high quality software already made and also good skill in this area. It is needed though to consider carefully what parts of the production system would be involved in this common development work.

F. IT infrastructure planning and implementation

Finally, FMI sees also possibilities to get benefit for all participants in common IT infrastructure development work as does the met.no and SMHI in their cooperation report. There are already several cooperation areas of the IT work that are seen as potential benefit for all the countries. The areas of cooperation could consist of at least development of supercomputing, storage and archiving, server systems and web production platforms.

Summing up, there are several possible services visible for the SSC to provide for its customers. In the beginning the services could only include the most critical components to the weather modelling system but in the future the cooperative solution could expand to cover wider area of services.

6.2.7 Service Center Setup

To set up the new SSC physically, there are at least two possibilities: first, to choose one physical center, which is the most cost efficient solution; or, second, to launch a multi-site center divided between different participating countries and supported by high speed telecommunications capabilities. In this proposal, the multi-site model is limited to a SSC model divided between two countries.

A Single site service center

In the case of one physical center, the site could be located in one of the participating countries, in one of the already existing meteorological offices and computer halls. The IT infrastructure in the Nordic countries is very developed, and it would be cost efficient to utilize these existing premises as much as possible.

Financing of these activities would be implemented so that every participating country would invest in this single center's activities.

Telecommunications connections in the meteorological organizations already exist to NORDUnet in every Nordic country and these connections would create the foundation for this cooperation. There is possibility that the bandwidths of these connections would need to be increased in some cases but mostly the existing connections can be utilized in as is state.

Procurements could be made so that a duplicated supercomputing system and storage systems to the center would be bought at the same time every four years. The equipment could be located in the selected center location, at least, for one computing system lifetime; and the next procurement could be made to a neighboring country, if needed. Supercomputing systems are usually hard to be located in the same computer halls as the current systems are located; and by changing the countries in cycle this difficulty can be overcome.

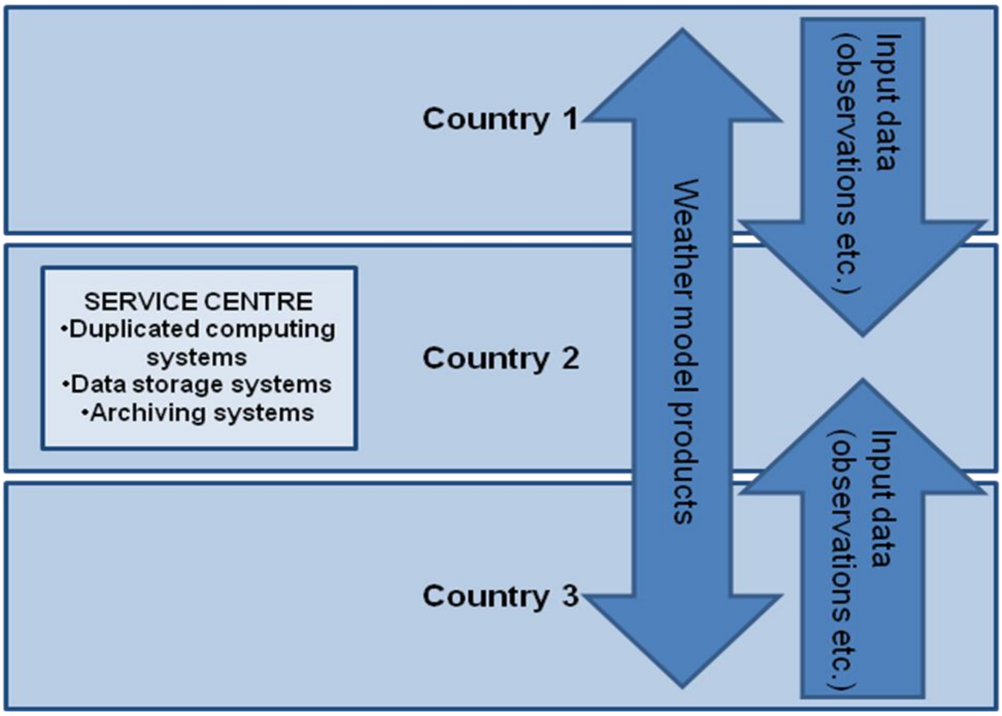

Figure 25. A single site service center solution.

In the single service site model, presented in the figure 25, every participating country need to deliver the input data needed for the weather model calculations (observations etc.) to the center; and the center then runs the weather model calculations and delivers the model products to the member countries for further processing in each country.

The backup supercomputing system in the service center could be used for research purposes when not needed for operational functions.

Figure 25 illustrates the proposed structure.

A Multi-site service center

In case a two-site center is implemented in two of the participating countries, the sites could be located in two of the already existing meteorological premises and computer halls. The IT infrastructure in the Nordic countries is well developed, and it would be cost efficient to utilize the existing premises as much as possible.

Financing of these activities would be implemented in similar way as presented in the single site. Only in this case the hardware would be located in several sites.

Telecommunications solution would also be similar than in the single site model and based on the existing NORDUnet solution.

Procurements would be made so that a duplicated supercomputing system and storage systems for it would be bought at same time around every four years. The solution would be divided to these two centers at least for one computing system lifetime and the next procurement could be made to different neighboring countries if needed. Procurements could also be made so that every two years a new system would be bought and the newer computer would be the operational one and the older one the backup and research computer as is planned in the cooperation between met.no and SMHI currently. Supercomputing systems are usually hard to be located in the same computer halls than the current systems are located and by changing the countries in the cycle this difficulty could be made easier. Usually anyway there exists also other IT systems on the side of the supercomputing system and this makes it more difficult to change countries in this SSC set-up.

