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PARTICIPATORY APPROACHES TO FORESIGHT AND PRIORITY-SETTING IN INNOVATION NETWORKS

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Title: Participatory Approaches to Foresight and Priority-Setting in Innovation Networks

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Abstract: In innovation networks, participatory foresight activities can typically have several functions. They can be seen as a tool for supporting decision-making on science and technology (S&T) priorities, but they can also be expected to contribute to the structures of a network beyond the scope of decision making. Foresight activities are often limited by tight timeframes, budgets and they need to be synchronized with other S&T processes. In this setting there is a need for tools that reflect foresight process owners' visions on trade-offs between objectives that are more important than others, and goals that can be achieved, given relevant constraints.

This thesis develops, deploys and analyzes decision analytic methodologies for participatory foresight and priority-setting. The methodology enables foresight managers to adjust their foresight process to serve multiple goals and place emphasis on the objectives that are seen as most important. Foresight processes can be adjusted to meet the desired objectives by i) selecting a suitable "unit of analysis" for the analysis and discussion, ii) defining an appropriate composition of stakeholders for the different phases of the process, iii) different uses of decision analytic methodologies and iv) varying emphases on internet surveys, decision analysis, and face-to-face workshops.

This thesis consists of six articles, where variants of the methodology are applied in different contexts. The articles include reflections from foresight activities carried out in support of management processes in Finnish industry clusters and in international research programs. They also include case studies from public S&T policy making, supporting the identification of small niche areas as well as providing input for decision-making on national innovation policies.

Keywords: Participatory foresight, S&T priority setting, multi-criteria decision analysis, group decision support, participatory decision making, expert engagement, technology management, innovation networks.

Otsikko: Osallistavia lähestymistapoja ennakointiin ja priorisointiin innovaatioverkostoissa

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Tiivistelmä: Osallistavalla ennakoinnilla voi olla monia eri käyttötarkoituksia innovaatioverkostoissa. Ennakointi voi tukea tiede- ja teknologiateemojen priorisointiin liittyvää päätöksentekoa, mutta se voi vaikuttaa verkostojen rakenteisiin myös yleisemmällä tasolla. Käytännössä aikataulut, resurssit, ja tarve kytkeä ennakointi osaksi muita tiede- ja teknologiaprosesseja asettavat rajoitteita ennakointihankkeille. Näiden rajoitteiden takia tarvitaan ennakointityökaluja, joilla ennakointi voi palvella tavoitteita, jotka on katsottu tärkeimmiksi ja jotka voidaan saavuttaa näiden rajoitteiden puitteissa.

Väitöskirjassa kehitetään, sovelletaan ja analysoidaan päätösanalyyttisiä menetelmiä ennakoinnin ja priorisoinnin tueksi. Kehitetyt menetemät tukevat ennakointiprosessien erilaisia tavoitteita siten, että prosesseilla voidaan vastata tärkeimmiksi katsottuihin tavoitteisiin. Menetelmän puitteissa ennakointiprosesseja voi ohjata i) määrittelemällä sopivia tarkastelutasoja analyysin ja keskustelun pohjaksi, ii) osallistamalla viiteryhmiä prosessin eri vaiheisiin, iii) soveltamalla erityyppisiä päätösanalyysin menetelmiä ja iv) soveltamalla Internet-kyselyitä, päätösanalyysia ja työpajoja eri laajuudessa.

Väitöskirja koostuu kuudesta artikkelista, joissa menetelmän muunnoksia sovelletaan erilaisissa toimintaympäristöissä. Artikkeissa kuvataan ja arvioidaan tapaustutkimuksia, joissa ennakointia käytetään suomalaisten teollisuusklusterien ja kansainvälisten tutkimusohjelmien johtamisen tukena. Ne sisältävät myös julkisen tiede- ja teknologiapolitiikan tapaustutkimuksia, joissa on tunnistettu uusia niche-alueita ja tuotettu tietoa kansallisen innovaatiopolitiikan päätöksenteon tueksi.

Avainsanat: Osallistava ennakointi, T&K prioriteettien asetanta, monikriteerinen päätösanalyysi, ryhmäpäätöksenteon tukeminen, asiantuntijoiden osallistaminen, teknologiajohtaminen, innovaatioverkostot.

Academic dissertation

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Participatory Approaches to Foresight and Priority-Setting in Innovation Networks

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Official opponent:	Professor Ron Johnston, Australian Centre for Innovation

Publications

The dissertation consists of the present summary article and the following publications:

[I] Könnölä, T., Brummer, V. and Salo, A. (2007). Diversity in Foresight: Insights from the Fostering of Innovation Ideas, *Technological Forecasting and Social Change* 74(5), 608-626.

[II] Könnölä, T., Salo A. and Brummer, V. (forthcoming) Foresight for European Coordination: Developing National Priorities for the Forest-Based Sector Technology Platform, *International Journal of Technology Management*.

[III] Brummer, V., Könnölä, T. and Salo, A. (2008). Foresight within ERA-NETs: Experiences from the Preparation of an International Research Program, *Technological Forecasting and Social Change* 75(4), 483–495.

[IV] Brummer, V., Salo, A., Nissinen, J. and Liesiö, J. (forthcoming). A Methodology for the Identification of Prospective Collaboration Networks in International R&D Programs, *International Journal of Technology Management*.

[V] Salo, A., Brummer, V. and Könnölä, T. (2009). Axes of Balance in Foresight – Reflections from FinnSight 2015, *Technology Analysis and Strategic Management* 21(8), 287-1001.

[VI] Brummer, V., Salo, A. and Ollila, M. (2009). Balancing incentives in thematic priority setting for collaborative innovation networks, *Proceedings of the EuroMOT 2009, the 4th Fourth European Conference on Management of Technology: "Closing the Innovation Gap: Theory and Practice"*, September 6-8, Glasgow, Scotland.

Contributions of the Author

Brummer is the primary author of papers [III], [IV] and [VI]. In paper [I], Brummer was responsible mainly for the reporting of the foresight process and development of the decision analytic methodology for analyzing innovation ideas. In papers [II] and [V], Brummer contributed to design of the participatory process. He also took part in the scientific reporting of the results.

Preface

This dissertation wouldn't have been possible without help, support and commitment of several people.