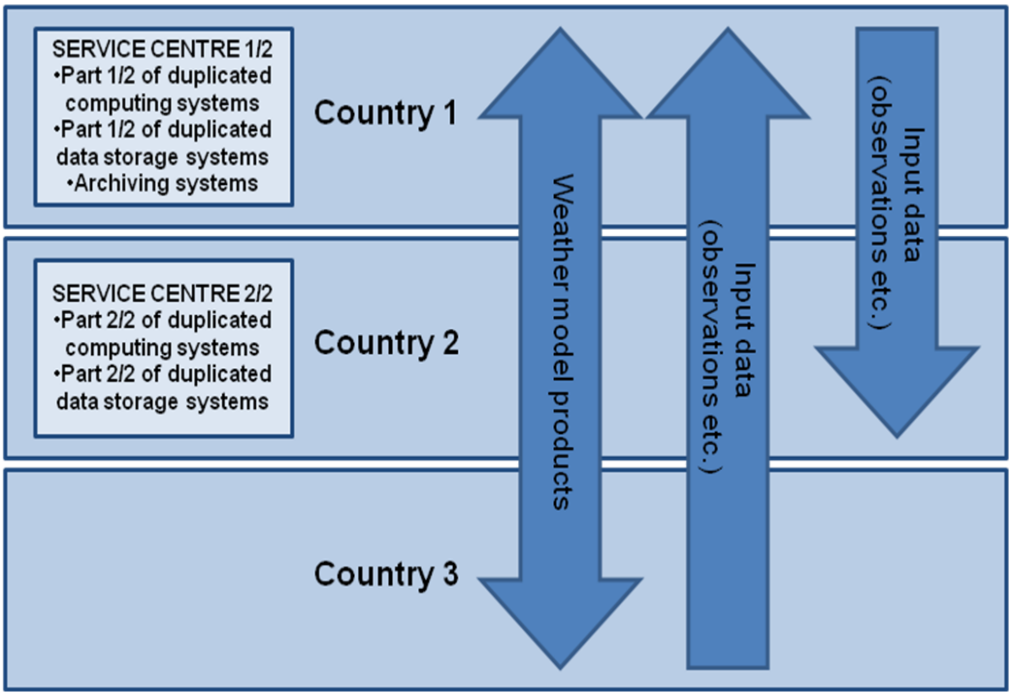

Figure 26. Multi site service center solution.

In this model, presented in the figure 26, every participating country delivers the input data (observations etc.) to both centers. Then, the primary center does the weather model calculations and delivers the model products to the member countries for further processing in each country. In case of problems in the primary center, the backup center can run the weather models and then deliver the products to all the countries.

The backup computer in the second location could be used for research purposes when not needed for operational functions.

6.2.8 Service Center Name

The new service center needs a name that would describe its activities in a proper manner and create a feeling of high competence and cooperation in its working area. The name should include some or all of the following aspects presented in Table 22.

Aspects related to the center name
• Weather forecasting and prediction
• Numerical Weather Prediction (NWP)
• Limited Area Modelling (LAM)
• Short-range and very short-range
• Nordic or North European
• Shared service Center (SSC)

Table 22. Aspects related to the center name.

The following examples can be suggested for the name of the SSC as working names:

Proposals for the name of the service center
• Nordic Limited Area Numerical Weather Prediction Center
• North European Limited Area Numerical Weather Prediction Center

• Nordic Center for Limited Area Numerical Weather Prediction Services

Table 23. Options proposed for the name of the service center.

The name beginning with *Nordic* would most likely describe the type of partnership and geographical area of the proposed cooperation. The name including *North European* would leave the possibility for other than Nordic countries to participate, which could be seen as inviting to other countries to this cooperative solution.

6.3 Validation with Experts

The new SSC model proposal was validated with leading experts at FMI. The validation group consisted of the IT professionals responsible for the service production at FMI. The proposal was also discussed with the FMI management.

The validation interview included the following aspects: 1) literature review suitability; 2) case studies value for proposal; 3) quality of the study of the current situation; 4) proposal for a new SSC, including: a) the analysis of the suitability of the proposed model (with the requirements analysis for the operational, functional, technical, economic, cooperation requirements and political support of the planed SSC), and b) practical suggestions for the common arrangement to the SSC.

The literature review was considered suitable as a foundation for the work. The case analysis was also considered valuable for the study. The current state analysis was considered to be well presented, with a through focus on the plans already made in this area. The proposed model was considered to suit the needs of FMI on the technical level relatively well. The scale advantage and the need for higher cooperation were also supported. Some disadvantages were seen in losing the independence in the proposed cooperative solution. But the most challenging part was considered to be the fact that the proposed cooperation would lead to the situation where the national capacity would possibly be lost.

Overall, the proposed SSC model in this Thesis was seen as necessary to secure the future high performance capacity, from the cost point of view. The deepening Nordic cooperation was also considered as positive development. No major changes to the service proposal were seen necessary, although a deeper planning was considered essential in the future.

6.4 Key Elements and Beginning Tasks of the Proposed Service Solution

The key elements of the proposed service solution based on the SSC model are shown in Figure 27.

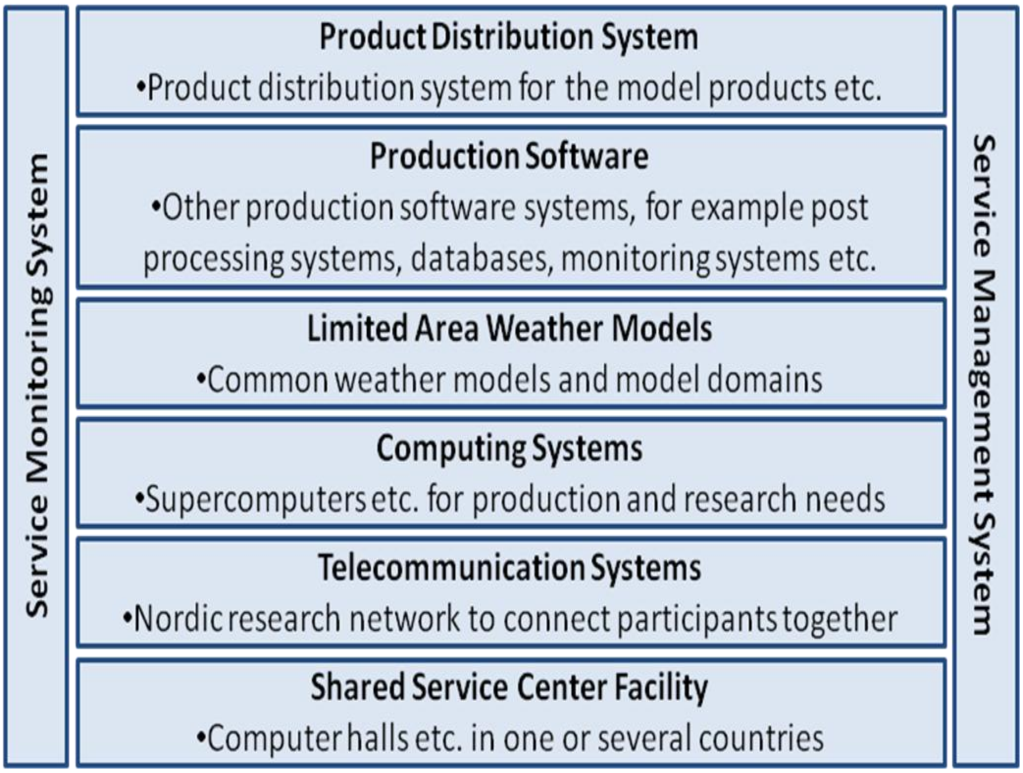

Figure 27. The key elements of the proposed service model.

As can be seen in the Figure 27 the key elements of the proposed service model are the physical site for the SSC, the telecommunications systems, computing systems, the weather model and other production software and the product distribution systems.

The key tasks to be done as the next steps to begin the proposed service solution based on the shared service center model are listed in Table 24.

Task	**What needs to be done**
Detailed planning	It is needed to start the detailed planning of the new shared service model.
Choosing the models and domains	It is needed to choose common weather models and their domains to be calculated in the shared service.
Setting up the new SSC	Setting up either a SCC in one physical location which can be considered the most cost efficient solution; or, a multi-site center divided between different participating countries with high speed telecommunications capabilities.
Starting the operational services	Establishing cooperation in supercomputing and weather model calculations between the Nordic countries. This phase includes possible supercomputer and other hardware procurements.
Integration of shared services to the production systems	It is needed to integrate the shared production system to each participating countries own meteorological production systems to get the operational phase running.

Table 24. Key tasks to start the proposed service solution.

As can be seen in the Table 24 the key elements of the developing cooperation are more detailed planning and after that to build up the key components of the shared systems. This study acts as a ground work for the wider shared services and the planning and cooperation development work need to be done in all the fields before any actual production system changes can be done.

6.5 Synthesis of the New SSC Model

As was demonstrated in the proposed SSC model, the SSC could provide many different benefits for the participating meteorological organizations. Various services are possible to be arranged successfully within this model, and its cost efficiency is visible quite well when estimating based on the case examples presented in this study.

The proposed SSC model is considered suitable by, first, studying the successful case examples; second, by considering the plans already made in this area, and third, by interviewing a wide group of experts in this area, as well as validating the proposal with the experts in the case organization. Based on the findings, the Nordic meteorological services can be considered suitable for the SSC model as these, first, act in a defined regional area, second, provide similar services in this area; and third, can achieve the scale advantage which is well visible in this kind of services. Additionally, the knowledge and expertise enhanced by the cooperation tend to create even higher level skills and result in better products and services for the customers.

There are two possibilities to set up the new SSC suggested in this study. First, it is either a SCC in one physical location which can be considered the most cost efficient solution; or second, a multi-site center divided between different participating countries with high speed telecommunications capabilities.

The first service in the proposed SSC model would most likely concentrate on establishing cooperation in supercomputing and weather model calculations between the Nordic countries and their meteorological organizations. Once this cooperation has started, further cooperation could be arranged on top of that. This could help to produce even more cost savings in meteorological production and also help other new services or service models to be born in cooperation.

The collaboration could be based on equal sharing of the costs for setting up and using these services, especially if the participants would consist of the countries such as Finland, Sweden, Norway and Denmark which have similar financial capabilities in their meteorological operations.

The collaboration would be managed by a steering group as the main governing body for the common production collaboration that would have members from all the participating organizations. The daily operational work would be carried out using an operations group managed by an operations manager.

Using the proposed shared service model with careful planning and implementation the needed supercomputing capacity and other meteorological production resources could be acquired which would in best case lead to considerable cost savings, enhanced knowledge sharing and expertise, and eventually to improved services.

7 DISCUSSION AND CONCLUSIONS

This section discusses the results this study. It also provides recommendations and managerial implications for the case company and its cooperation partners. The research process, validity and reliability of the study are evaluated at the end of this section.

7.1 Summary

The basic business problem in this study is the cost efficiency of meteorological production systems and the high performance computing solutions for weather services production. The current trend in computing systems is the overall increase in costs, so that in the future it may be difficult to ensure the necessary technical capacity required for calculations of the new weather models. There are opportunities, however, to join forces internationally which help to overcome the challenges of funding.

In the current situation, the whole meteorological production system in the Nordic countries is organized individually, with the countries servicing their needs by themselves. The supercomputing backup systems are also handled nationally, by each country on their own. If the expenses of these systems were shared through a joined cooperation solution, a cooperative service center model could help to solve this problem. Sweden and Norway has already started to plan and implement a cooperative production system, and Finland is now interested to investigate a possible solution so that Finland could also participate in such cooperation in the future.

With this goal in view, this Thesis aims to increase the cost efficiency and cooperation of the meteorological weather prediction system(s) in the Nordic countries, potentially extended to other interested countries, with similar needs in limited area weather model calculations. The objective of this research is therefore to investigate and propose an effective cooperative solution for weather predictions system(s) using a shared service center (SSC) model. The outcome of this study is thus a model for the case company for creating a common Nordic SSC for weather prediction system(s).

First in this study the SSC concept was studied as literature research and by using expert interviews. Based on this information a SSC successful implementation requirements model was built to find out what is needed as a beginning state of service production to be able to build a SSC for these services successfully.

Second step was to do a case study including two case organizations that are relevant to this field of work (CSC and ECMWF). The SSC successful implementation requirements found out from the literature review were then compared to the case study organizations. It seemed that the requirements found in the literature best practices study were relevant also in the case examples. The presented requirements were very well fulfilled in the case examples and as these SSCs were already shown to be successfully implemented the requirements model proved to be a decision making supporting tool.