First of all, I want to express my sincere gratitude to my supervisor, Professor Ahti Salo, for the support and the guidance during the work. Offering an inspirational space for looking at facts and fiction from new perspectives, and demanding that ideas inside my head should be understandable also for other people, have been priceless – not just during the preparation of the thesis – but beyond. I am also grateful to Dr. Totti Könnölä for encouraging attitude from the beginning and my other co-authors Dr. Juuso Liesiö, Juuso Nissinen and Margateetta Ollila. It really has been fun to work with you. I also wish to thank preliminary examiners Dr. E. Anders Eriksson and Dr. Michael Keenan for instructive comments that indeed helped me to improve the thesis and gave new ideas for the future research.

During the preparation of the thesis, I have worked in the Systems Analysis Laboratory and in the Crisis Management Initiative. These organizations have given me a privilege to co-operate with amazingly talented, open-minded and genuinely friendly people. I wish to thank each of you for making the work meaningful and turning ideas into reality.

I wish to express my thanks to my friends and family – from the past, present and future – for raising me to a rather decent citizen.

And finally I want to say my own, genuine Hetula, that I love you.

Equally to all, thank you for the music, my friends.

Helsinki, 28 May 2010

Ville Brummer

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1. Introduction

Expert engagement and stakeholder participation are currently seen as one of the key elements for the design and the implementation of successful science and technology (S&T) policies (Asaro, 2000; Schot, 2001; Salo and Cuhls, 2003). Participatory approaches in particular have been seen as useful in forward-looking identification and analysis of future developments and S&T actions – i.e. foresight activities – (Irvine and Martin, 1984; Salo and Cuhls, 2003; HLEGEU 2002), both in the public (Martin and Johnston, 1999; Georghiou and Keenan, 2006) and private sector (Reger, 2001).

Initially participatory foresight activities were mainly seen as a means for improving decision-making on innovation policies and strategies, by engaging experts to consider alternative futures, and using their expertise to making better decisions (Irvine and Martin, 1984; Salo and Cuhls, 2003). Especially, participatory approaches were seen as useful in supporting the development of thematic S&T priorities (Martin and Irvine, 1989), where expert participation is needed to compensate and complement the lack of quantity and quality of statistical data and empirical evidence. From the 1990's onward, however, there has been a growing trend of characterizing the value of participatory foresight activities also in view of how they may "wire-up" international, national and regional innovation systems and contribute to the innovation capacity of industry clusters and research communities on a structural level (Martin and Johnston, 1999; Barré, 2002; Cuhls, 2003). In this setting, foresight processes can be seen as a way of, for example, engaging stakeholders to build a common vision and increasing their awareness and commitment to S&T actions (Cuhls, 2003), creating new networks, strengthening existing ones (Lundvall, 1992; Martin and Johnston, 1999), and fostering diversity (Könnölä, 2006).

The realization of new rationales for foresight processes does not mean that the more traditional objectives are less important. Instead, nowadays the value of foresight processes is seen through several functions. For example, Salo and Cuhls (2003) define participatory foresight as follows: "*an instrument of strategic policy intelligence which seeks to generate an enhanced understanding of possible scientific and technological developments and their impacts on economy and society, in order to support the shaping of sustainable S&T policies, the alignment of research and development (R&D) efforts with societal needs, the intensification of collaborative R&D activities and the systemic long-term development of innovation systems.*"

The need to deal with multiple objectives can also be seen in the management of foresight activities (Salo et al., 2004). Several studies have raised the question of how to balance the requirements of developing coherent and readily implementable recommendations for decision makers and contributing to the innovation system at the aggregate (Rip, 2003; Havas, 2003; Rask, 2008). However, despite the recognition of the need to include multiple objectives, there seems to be lack of rigorous approaches and methodologies for this purpose (Havas, 2003), especially within the coordination of priority-setting activities in innovation networks (Salmenkaita and Salo, 2004). On one hand, too decision-oriented processes and the domination of decision-makers may stifle creativity and new ideas (Weber et al., 2008). On the other hand, the results of processes carried out through methodologies that aim to produce information on alternative futures (such as the Delphi-method; e.g. Linstone and Turoff, 1975; and scenarios; e.g. Bishop et al., 2007) or foster interaction and creativity (such as expert workshops; e.g. Salo and Gustafsson, 2004) may be difficult to translate into actionable recommendations for the decisions that the foresight process may be expected to support (van der Meulen et al., 2003; Hjelt et al., 2001). Excessive emphasis on the building of shared visions may also make foresight results difficult to use; they may become too abstract and self-evident to benefit decision-making (Keenan, 2003).

In large-scale national foresight activities, the need to serve several objectives is partly met by applying multiple methodologies and by engaging a wide range of stakeholders (e.g. Durand, 2003; Havas, 2003; Keenan, 2003; Georghiou and Keenan, 2006). However, this may be resource-intensive and make the process time-consuming. In contexts such as innovation networks, that are characterized by voluntary coordination of S&T activities and relatively light weight management structures, the possibilities for extensive participation and using several methodologies may be limited (Salo, 2001; Azzonea and Manzini, 2007). Despite having multiple objectives, foresight activities often must be carried out within rather tight timeframes and budgets. Moreover, as foresight activities are often expected to constitute an integral part of the broader S&T strategy development, they should be adaptive to possible parallel processes and enable agile responses to the rapidly changing innovation environment (Salo, 2001; Salmenkaita and Salo, 2004, Eriksson and Weber, 2008).

The six papers of this thesis seek to respond to these challenges by developing new methodologies for assisting experts and other professionals responsible for the design, coordination and dissemination of foresight activities (later ‘foresight managers’) to better deal with multiple objectives and limitations that process owners and participants set for the foresight activities. Especially, this thesis develops methods for assisting thematic R&D priority-setting in innovation networks where, *alongside* this function, priority-setting process can be adapted to also respond to other foresight objectives, such as the consideration of S&T opportunities from different perspectives, or enhancing networking and diversity. Methodological development is focused to serve the management of innovation networks, where the tight timeframes, restricted resources, and parallel processes call for relatively light weight and readily implementable methodologies. Each essay also describes a real life case. The relevance of these methodological approaches and processes is thus reflected not only from related literature, but also from how they are suited to support priority-setting and foresight activities in their particular contexts.

The rest of this summary article is organized as follows. Section 2 gives an overview on the use of participatory foresight and summarizes the contributions of this thesis. Section 3 describes the methodological development presented in the thesis. Section 4 discusses the use of the methodology, and Section 5 concludes with some future research topics.