Third step was to study the current situations in service center potentially participating Nordic meteorological organization's weather prediction systems. Also the current Nordic cooperation plans were analyzed based on official reports and expert interviews. The current situations in Nordic meteorological organizations were also compared to the SSC requirements model in similar way as to the case examples to see if the SSC model would be suitable for this practical meteorological service case. It showed that these requirements from the model were fairly well fulfilled and that there could be a possibility for successful service center implementation. It is certain that there exits also many other points to affect the possibility to succeed in the SSC implementation but these did not come out in this study.

Fourth step in this study was to build up a proposal for the future cooperation model for the Nordic weather prediction systems. The SSC model was considered to be suitable in this case and the proposal is built on this concept. Nordic meteorological services are considered suitable in the SSC model in weather prediction systems as these act in certain regional area that benefit well with similar services in its area and the scale advantage is well visible with this kind of services. Also the knowledge achieved by the cooperation creates usually higher level skill and results in better products for the customers.

The first service possibility in shared service model would be most likely co-operation between Nordic countries meteorological organizations in super-computing and weather model calculations. Once this cooperation would be started, further cooperation could be arranged on top of this. This could help to produce even more cost savings in meteorological production and also to help all new services or service models to be born in cooperation.

Currently the operational models at SMHI, met.no and FMI are working at different resolutions and different domains but in a common production harmonization of domains, versions and output is needed. SMHI and met.no are prepared to continue the HIRLAM and ALADIN NWP cooperation and that the future modelling system will be based on HARMONIE. These plans suit FMI's plans also very well.

For the timetable to this development, the new SSC cooperation model could possibly be set up at later time when met.no and SMHI has already started their common production in 2013 or 2014. At this phase of the cooperation between SMHI and met.no no disturbance is allowed to affect the plans already made in this area. Discussion of the future plans can be held in the meanwhile to create plans for the future development at this time. Sweden and Norway would like to get the collaboration up and running first, and then they are ready to start discussions on a cooperation extension. Finland and the other Nordic countries would be anyhow the first countries to be involved in such a discussion which is an encouragement for these wider shared service plans.

After the common weather model system would be implemented, the planned cooperation could expand even further. This could help to achieve better quality in meteorological production and help other new services or service models to be born. This would also lead to a situation when the costs for service maintenance would become lower, and a closer collaboration between institutes would emerge, with other positive developments resulting from this cooperation.

7.2 Managerial Implications

This section presents the managerial implications (MI) for the case company, based on the findings from the study.

This research is one of the first steps to create a wider meteorological cooperation in technical aspects. The actual implementation of the cooperation will require more discussion between the potential participants to build a stronger foundation for cooperation. The planning of the actual implementation will also be needed in more detail before starting on the project. The timetable for potential cooperation will require up to several years, as there is already a started cooperation project between two potential participants that need to be implemented first. At the moment, there is a lot of interest for a wider cooperation, and this will likely to keep up this discussion also in the near future. To better prepare for this discussion, this study suggest the following managerial suggestions.

MI-1, Current state of cooperation in this field of work: Currently, in the Nordic countries, there is no exact opinion formed on the cooperation development in this field. Sweden and Norway will develop their bilateral NWP cooperation, and after 2014 further steps can be taken if the cooperation is seen as possible and open for more countries. Still, it can be argued that it is important to keep on planning for the future Nordic cooperation in different areas. For many decades the Nordic countries have had close collaboration in many areas and acted successfully towards common goals. The question of creating a SSC in weather predictions systems is a difficult one, and no rapid results can be expected. It is still important to plan for different options in cooperative models; therefore, conducting more in-depths investigation can be recommended to keep up professional discussion with the Nordic countries in order to achieve results in its time.

MI-2, Proceeding with cooperation: The results of this study need to be presented to FMI and to the possible cooperation partners in order to evaluate the value proposition. After this, discussions need to be held in each organization or country about the acceptance of the proposed plans taking into consideration also the security point of view. After these steps, further discussions need to be conducted with possible partners interested to participate in the shared service model; and based on the results, a consortium for the SSC could be established. In case of political, operational and technical acceptance of the proposed plans, the implementation phase can subsequently start. The implementation phase needs to be preceded with a more detailed planning and the actual implementation process of the SSC. The implementation phase could require up to a couple of years followed by the transition phase for the operational change to the shared services center. It is needed to prepare to the possible cooperative solution at FMI and consider the possibility in near future HPC investments.

MI-3, Timetable of possible wider cooperation implementation: The new SSC could possibly be set up at a later time when met.no and SMHI has already started their common production in 2013 or 2014. At the current phase of the cooperation between SMHI and met.no, no disturbance is allowed to affect the plans already made in this area. Meanwhile, discussion on the future plans can be held to develop the plans for the future development. Sweden and Norway would like to get the collaboration up and running first, and then start discussions on a cooperation extension. Finland and the other Nordic countries would be the first countries to be involved to such a discussion, which they should wisely arrive at thoroughly prepared. It is needed to keep up the active discussion in this area and start the more detailed discussions with Sweden and Norway after they are ready to expand their cooperation.

7.3 Evaluation

The evaluation of the study is made by comparing the achieved results to the initial target, and by estimating the validity of the research results and evaluating the reliability of the research work conducted.

7.3.1 Results Achieved Compared to the Initial Targets

The business problem in this study did stress the importance of cost efficiency in weather prediction systems and set it as the main study goal. If taken on a general level, this study did aim to increase the cost efficiency and co-operation in the meteorological weather prediction system in the Nordic countries, including possible other participants with similar needs in limited area weather model calculations. If described on a more detailed level, the objective of this research is to propose a more effective cooperative weather predictions system compared to the current state by using a Shared Service Center (SSC) concept. As the outcome of this study, the Thesis needed to develop a model for the case organization for creating a Nordic SSC for weather prediction system.

The results compared to set targets could be considered as successfully achieved, and the research process followed as planned. The cooperative service model proposal was built to increase the cost efficiency of the weather prediction systems. Also a proposal for actions is presented for the further planning and implementation of the shared service center.

7.3.2 Validity

According to Yin (2003), the validity of results of the study can be improved by investigating several case examples in the research field, as well as by establishing a chain of evidence and by gathering stakeholders' views on the draft of the research report, among other means. Yin (2003) also argues that any case study finding or conclusion will be more convincing and accurate if based on several sources of evidence.

In this research, the validity was ensured by following the recommendations of Yin (2003), namely by studying several case examples and by investigating different sources of data which support the study conclusions. The data collection includes qualitative interviews, literature research and also the researcher's own work experience. The persons interviewed in this study have years of experience in the work field. The case examples chosen for this

Thesis work are well-known in the professional field and presented in sufficient detail, since the researcher has years of cooperation experience with these organizations.

The chain of evidence in this Thesis work is constructed by documenting the research process consistently and clearly for the reader to be able to follow the process from the beginning to the end by describing what was done in each step and why was this needed to be done. In this study, this clarity of the research purposes and processes is ensured, first, by presenting the case organization and its needs for the study; secondly, by conducting a literature study in the professional area to support the case studies; and thirdly, by collecting information on two cases which are then presented and evaluated, with the learning from the cases compared to the current state of the case organization. The findings from these sources and the development needs are then applied to create the proposal for the new model.

The stakeholders' views on the problem and results of the study were gathered in three different ways. Firstly, these views were reflected in the data collection on the current state of the case organization which is heavily based on the existing ideas expressed by the stakeholders. These views were collected in the interviews, during the data collection phase. Secondly, the research process was developed in cooperation with the stakeholders throughout the study, by conducting special discussions at different research steps. Thirdly, the draft of the research report was presented to several experts in the field, for the results to be evaluated before the conclusions were finally drawn.

To ensure the quality of the research process, it was developed based on a theoretical study of the SSC as well as two practical cases of successful implementations of SSCs by using benchmarks from the same industry. After these in-depths studies, a proposal for the model of a SSC was developed to meet the specific needs of meteorological organizations in weather prediction systems. The developed model was then compared to the case examples to verify its validity.

The validity of the data in this Thesis was based on gathering the research and case data from both official sources and people working in the case organization and benchmarking companies, skilled and experienced in their field of work. The researcher himself has also years of experience of working in this professional field applied for estimating the value of the data obtained.

7.3.3 Reliability

The reliability of the research implies the researcher's intention to minimize the possibility of misleading the readers of the research work and giving as true image of the reality as possible. The reliability of the research also means consistency of the research findings and implies that the research is conducted and documented in such a manner that the study can be repeated by following the indicated steps and arriving at similar results. (Kvale 1996: 235)

Qualitative research is sometimes criticized for being unreliable and subjective. One of these critics, Patton (1990), argues that qualitative research often lacks objective quantitative data. He also points to a possible bias caused by the researcher's subjectivity as for the research object. To address these challenges, Patton recommends creating a more reliable research process by carefully documenting all the research procedures, thus giving others a possibility to access the bias in the research work. (Patton 1990: 482)

In this research, the reliability was ensured by a number of steps. First, the reliability of the case examples was improved since the researcher was a customer of both of the case study companies for more than a decade now and has had considerable experience to collect and analyze the data on their services and the way of working. The researcher has also worked for the ECMWF (Case example 2) Technical Advisory Committee for more than four years which gives sufficient practical experience to analyze and evaluate this case organization. The cases were also analyzed using the literature available for studying these and also several experts were interviewed to improve the results that can be biased by the researchers own subjectivity. Second, all the other study steps also included expert interviews and studying of written material available for analyzing the state of meteorological organizations and their services. Findings from the case studies were compared to the meteorological organizations to find out reliable facts about the cooperation model suitability to this practical case. Also the work made by other Nordic meteorological institutes was utilized to achieve more reliable results.

The documentation on the interviews and brainstorming sessions was used in all the research steps. As the material was gathered in longer time and had several different forms it was needed to be very careful to keep the facts clear for the final analysis. The researcher had the fortunate possibility to discuss with the interviewees almost daily and this way confirm the image that was drawn based on the interviews and discussions. Supporting information about the subject of the study was also provided in all these years that the researcher has been working with similar challenges as was the subject of this study in the same organization that the work was made to.

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Appendix 1.

FMI Mission and Priorities

Mission and service areas of the Finnish Meteorological institute:

Mission and service areas
• FMI observes the physical state, chemical composition and electro-magnetic phenomena of the atmosphere
• FMI observes the physical state of the Baltic Sea and the Arctic sea areas
• FMI is operating on the 24/7 principle, produces high-quality information and services about the past, present and future states of the atmosphere and seas
• FMI conducts high-standard research and development in the fields of meteorology, maritime sciences, air quality, space physics and earth observation
• FMI carries out competitive commercial activities, based on expert services, both in Finland and abroad
• FMI plays an active role in national and international cooperation
• FMI actively disseminates information about matters associated with the atmosphere, seas and near space.” (FMI 2012)

Table 25. Mission and service areas of the Finnish Meteorological institute.

Priorities of the Finnish Meteorological Institute:

Weather and safety
• Supporting the functioning of society in challenging weather and maritime conditions • 24/7-based weather, water, climate and marine services • Acting as a safety authority, making provision and ensuring preparedness • Monitoring the spreading of ash, smokes and hazardous substances Global monitoring and warnings for natural disasters
Climate change and society
• One of the leading experts in atmospheric sciences in Finland • Support for decision-making • The threats and opportunities of climate change for Finland • Economic impacts of the weather and the climate

• Climate Service Center
The Baltic Sea and Arctic regions
• Maritime safety (weather, waves, ice and sea level) • Changes and safety services in the Baltic Sea and Arctic regions • Interaction between the climate and seas • Emissions from shipping and their dispersion
Transport and energy
• Fluency and safety of transport as part of intelligent transport • Impacts of emissions on air quality and on the climate • Low-emission energy. (FMI 2012)

Table 26. Priorities of the Finnish Meteorological institute.

Appendix 2.

FMI Staff: Facts and Numbers

FMI has a total of around 680 persons working for it. Figure 27 presents the number of person years working in FMI's different divisions and educational background of the employees.