2. Background and Contributions

2.1 Innovation Process and Innovation Networks

One of the main rationales for applying foresight methodologies is the need to anticipate, foster and respond to *technological change* (e.g. Dosi, 1982, see also TFAMWG, 2004). Keeping with the common approach of scholars and practitioners, in this thesis technological change is not seen only as the development of a single technology, but as a complex chain of technological development and product and process innovations, in which their interrelations and dependencies play a central role (Metcalfe 1995). Moreover, the focus of foresight activities is not just in technological development, but in the *innovation process.* That includes also the system, where the technology is embedded, and the dynamics, how technologies interact with the surrounding environment (Smits and Kuhlman, 2004; Hekkert et al., 2007).

Participatory foresight can be seen as a tool for contributing to the innovation process and it can be applied at many different levels of the innovation system (Edquist, 1997; Martin and Johnston, 1999). The focus of foresight activities can be on the international (Georghiou, 2001; Jewell, 2003; Carlsson, 2006) or national (Lundvall, 1992; Durand, 2003; Havas, 2003; Keenan, 2003) level, in a network (Salmenkaita and Salo, 2004) or in a single organization (e.g. Reger, 2001; Könnölä et al., 2009).

The case studies represented in the articles engage mainly S&T experts from academia, the private sector and the governance. In this thesis, foresight activities are considered in the context of *innovation networks* (Bullinger et al., 2004) that include, among others, research communities and industrial clusters. Compared to innovation system-wide foresight processes, where technologies are analyzed in a broad context and considerable emphasis is placed on their interactions with the surrounding society at large, this approach narrows the focus. Such activities do not engage experts from organizations that have more indirect impact on S&T activities, such as media, ministries responsible for taxation, regulations and education and NGO's that aim to influence public opinion. They mainly involve only organizations and actors that proactively contribute to technological development through shared S&T activities. Moreover, foresight processes focus mainly on identification and analysis of joint S&T activities and changes in society of particular relevance to the innovation network, and do not analyze the impact of, for example, tax incentives, public awareness campaigns and education policies that, indeed, are essential part of the broader innovation system. Thus when referring to an innovation process, this thesis considers technological development in context of innovation networks (see e.g. Orsenigo et al., 2001).

2.2 Functions of Participatory Foresight in Innovation Networks

In innovation networks, foresight activities can be seen as a tool for managing the innovation process – assisting the coordination of S&T activities and facilitating responses to rapid changes in technology and society (Irvine and Martin, 1984, Faucheux and Hue, 2001). Foresight activities can have at least two kinds of functions; i) supporting decision-making regarding the innovation process, especially thematic R&D priority-setting (Martin and Irvine, 1989) and ii) contributing to the capacities of the network at a structural level (Martin and Johnston, 1999).

2.2.1 Supporting Forward-looking Priority-setting

Priority-setting is one of the most common tools for managing the innovation process in innovation networks (Martin and Irvine, 1989; Salmenkaita and Salo, 2004). Within priority-setting, the role of foresight activities is often to identify trends and developments, elicit prospective ideas on process and product innovations, and foster debate on their interrelations among participating stakeholders.

Foresight activities can assist priority-setting deriving from both external and internal pressures:

- <u>Function 1.1 Matching S&T opportunities with changes in society and economy:</u> Priority-setting activities can explicitly seek to respond to external pressures such as societal, environmental and economical changes in the broader innovation system (e.g. Jarimo et al., 2005). In this context, foresight activities can assist decision-making by producing information on trends, weak signals, threats and challenges. It also offers a framework for analyzing potential S&T actions in view of alternative futures that may be derived from these developments.
- <u>Function 1.2 Internal coordination of S&T actions:</u> Priority-setting activities can also be driven by internal pressures to identify mutual synergies and overlaps, and coordinate S&T actions to form coherent entities that are needed to develop and commercialize innovations (e.g. Salo and Liesiö, 2006). In this context, foresight activities can be used to systematically map and analyze present and future S&T activities and search for potential to leverage existing expertise in new markets.

2.2.2 Contributing to Capacities of an Innovation Network on a Structural Level

Beyond supporting decision-making, another rationale of foresight activities is to contribute to innovation networks on a structural level (Martin and Johnston, 1999; Salmenkaita and Salo, 2002). By presenting a framework for experts and other stakeholders to debate on new S&T opportunities, new ideas and their relation to changes in society, foresight activities can be used in support of the following functions:

- <u>Function 2.1 Building a Consensual Vision:</u> One benefit of engaging experts and other stakeholders for foresight and priority setting activities is that it may increase their commitment to the decisions made as a result of the process. However, discussion of alternative futures and collaborative analysis of S&T opportunities and challenges is also useful in increasing mutual understanding and building a consensual vision – not only in view of ex-ante or ex-post evaluation of specific decision alternatives - but on a more general level. This, again, may be beneficial in synchronizing strategies and joint actions in a network, even beyond the decision making scope.

- Function 2.2 Creating New Networks and Strengthening Existing Ones: One of the characteristics of innovation networks is that the composition of actors and stakeholders involved to the innovation process evolves over time. In addition to changes in technological development, the roles of involved actors and stakeholders changes, and there is a continuous need to engage new actors to the innovation process. Sometimes there may be also a need for more systemic changes; for example, integrating national innovation networks to the EU level. In these kinds of contexts, by offering a structured framework for experts and other stakeholders to debate S&T challenges and opportunities, foresight activities can assist innovation networks to anticipate and shape their composition to keep pace with technological development and societal changes.
- Function 2.3 Fostering the Consideration of Innovation Processes From Several Perspectives: Within priority-setting, foresight activities can explicitly support the consideration of alternative S&T activities from several perspectives, thus helping decision-makers develop priorities that better respond to multi-faceted future challenges and opportunities. However, consideration of alternative trends and drivers, and prospective ideas on innovations from different perspectives can be viewed as a learning process for evolved stakeholders (Cohen and Levinthal, 1989). This again, may be a critical factor for the network's, and its' organizations capacity to develop new ideas and innovations (Cohen and Levinthal, 1990; Lane and Lubatkin, 1998).
- Function 2.4 Feeding the Innovation Network with New Innovation Ideas: Successful innovation processes do not always require totally new information and skills. On the contrary, often innovations are the result of combining existing knowledge in novel ways. Thus, by bringing researchers, industrialists, government officials, and customers together, and by providing structured framework for collaborative consideration of what kind of benefits new kinds of combinations of existing and new knowledge would have in changing innovation system, foresight activities can support the development of new ideas and innovations.

2.3 Contributions of the Thesis

This thesis develops, deploys and analyzes participatory methods for foresight and priority-setting activities in innovation networks. The methodological development described in the context of six case studies serves as a starting point for a methodological framework that can be used as a basis for designing and implementing different foresight and priority-setting processes.