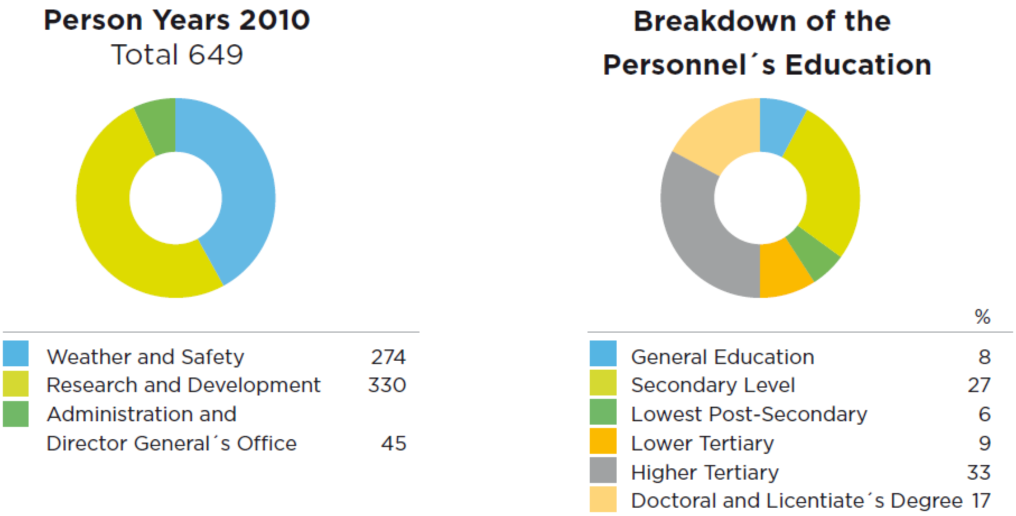

Figure 28. Figures of personnel at FMI (FMI 2012).

As illustrated in Figure 27, education level of the FMI staff is relatively high as research activities are taking more than half of FMI total person working years. The staff working for the meteorological forecasting has generally a Master's level education in various fields. (FMI 2012)

Appendix 3.

Measuring of FMI Activities

FMI utilizes different types of measurements for its activities, for example, it measures weather service quality, customer satisfaction and FMI's total productivity development. But all these measurements represent a standard way of measuring used in Finnish governmental organizations. This Thesis aims at developing a cost efficiency of FMI's computing systems and, as these investments are relatively large and run in millions of Euros range, they need to be visible in the total productivity measurements.

There also exist various supporting measurements in different units of FMI. For example, in IT services there are measures of availability of systems; data delivery rates; internal customer satisfaction, job satisfaction and other measurements. Additionally, in public sector yearly surveys are conducted that provide information about the development of costs, systems and electronic services of public actors. These numbers can also be used to consider the development of IT systems in general, as well as for comparisons of public organizations with each other and evaluation of their cost efficiency levels. Figure 28 illustrates the development of total productivity of FMI from year 2000 to 2010.

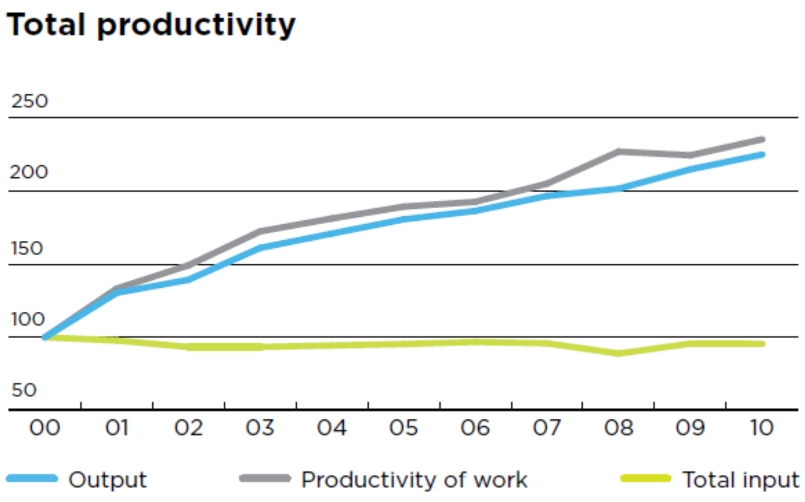

Figure 29. Total productivity development of FMI (FMI 2012).

As seen from Figure 28, the total productivity of FMI has been developing very well at FMI case and this development need to be continued and the

Nordic NWP cooperation can be one component in the future productivity development. Shared service solution can provide more computing power with similar amount of money and increase the productivity of the FMI.

Appendix 4.

Supercomputing Needs in Weather Services

Supercomputing is a critical part in most of FMI's services and the reasons for this are explained in the following chapters. Supercomputing is also the key component in this planned shared service cooperation and this section gives deeper understanding why the supercomputing is the foundation of all weather services.

Demand for weather services and their relation to supercomputing

According to FMI (2010) sensitivity to weather in Finnish society has continued to increase, which will affect functions such as road, railways, airways and maritime transport, energy supply, rescue services as well as a number of other business segments. Climate change, population growth, urbanization and globalization of society increase the sensitivity to climatic events and natural phenomena in general. Need for information and services to enhance public safety, as well as society in order to ensure that weather-related economic losses are minimized, increases all the time. National weather service's ability to near real time operation, at least in exceptional circumstances, is a special strength. The ability to provide 24/7 safety services on the other hand requires sufficient human resources and operational well maintained IT and other infrastructure. Operational IT environment is a central component in this weather service system and the high performance computing environment, in which weather forecasts are produced, is its key component. National weather service's most important role in Finland is to be a safety agency and support the functioning of society as well as possible.

According to FMI (2010) the demand for Finnish Meteorological Institutes know-how and services continue to increase in other areas also. Climate change and its consequences are needed to be understood with new knowledge and new research, and many different sectors of society are the customers for this kind of services and consulting. In particular, services should be developed and new skills in order to assess the climate developing in the next 10-20 years. Also the Baltic Sea is of great interest to FMI's actions. FMI is investigating atmosphere-ocean interaction, and developing its maritime security-related research and development activities. For these research activities in information technology components the high performance computing and archiving systems are the key components and make this kind of actions possible.