The characteristics of the framework and methodological choices described in the articles (later 'the methodology' in brief) give some responses to the challenge of balancing between different objectives - especially between those that are related to decision-making (functions 1.1 and 1.2) and those that expect foresight activities to contribute to the capacity of an innovation network at the aggregate (functions 2.1, 2.2, 2.3 and 2.4) (e.g. Salmenkaita and Salo, 2002; Van Aken and Weggeman, 2002, Keenan, 2003; Rip, 2003; Rask, 2008; Weber et al., 2008). Based on the set objectives of a foresight process, the methodology can be adapted to mainly support priority-setting, such as in papers [II] and [III]. If needed, the methodology also enables foresight managers to put more emphasis on, for example, the identification of new networks, such as in paper [IV]. The methodology enables foresight activities to serve several functions simultaneously. In paper [V], methodology is used for both the building of a consensual vision among involved S&T experts (Function 2.1) and supporting decision-making on S&T priorities (Function 1.1). In papers [I] and [VI], methodological choices enabled – at the same time - efficient coordination of S&T actions (Function 1.2), engagement of new experts to the innovation process (Function 2.2) and fostering the consideration of the innovation process from several perspectives (Function 2.3). In paper [I], foresight activities were also used to feed new ideas to the innovation process (Function 2.4).The methodological development aims to support the management of foresight activities constrained by tight timeframes and parallel processes (Salo, 2001; Azzonea and Manzini, 2007). If needed, the methodology enables the implementation of foresight activities within a couple of months; such as in paper [II]. If more time can be reserved for the activities, it can also be applied within longer processes that engage a wide range of stakeholders from different scientific and/or geographical areas, such as in papers [III], [IV] and [V]. The methodology allows the embedding of foresight processes in the surrounding innovation environment (Salo and Salmenkaita, 2002; Salmenkaita and Salo, 2004); it enables the use of results from other processes as input, such as in papers [II], [VI], and it produces results, that can be easily adapted for other activities, such in papers [II], [III], [IV].

Each paper presents a case study, where foresight activities serve several functions. In all papers, the methodology is used to support priority-setting, but it is also used as a means to contribute to capacity of innovation networks at a structural level. Table 1 below summarizes the case studies, specific research settings, and their relation to the foresight functions described above.

Table 1: Research Settings and Foresight Functions in Different Case Studies

Paper	Case study	Specific research topics	Foresight Function
[I]	Design and implementation of a participatory process for engaging stakeholders to support panel work with new innovation ideas and weak signals in the Finnish Foresight Forum	• Develop a multi-criteria decision analysis methodology for analyzing innovation issues from diverse perspectives and supporting the identification of weak signals	Primary 2.3 and 2.4 Secondary 1.2 and 2.2
[II]	Design and implementation of a process for participatory development of national Finnish Strategic Research Agenda (SRA) for Forest-Based Sector Technology Platform	• Analyze what kinds of challenges the European Commission's innovation policy instruments place for foresight activities and identify what kind of methodological choices are needed to respond these challenges.	Primary 1.2 Secondary 2.1, 2.2 and 2.3
[III]	Design and implement a process for the collaborative development of a joint research agenda for an international research program	• Analyze what kinds of specific challenges there exist in the management of priority-setting activities in multinational research programs and identify what kind of methodological choices are needed to respond to these challenges.	Primary 1.2 Secondary 2.1, 2.2 and 2.3
[IV]	Develop a methodology for the identification of expert networks in an international research program	• Develop a two-layered multi-criteria decision analysis methodology for the parallel identification of research issues and researcher networks.	Primary 1.2 and 2.2
[V]	Design and implement a national foresight exercise initiated by two Finnish funding agencies	• Develop a multi-layered methodology for supporting participatory foresight activities • Analyze tradeoffs between different foresight objectives.	Primary 1.1 Secondary 2.1 and 2.3
[VI]	Design a process for participatory development of a prospective research agenda for the Finnish packaging industry	• Analyze how foresight activities can be embedded in the highest decision-making bodies of innovation networks • Analyze the use of an interactive decision-support tool to support priority-setting activities.	Primary 1.2 Secondary 2.2 and 2.3

Indeed, a methodological approach as such does not guarantee that the process will meet the desired objectives. There is also a need to have an appropriate organizational setting and participant base, as these factors often have major influence on the outcomes of the process (e.g. Miles et al., 2002; Georghiou et al., 2008). In general, a strong institutional setting and homogenous participant base are often seen as a good starting point for producing readily implementable recommendations. Loose connections to the highest decision making bodies and a more heterogeneous participant base, on the other hand, are often associated with the objectives of enhancing creativity and diversity (e.g. Heijden, 2002; Rask, 2008; Weber et al., 2008).

Even though these basic principles were also the starting point for the described case studies, the fact that different sets of participants were engaged to different parts of the process made it possible to break the barriers to some degree. In case [I], for example, parallel processes for students made it possible to collect innovation ideas from a very diverse set of participants, but as the process for students was conducted separately, it did not hamper the objective of producing actionable outcomes. In case studies [III] and [IV], a broad set of experts (over 400) from different countries participated in the process by suggesting and evaluating ideas on potential research issues through the Internet, which, overall, gave a good base for identifying and fostering new networks. However, as the workshops were focused on certain research area and only 10-12 experts and decision-makers participated in each workshop, it was possible to generate concrete results in a limited time frame. A related approach was taken in case [VI], where a broad set of experts from the Finnish packaging industry gave their ideas on research themes, but the final decisions were taken by the board of the particular industry cluster association.

3. Methodological Development

3.1 Methodological Framework

The methodological development described in this thesis builds on four consecutive phases:

1. Elicitation (or equivalently ‘solicitation’) of issues
2. Evaluation and comments
3. Development of shortlists of potentially interesting issues
4. Identification and analysis of the most interesting issues

Overall, this kind of framework provides a generic approach for a funneling process for identifying important signals and trends, and selecting the S&T themes with the most potential for further development (see e.g. Keenan 2003; Havas 2003; Georghiou and Keenan 2006; Salo and Liesiö 2006). However, based on the reflections from practical foresight studies and literature reviews described in the articles, methodological choices described below make the case studies also interesting for a broader audience, especially in light of the need to serve several functions within limited time frames.

3.2 Methodological Choices

3.2.1 Definition of “Units of Analysis”

The methodological choice made in all of the described processes is the definition of the unit of analysis – the basic element of analysis and discussion throughout the process (see also Shim et al., 2002). In paper [I], foresight activities were built around the identification of “innovation ideas” and in papers [II], [III], [IV] and [VI], where the aim of the foresight activities was to assist decision-making on S&T priorities, participants identified and analyzed “research themes” and “research issues”. In paper [V], which had a larger scope to analyze some parts of the Finnish innovation system, foresight activities focused on identifying “driving forces” and “focus areas of competences”.

Defining units of analysis gives the basic shape for the foresight process and it is a pre-condition for other methodological choices, such as modularity and use of multi-criteria decision analysis. A strict focus on pre-defined units makes it possible to focus the process on the desired direction. In paper [III], participants were encouraged to suggest and analyze issues that may especially possess potential for EU wide cooperation and in paper [I], participants were asked to suggest issues that, in their opinion, are new and innovative in the given context. Through this definition, it was also possible to link other processes to the foresight activity in question; in paper [II], participants were asked to indicate how their suggestion of research themes would contribute to a broader vision building process and in paper [VI], participants were asked to link their proposals to other strategy processes and consumer workshops. Using action-oriented units – such as a research issue or an innovation idea – also helped foresight managers to guide the process towards concrete results and overcome the challenge of foresight results being too abstract for decision-making (Keenan, 2003).

As these basic elements of analysis were defined at the beginning of the process, it provided space for freedom and creativity elsewhere. For example, there was no need to produce background research or set a strict focus regarding the substance of the process. Participants of the process were allowed to suggest, analyze and discuss any issues they saw as important. At the same time the process remained understandable and transparent for both for the involved stakeholders and instants that use the results of the process.

3.2.2 Well-defined Roles and Responsibilities

Another methodological choice that is common for all of the described studies is the definition of roles and responsibilities for each involved stakeholders (see also Salo et al., 2004). For example in paper [III], researchers, industrialists and decision-makers had different roles; researchers suggested research issues and evaluated them with regard to novelty and tentative interest, industrialists evaluated issues with regard to their relevance and suitability, some researchers and industrialists developed the first results to support decision-making, and decision-makers made a tentative allocation of funds.

Through these choices, it was possible to engage a wide range of stakeholders to the process cost-efficiently (both in view of funds used for process and the effort that the stakeholders have to dedicate to the activities) as involved experts and stakeholders only contributed to a small part of the process. This also made the process more transparent and understandable for the foresight participants and the instants that use the results. Well-defined roles and responsibilities also made it possible to focus the foresight process to serve defined objectives – for example in paper [V] panels where particularly designed to be interdisciplinary – as well as to design the foresight process to meet requirements, such as geographical (papers [III] and [V]) and/or gender (paper [V]) balance.

3.2.3 The Use of Multi-criteria Analysis

One of the distinctive methodological choices described in the articles is the use of multi-criteria decision analysis (MCDA; Keeney and Raiffa, 1976) to analyze and communicate the results of the surveys (see also Linstone, 1999; Salo et al., 2003). MCDA was used to compile shortlists of issues (i.e. 'innovation ideas' in paper [I], 'research themes' in papers [II] and [VI] and 'research issues' in paper [III] and [IV]) that, in view of the evaluations, seem to be most interesting with regards to evaluation criteria. These analyses, again, provided input for workshops organized after surveys.

The use of MCDA diminishes the time required for the workshops, as discussion in workshops can be focused on those issues that seem to possess potential for further analysis and productive debate. This again makes it possible to carry out rather broad consultation processes (for example in paper [III], over 200 experts from different European countries gave their suggestions on research issues) without making the workshop agenda too excessive. Moreover, MCDA can also be used to highlight issues that might be important from different perspectives; in addition to support of consensual decision-making, the analysis can be used to facilitate a more multi-faceted debate on varying issues and their different characteristics.

The described case studies apply Robust Portfolio Modelling (RPM; Liesiö et al., 2007, 2008) for analyzing the results. This method identifies the issues that receive highest evaluations by calculating the Core Index (Liesiö et al., 2007) for each issue. In this thesis, this measure was used as a tentative indication on how relevant the particular issue is in view of decision making scope and thus, how much effort foresight participants might should pay attention to the particular issue in workshops.

The RPM-methodology has at least two distinct advantages; i) instead of analyzing what issues receive the highest scores with regard to a certain criteria (for example, the most novel ones), RPM highlights issues that get highest scores with regard to all of the evaluation criteria (for example novelty, relevance and feasibility). Moreover, ii) instead of giving strict weights for criteria (i.e. novelty=30%, relevance=20% and feasibility=40%), the analysis allows for the use of incomplete information (e.g. Kirkwood and Sarin, 1985; Salo and Hämäläinen, 1992) and preference information on weights can be elicited as incomplete rank-orderings. Thus, foresight managers can make statements such as 'Novelty is more important than Feasibility' or "Relevance is less important than Feasibility" (Salo and Punkka, 2005), and visualize what issues get highest Core Indices, given information on weights. Based on the objectives of the foresight process, discussion can be focused on issues that best match the objectives of the process. For example, in the case study described in paper [III], the analysis puts the most emphasis on issues that receive high rankings in criteria "Suitability for International collaboration" whereas in paper [IV], the most emphasis is placed on the criteria "Networking".

Beyond focusing discussion on issues that receive the highest scores in evaluations, RPM-analysis can be used for different purposes. In paper [I], two kinds analysis were presented in the workshops: i) consensual analysis that identifies the issues that receive the highest scorings and ii) dissensual analysis, that identifies the issues that receive not only the highest, but *also* the most controversial scorings. The latter one was used to identify issues that may include elements of weak signals (Ansoff, 1975). Thus, beyond focusing workshop discussion on issues that are seen as the most relevant based on the evaluations, RPM-analysis was used to focus the discussion on issues that may be surprising, and controversial, and thus worth further consideration (Ansoff, 1984).

In paper [VI], workshop discussion was supported by an interactive decision support tool, RPM-Explorer (Jalonen, 2007), that enabled the workshop facilitator to change relative information on weights and illustrate how Core Indices vary by changing the emphasis of different criteria. In addition to focusing the discussion on issues that seem to be most relevant from a certain perspective (i.e. highest Core Indices with some weights), RPM was used to screen and identify issues that are important from different perspectives.

In paper [IV], the RPM-framework is extended to identify potential researcher networks. The developed analysis identifies issues that receive the highest evaluations with regard to different evaluation criteria as well as researcher networks that could be built around these issues. In addition to focusing the discussion on issues with the highest Core Indices, discussion can be focused on issues that also possess potential for collaborative efforts *and* on researcher networks that might be interested in carrying out the research related to the identified issues.