According to FMI (2010) also the maritime transport is growing in the Baltic Sea and the Gulf of Finland. This results in situation where the oil and chemical related environmental risks are growing. Russia is also about to increase its oil exports in the Baltic Sea. Growing traffic requires new measures to safety, traffic flows and improving the economy by providing better weather, ice and ocean information and services. FMI is developing for shipping needs better customer-focused information and prediction services, as well as open water and for winter seasons. Services can be generated in the Baltic Sea in addition to covering the Arctic regions corresponding to new needs for services. FMI is also actively developing the Arctic region service production and observation system know-how. The sea safety is a different type of modeling function, which also requires efficient high performance computing environment.

Weather modelling and its relation to supercomputing

National weather model system is based on a limited area, which can be driven at a higher resolution than the global system. Because of the more accurate resolution, the limited area models are able to describe the small-scale phenomena (e.g. wind conditions near the coast, areas of the lakes and mountains), and thus provide added value in relation to global models. Global models spatial resolution approaches in the next five years the current resolution of the national models (about 10 kilometers). Global models, despite of their rapid development seen in previous years, cannot always predict the major extreme weather phenomena in smaller scale. Such phenomena are for example thunder storms and its related very heavy rainfall. Air transport needs also bring new challenges, such as cloud base height, cloud thickness, fog and visibility, for weather forecasting. Urban heating effect and its associated small-scale structures into the flow claims better resolution from the weather models. For severe weather forecasting challenges, through demands in a km-scale, high-quality, restricted area weather modelling, a high capacity computing systems are required. (FMI 2010)

According to FMI (2010) in the limited area weather modelling a key trend in the world has been a special focus on small-scale, short-term weather modeling. In weather models, this means a setup that allows non-hydrostatic convection in the prediction systems. These future prediction systems, because of the difference between the calculation methodologies, are significantly heavier than the current operational models. Short-term numerical weather prediction in Finnish case also requires enhanced remote-sensing observations (e.g. satellite instruments and weather radar data) in the use of a sufficiently large area (Northern Europe) into the model for determining the initial state. A weather model that covers Northern Europe and Arctic Seas in 2.5 km horizontal resolution requires about 15 times more computing power compared to FMI’s existing capacity. Similarly, only the Finland covering 1 km horizontal resolution model, also requires about 15 times more processing power compared to FMI’s existing capacity. So it is obvious that the amount of available capacity in supercomputing plays a vital role in weather model development.

FMI has been at the forefront of km-scale weather prediction system HIRLAM as part of an international consortium. The future supercomputing capacity, for internationally co-developed km-scale model, can be used at full capacity as part of the daily operational weather forecasting activities. Increasing the computing capacity is vital to secure the FMI’s research status in weather model international development activities.

IT systems in weather service productions

FMI service production and delivery system is one of the most modern in its field and this has been FMI’s goal for years. Modern production system has made it possible in service development and deployment to entirely new kinds of weather and sea products. By combining the same type of production activities throughout the service chain, the meteorological services in production are even more effective for the customers and new services can be implemented effectively. Active participation in international activities will also ensure FMI's competitiveness and cost effectiveness in the future. In FMI's information system management it is a continuous challenge to secure the necessary computing and archiving capacity available in all circumstances. The FMI's aim is to ensure that both research and operational services have the needed IT systems in use.

High performance computing is also socially very important in the dispersion model use for example in case of nuclear accident, chemical accident and in ash emission situations. Dispersion models cannot be performed in emergency conditions if the weather model input data is not available and these are produced in supercomputer weather calculations. The spreading is also calculated FMI supercomputers and used directly by radiation safety officials. For these reasons FMI's computing activities are not permitted to be available under the 99.9 % availability. Long interruptions in operation of this equipment are reflected in society as a whole and the effects of it are multiple in costs compared to the investment made to the system. Hardware purchases, however, makes sense to do in cooperation with the computing centers to utilize the scale advantages and the highest skills at the national or international level.

Development needs in supercomputing

Because of the weather model needs FMI has a need to develop its high performance computing systems according to the current plans to have 15 times the capacity compared to the current system. The next procurement will take place in 2013. In the previous high performance procurement at 2009 the supercomputer facility capacity increased by approximately 19 times compared to the earlier 2005 purchased equipment. The investment amounts in high performance computing have grown all the time in recent years. Amount of investment in relation to its benefits can still be seen very reasonable but the financing is difficult anyhow as more money is not easily available. Similar trends in costs are faced in all industrially developed countries and the work towards this direction has been considered necessary. Also Finland should remain involved in this process of developing the available supercomputing capacity.

Appendix 5.

Interview Questions for the Case Analysis (Cases 1-2)

Interviewed managers and specialists have been the customers of the Case organizations for several years and are responsible for providing these services to FMI's internal customers.

List of Interview Questions for the Case Analysis (Cases 1-2) was the following:

1. What kind of services have you bought from the Case organization?
2. How would you estimate the Case organization succeeded in its services for the meteorological field?
3. How cost efficient do you think that the Case organization is in its actions?
4. What do you consider to be the added value for the customer to use the services of this Case organization?
5. Do you consider it valuable to keep purchasing these services from the Case organization in the future also?
6. Any other comments about the Case organization?

Appendix 6.

Interview Questions on the Requirements Model (used the analysis in Cases 1-2 and for the current state analysis)

Interview for the New Shared Service Model was based on the following questions:

1. What kind of operational and functional requirements do you see needed for a successful shared service centre?
2. What kind of technical and other requirements do you see needed for a successful shared service centre?
3. What kind of cooperation requirements do you see needed for a successful shared service centre?
4. What kind of political support requirements do you see needed for a successful shared service centre?
5. Any other comments on the requirements or factors affecting the possibility for a successful shared service centre implementation?

Appendix 7.