Even though RPM-methodology has solid methodological foundations (see Liesiö et al., 2007, 2008), it does not mean that in the described case studies, the methodology would have given straightforward answers to questions on which issues are explicitly better than others. Firstly, it uses additive value function and in the case studies, each issue was assumed to be independent from each other. Both characteristics can be criticized for not capturing the real values of issues and the portfolios they constitute (e.g. Stewart, 1996). Secondly, in the case studies, each issue was assumed to consume an equal amount of resources and there was no strict estimation on the budgets reserved for S&T activities. Thirdly, there was no explicit analysis on how statistically relevant the evaluations are, and how well the evaluators represent different stakeholder groups.

Despite these weaknesses, RPM methodology, and the way it was used, was suitable for supporting workshop discussions in the case studies. Additive value function is generally considered as a reasonable approximation, especially if there is a need for transparent and understandable decision support (e.g. Keefer et al., 2004; Hämäläinen, 2004). Moreover, in the workshops, the results of the analysis were only given as a starting point for further debate and thus, the described weaknesses did not hamper the original purpose of the use of the methodology; to give an indication of which issues might be relevant for decision making on higher level priorities of collaborative S&T actions and screening the issues from different perspectives.

3.2.4 Modular Process Design

The case studies build on four consecutive phases described above. In the case studies, the foresight activities were divided into different sectors (i.e. panels in paper [V], research areas in papers [II], [III], [IV] and [VI]) and in each sector, foresight activities were carried out parallel through the replications of these phases. Overall, the processes consisted of different modules (i.e. execution of a process phase in a certain sector using similar methodological support), that gave foresight managers the flexibility to design and adjust the process to different contexts.

Modularity provides some response to the challenge of balancing between ‘centralized’ and ‘autonomous’ management of foresight processes (Havas, 2003). On one hand, using similar phases and decision support tools in all sectors simultaneously facilitated the synthesis of inputs from different sectors. On the other hand, modularity also gave different sectors some freedom to use the given methodology adaptively. This was especially the case in papers [II] and [V], where each sector (i.e. ‘theme area’ in paper [II] and ‘panel’ in paper [V]) had a dedicated chair responsible for the foresight work in a particular sector; some chairs built the workshop discussion mainly around web-surveys and analysis, and some chairs used them only as one starting point for discussion.

Another advantage of modularity is that it makes the methodology suitable for different contexts. It enables scalability in view of how many participants and sectors are included in the foresight process. For example in paper [III], the foresight activities engaged well over 400 experts around the Europe and the taxonomy of the internet surveys included over 20 sub-areas. Modularity also makes it possible for foresight managers to adjust the process based on given time frames and objectives. For example in paper [I], where foresight activities were designed to produce new ideas, phase 2 was repeated twice; in the first evaluation round, participants gave verbal comments on innovation ideas after which they elaborated their own suggestions based on the comments. Only in the second evaluation round, participants gave numerical evaluations on innovation ideas. On the other hand, in paper [II], where most emphasis was placed on supporting decision-making in rather tight schedules, there was no round for elaboration. In paper [V], that aimed to analyze S&T opportunities especially in view of changes in the innovation system, the whole procedure was repeated twice; the first round focused on analyzing changes in the innovation context and identifying “”driving forces”, and the second round focused on identifying S&T actions – i.e. “focus areas of competences” - that would best respond to the change in context.

Modularity enables an iterative process design that makes it possible to adapt the process to parallel processes and changes in context and objectives. For example in paper [III], surveys were organized using taxonomy containing five research areas and over 20 sub-areas and workshops were organized around 3 different themes. This was because there was a need to organize workshops in which the participant base would be coherent enough to carry out goal-oriented discussions. In this similar process, due to restrictions related to the broader strategy development of the particular research program, analysis on possible research networks (extension of phase 3 introduced in paper [IV]) was carried out only after the first decisions on S&T priorities. This was due to an urgent need to provide some input for decision-making. In paper [I], in order to get fresh inputs for panel work, phases 1-3 were carried out separately with students from the Helsinki University of Technology.

4. Discussion

The methodological development presented in this thesis is described in context of case studies on participatory foresight and priority setting activities in innovation networks. However, the methodological framework is largely applicable in many other contexts and it can be used in different kinds of ex-ante and ex-post (see Salo et al., 2006) S&T evaluations and foresight activities.

4.1 Using the Methodology

The framework and the methodological choices described above, give a starting point for designing and implementing participatory foresight processes in situations, where i) decision makers must choose several S&T-related themes from a larger set of proposals (in case studies, the number of proposals varied between 50-300, and the decisions typically included 5-10 themes that were selected for further consideration), ii) there is need for a rather broad involvement of experts and stakeholders (in case studies, the number of participants varied from about 50 to over 400 experts) and, iii) decisions are made jointly by several decision-makers (in case studies, final workshops engaged typically 10-15 representatives from key organizations). The consecutive phases and methodological choices provide a base for methodological support of mid-term foresight activities with a time scope of 5-15 years: in general, variants of the methodology are useful for activities that look forward at least 2-3 years as this is the minimum time required for translating decisions into the actions, and generating the first results from S&T activities. There is no maximum time limit – however, when dealing with issues with a time horizon of 15 years or more, there may be need to complement the process with other methodologies, such as macro-scenarios and creative techniques.

The starting point for applying the methodology is that foresight activities must be carried out by (or in close cooperation with) an institution or a network that has a strong mandate to carry the decisions further and facilitate them among evolved organizations and stakeholders. This gives the process the legitimacy that is one of the initial requirements for attracting experts and other stakeholders to participate in the activities (Irvine and Martin, 1984). Another starting point is that there must be enough qualified experts and stakeholders available that are capable of identifying and developing relevant proposals for S&T activities and/or developments and evaluating them from several perspectives. When supporting the identification and development of concrete, actionable recommendations for S&T actions, this requirement obviously makes the potential participant base rather homogeneous (i.e. researchers and other experts involved in S&T activities). However with their specific expertise (i.e. scientific and/or industrial background), the participant base can be more diverse and when exploring new, surprising ideas and opportunities (i.e. weak signals), it may be valuable to broaden the participant base to be more heterogeneous (for example in paper [I], parallel process were carried out among students of the Helsinki University of Technology).

The process is started with the identification of objectives and specific requirements related to the foresight process. This includes discussions on higher level objectives related to the functions described in Chapter 2.2 as well as defining the specific objectives and requirements of the process (i.e. scope, participants, available time, budget, parallel processes, etc.).