Interview Questions on SSC Suitability to Nordic Weather Prediction Cooperation

This appendix provides information about the interviews on the shared service center suitability to the possible Nordic cooperation in the weather prediction area. The daa collection was based on discussions and brainstorming sessions with the colleagues at FMI, SMHI and met.no. Since the information on such cooperation is considered as sensitive and cannot be disclosed, the exact answers to the interviews, discussions and brainstorming sessions cannot be provided.

Interview questions for the discussions with colleagues from FMI, SMHI and met.no

Central questions for discussion
1. Do you see the need to develop the Nordic NWP cooperation to include also Finland?
2. Can it be possible, even if on a theoretical level, to expand the NWP cooperation between met.no and SMHI in the future to include Finland and possibly other countries, if those become interested (Denmark, Island and possibly also other countries around the Baltic Sea area)?
3. In what timetable could this cooperation expand, if ever, to include several countries?
4. How could this kind of cooperation be implemented in practice as there would be more than two countries sharing their resources? A shared service center is one possibility. Can this model be considered as a good solution for this cooperation, if such cooperation would expand to include several countries?

Table 27. Questions for cooperation interviews, discussions and brainstorming sessions.

Appendix 8.

Summaries of the Interviews, Discussions and Brainstorming Sessions on SSC Suitability to Nordic Weather Prediction Cooperation

The following summaries of responses represent the research data gathered from the interviews, discussions and brainstorming sessions (without giving names or providing details of the responses which cannot be disclosed due to business and political reasons).

Question 1: Possibility to widen the Nordic cooperation

The possibility to widen the weather prediction cooperation is seen possible at least in theoretical level at FMI, met.no and SMHI. These opinions are anyhow very careful estimations and no clear opinions in this matter currently exist. It is seen important that there should be no delays in current already existing co-operation between SMHI and met.no because of the possible participation of FMI or any other countries meteorological institute. In case of more than two countries involved in weather model calculations cooperation it is needed anyway to consider the possibility of having a common Nordic meteorological computing and storage system center.

Question 2: Timetable for possible cooperation expanding

The new shared service center cooperation model could possibly be set up at later time when met.no and SMHI has already started their common production in 2013 or 2014. At this phase of the cooperation between SMHI and met.no no disturbance is allowed to affect the plans already made in this area. Discussion of the future plans can be held in the meanwhile to create plans for the future development at this time. Sweden and Norway would like to get the collaboration up and running first, and then they are ready to start discussions on a cooperation extension. Finland and the other Nordic countries would be anyhow the first countries to be involved in such a discussion which is an encouragement for these wider shared service plans.

Question 3: Suitability of shared service center model

Shared service center can be seen as one possible suitable model but it is not clear how it should be set up. Estimations in this matter are also very careful and no exact opinions exist currently in this also. Shared service center can be a good model but the risk is seen in losing the national capacity from some countries and this need to be planned well before any actions towards the shared center can be taken. SMHI and met.no will have to learn from the experience they are gathering now in their current developing cooperation before it is possible to list the possible future cooperation options in more detail.

Question 4: Ways to proceed in the cooperation

As no clear opinions exist currently in the cooperation development, the way forward can be seen as such, that a proposal is made by this Thesis and the possibilities to develop are estimated in later discussions. It anyhow will take some years before any concrete actions towards the shared service can be taken as Sweden and Norway will develop their bilateral NWP cooperation first and after 2014 the further steps can be taken if the cooperation is seen possible to develop to include more countries.

In summary, it can be concluded that it is important to keep on planning the future including more Nordic cooperation in different areas. Nordic countries have had close collaboration in several areas for many decades now and it has given more strength to the countries acting together towards common goals. This question about creating a shared service for several countries in weather predictions systems is a difficult one and no rapid results can be achieved in it. It is still important to plan different options for cooperative models and keep up the discussion in Nordic countries and with patience results can be achieved in time.

Appendix 9.

Interview Questions for the New Shared Service Model

Interview for the New Shared Service Model was based on the following questions:

1. Do you see it possible to implement a shred service for the limited area weather modelling services in the Nordic area?
2. What kind of model domains could this kind of cooperation include?
3. Could there be same weather model domains in use for all the Nordic countries (at least for Finland, Sweden and Norway)?
4. Could there be the same limited area models in use for all the Nordic countries (at least for Finland, Sweden and Norway)?
5. Do you know any good examples of this kind of service and how these have been working in practice?
6. How many sites should the shared service model have in the future co-operation?
7. How many countries could participate in the cooperation?
8. How would the cost sharing work in the best possible way?
9. How should the cooperative model be managed?
10. What kind of telecommunications solution should this kind of service be built on?
11. Can you describe an existing telecommunications solution that could be utilized in this kind of cooperation in the Nordic countries?
12. What would be a suitable name for this kind of service centre?
13. How would the Nordic countries develop their services together in the common service?

14. Are there some risks to be considered when developing this kind of service?

15. How should the customers be taken into account when developing this kind of service?

16. Is national safety a thing to be considered in this kind of development?

17. Any other points to consider when creating a new model for the shared service?

Appendix 10.

Interview Questions for the Current State Analysis at FMI

Interview for the Current State Analysis at FMI was based on the following questions:

1. How does the FMI produce its weather modelling services currently?
2. Has FMI been interested in international service production possibilities?
3. Has FMI been already planning international service production in weather prediction services?
4. Has FMI been already part of international service production in weather prediction services?
5. Has FMI needs for developing the international cooperation in the field of weather prediction services
6. What would be the reasons for developing the services to multinational direction?
7. Is FMI aware of the plans made by other Nordic countries and if so, what kind of plans have they made?
8. Any other comments or facts about the current state of FMI weather prediction systems concerning the work to be made in this study?

Appendix 11.

Interview Questions for Validation with experts of the draft proposal

Interview for validation with experts was based on the following questions:

1. Literature review suitability for the case studied?
2. Case studies value for the proposal in this meteorological case?
3. Quality of the study of the current situation at FMI and in the other Nordic countries?
4. Proposal value for a new SSC, including:
    a. The analysis of the suitability of the proposed model (with the requirements analysis for the operational, functional, technical, economic, cooperation requirements and political support of the planed SSC), and
    b. Practical suggestions for the common arrangement to the SSC.
5. Other opinions or comments on the work made?