The design of the activities is started by defining the kind of modules the process will consist of and who will participate in the foresight work in these modules. If the objective of the process is mainly to support decision-making by deepening knowledge on certain themes, the parallel parts of the process can be divided so that the experts that participate in the work of the modules (i.e. surveys, workshops) have similar professional backgrounds (such as workshops in paper [II]). However, if the aim of the project is, for example, explore new opportunities at the interfaces of present S&T communities, the process can be designed to mix experts from different backgrounds. For example in paper [V], panel work was especially designed to be multi-disciplinary. The process can also mix both models; in paper [III], web-based activities were designed to be multi-disciplinary but the workshops were organized with a focus on more traditional themes. Moreover, the process can be adjusted by putting different kinds of emphasis on consecutive parts of the process. In case [V], web-surveys, evaluation and analysis were only seen as a means of orienting participants to panel work and tentatively collect some ideas for further discussion. In paper [VI], on the other hand, most of the foresight work was done through the internet, and results from the surveys and analysis were straightforwardly taken to support the discussions of the highest decision-making body (the board of the particular industry cluster association).

The process can be also focused to meet the desired objectives though different definitions of the unit of analysis. In paper [I], for example, foresight participants were especially encouraged to identify innovation ideas that are new and surprising in the given context and in paper [III], participants developed and analyzed issues that are particularly suitable for EU wide cooperation.

Also multi-criteria analysis can be used to adjust the foresight process in the desired direction; this can be done, by i) using criteria that particularly aim to capture characteristics that are seen as relevant; i.e. innovativeness, relevance and feasibility in case [V], ii) emphasizing certain criteria over others; i.e. stating that networking is the most important criteria in case [IV], and iii) using different kinds of approaches to analyze the issues; i.e. the consensus/dissensus perspective in paper [I], parallel identification of networks in paper [IV] and the use of RPM-Explorer© to identify issues that are important from different perspectives in paper [VI].

4.2 Variants and Limitations of the Methodology

Even though this thesis presents the methodology as one coherent entity, the different modules can also be applied separately and for different purposes. For example in the described case studies, the elicitation of issues was done through internet. This was mainly due to i) cost efficiency – i.e. ability to engage a broad range of experts and stakeholders within very tight time frames and budgets such as in papers [II] and [III] and involve experts that may not have the time to participate to workshops such as in papers [I] and [VI], ii) avoiding 'groupthink' such as in paper [I] or iii) orienting participants to panel work such as in paper [V]. However, the elicitation of issues can also be done differently. After the case studies described in this thesis, the methodology is applied in different projects, where phase 1 is carried out through structured brainstorming sessions in face-to-face workshops[1] and a literature review by dedicated experts[2]. Moreover, in the latter case study, the methodology was not applied for the identification of actions-oriented research topics, but for identifying global trends and weak signals that may be particularly interesting to the European Commission.

When applying the methodology, certain limitations must be taken to account, especially regarding how much the process should rely on elicitation, evaluation and analysis of issues (phases 1, 2 and 3) and how much emphasis should be placed on face-to-face discussions. The first three phases are a good starting point for further discussions, but not enough in itself. The methodology does not explicitly support the identification of interdependencies and synergies between S&T actions; in the described case studies this analysis is left purely for workshops. Nor does the methodology support more comprehensive analysis between alternative contexts (i.e. trends, challenges, drivers, macro-scenarios) and their relation to the potential S&T actions. Indeed, descriptions of issues and discussions in the workshops included both of these kinds of elements and in paper [V], foresight activities were carried in two layers (driving forces, focus areas of competences), but there was no rigorous methodological support for combining these two analytical layers. Moreover, in the described case studies, even though different parts of the processes also included informal references on evidence-based information and statistical data, they were not explicitly used in the analysis, which can be considered a weakness of the methodology – especially, if such information is easily available.

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[1] In Spring 2008, the Research group at the Systems Analysis Laboratory of the Helsinki University of Technology carried out a survey and multi-criteria analysis on action priorities to support the development of a Strategic R&D agenda for the Finnish Wood Product Cluster in Finnish Forest Industries. See more http://www.rpm.tkk.fi/Puutuoteteollisuus/ (In Finnish)

[2] In Spring 2009, the Research group at the Systems Analysis Laboratory of the Helsinki University of Technology carried out a multi-criteria analysis on global trends and weak signals, that supported discussion in a workshop "Facing the future: global challenges in 2025 and policy implications" organized by the Bureau of European Policy Advisors to Facing the future. See more http://ec.europa.eu/dgs/policy_advisers/activities/conferences_workshops/challenges_2025_en.htm

5. Conclusions and Future Research Questions

In innovation networks, foresight activities are typically expected to serve several functions. They can be seen as a tool for supporting decision-making on S&T priorities, but they can also be expected to contribute to the structures of a network beyond the decision making scope. Often, foresight activities are expected to produce desired outcomes in rather tight timeframes and budgets, and engage experts, stakeholders and decision-makers that only have limited time to participate. Typically, foresight activities are also expected to be an integral part of the broader S&T strategy design – this means that foresight activities should use results from other processes as input as well as produce outcomes that can be taken to support several other S&T-related activities.

These demands place challenges on foresight methodologies – they should enable foresight managers to reflect the emphasis of different objectives as well as to allow foresight activities to have multitude functions. This thesis presents participatory methodologies for priority-setting and foresight activities that represent a step forward in responding these challenges. The methodological development relies on methodological choices such as surveys, multi-criteria decision analysis and structured workshops that, in general, are an established part of the methodological toolbox of participatory foresight (e.g. Miles et al., 2002; Glenn and Gordon, 2004; TFAMWG, 2004; Georghiou et al., 2008). However, the main contribution of this thesis is the tools and analysis of *how* these methodological elements can be used to focus foresight activities towards desired objectives. In the developed methodology, this can be done by i) selecting feasible “unit of analysis” as the base for analysis and discussion ii) defining an appropriate composition of stakeholders in each part of the process iii) different uses of decision analytic methodologies and iv) different emphasis on internet surveys, decision analysis and face-to-face workshops.

As the methodology relies on phases and modules, through which the methodology can be expanded and used for different kinds of processes, it also presents a fruitful foundation for further research. For example, applying an extended RPM-framework that enables the consideration of project interdependencies (see Liesiö et al., 2008) would be a valuable addition to the methodology as different trends, research themes and issues are quite often dependent on each other. Also methodological support for multi-layered analysis (i.e. changes in broader context vs. S&T actions) would enable a more comprehensive view of future S&T opportunities and challenges (see also Liesiö and Salo, 2008). One dimension for further development is a decision analysis, that would better distinguish different groups and/or individuals (i.e. analysis on how priorities differ, for example, among academia, industry and practitioners) (see also Vilkkumaa et al., 2009). Other dimensions for further development include, among others, embedding analysis that would apply real options for modeling future uncertainties (see Eriksson and Weber 2008), development of analysis that would explicitly support clustering of different issues in workshop discussions and development of methodologies that would enable the use of evidence based information and statistical data alongside expert opinions. Moreover, using the methodology in different kinds of contexts, such as single organizations or value chains as well as in less technocratic fields such as social sciences, may provide valuable insights for the further development of the methodology.

References

Ansoff, I. (1975) Managing strategic surprise by response to weak signals, *California Management Review* 17(2), 21–33.

Ansoff, I., H. (1984) *Implanting strategic management*, USA: Prentice/Hall International Inc.

Asaro, P. M. (2000) Transforming society by transforming technology: the science and politics of participatory design, *Accounting, Management and Information Technologies* 10(4), 257-290.

Azzonea, G. and Manzini, R. (2007) Quick and dirty technology assessment: The case of an Italian research centre, *Technological Forecasting and Social Change* 75(8), 1324-1338.

Barré, R. (2002) *Strategic Policy Intelligence: Current trends, the state of play and perspectives. Synthesis of technology foresight*, Institute for Prospective Technological Studies (IPTS), Seville: Technical Report EUR-20137-EN.

Bishop, P., Hines A. and Collins, T. (2007) The current state of scenario development: An overview of techniques, *Foresight* 9(1), 5-25.

Bullinger, H-J., Auernhanner, K. and Gomeringer, A. (2004) Managing innovation networks in the knowledge-driven economy, *International Journal of Production Research* 42(17), 3337-3353.

Carlsson, B. (2006) Internationalization of innovation systems: A survey of the literature, *Research Policy* 35(1), 56-67.

Cohen, W. M. and Levinthal, D. A. (1989). Innovation and learning: Two faces of R&D, *Economic Journal* 99(397), 569-596.

Cohen, W. M. and Levinthal, D. A. (1990). Absorptive capacity: A new perspective on learning and innovation, *Administrative Science Quarterly* 35(1), 128-152.

Cuhls, K. (2003) From forecasting to foresight processes – new participative foresight activities in Germany, *Journal of Forecasting* 22(2-3), 93-111.

Durand, T. (2003) Twelve lessons drawn from ‘Key Technologies 2005’, the French technology foresight exercise, *Journal of Forecasting* 22(2–3) 161–177.

Dosi, G. (1982) Technological paradigms and technological trajectories: A suggested interpretation of the determinants and directions of technical change, Research Policy 11(3), 147-162.

Edquist, C, (ed.) (1997) *Systems of innovation: technologies, institutions and organizations*, London: Pinter.

Eriksson, E.A. and Weber, K.M. (2008) Adaptive Foresight: Navigating the complex landscape of policy strategies, *Technological Forecasting and Social Change* 75(4), 462-482.

Faucheux, S. and Hue, C. (2001) From irreversibility to participation: Towards a participatory foresight for the governance of collective environmental risks, *Journal of Hazardous Materia*ls 86(1-3), 223-243.

Georghiou, L. (2001) Evolving frameworks for European collaboration in research and technology, *Research Policy* 30(6), 891-903.

Georghiou, L., Cassingena, H.J., Keenan, M., Miles, I., and Popper (eds.) (2008) *The Handbook of Technology Foresight – Concepts and Practices*, Cheltenham: Edward Elgar.

Georghiou, L., and Keenan, M. (2006) Evaluation of national foresight activities: assessing rational, process and impact, *Technological Foresight and Social Change* 73(7), 761-777.

Glenn, J.C. and Gordon, T.J. (2004) *Futures Research Methodology – V2.0*, AC/UNU Millennium Project. New York.

Havas, A. (2003) Evolving foresight in a small transition economy, *Journal of Forecasting* 22(2-3), 179-201.

Heijden, K.V.D. (2002) *Scenarios. The Art of Strategic Conversation*, Chichester UK: Wiley

Hekkert, M.P., Suurs, R.A.A., Negro, S.O., Kuhlmann, S. and Smits, R.E.H.M. (2007) Functions of innovation systems: a new approach for analysing technological change, *Technological Forecasting and Social Change* 74(4), 413-432.

High Level Expert Group for the European Commission (HLEGEU) (2002). *Thinking, Debating and Shaping the Future: Foresight for Europe*, Final Report of the High Level Expert Group for the European Commission, April 24, 2002, Brussels.

Hämäläinen, R.P. (2004) Reversing the perspective on the applications of decision analysis. *Decision Analysis* 1(1), 26-31.

Hjelt, M., Luoma, P., van de Linde, E., Ligvoet, A., Vader, J. and Kahan, J. (2001) *Experiences with national technology foresight studies*, July, No. 4, Helsinki: SITRA Report Series.

Irvine, J., and Martin, B.R. (1984) *Foresight in science: Picking the winners*, London: Dover.

Jalonen, E. (2007) *Portfolio decision making in innovation management*, Master's Thesis, Espoo: Helsinki University of Technology, Systems Analysis Laboratory.

Jarimo, T., Pulkkinen, U. and Salo, A. (2005) Encouraging suppliers to process innovations: A game theory approach, *International Journal of Technology Intelligence and Planning* 1(4), 403-423.

Jewell, T. (2003) International foresight's contribution to globalisation, *Foresight - The Journal of Futures Studies, Strategic Thinking and Policy* 5(2), 46-53.

Keefer, D.L., Kirkwood, C.W., Corner, J.L. (2004) Perspective on Decision Analysis Applications, 1990-2001, *Decision Analysis* 1(1), 4-22.

Keenan, M. (2003) Identifying emerging generic technologies at the national level: the UK experience, *Journal of Forecasting* 22(2-3), 129–160.

Keeney, R.L. and Raiffa, H. (1976) *Decisions with multiple objectives: Preferences and value trade-offs*, New York: John Wiley & Sons.

Kirkwood, C.W., Sarin, R.K., (1985). Ranking with partial Information: A method and an application, *Operations Research* 33(1), pp. 38-48.

Könnölä, T, Ahlqvist, T. Eerola, A. Kivisaari, S. and Koivisto, R. (2009) Management of foresight portfolio: analysis of modular foresight projects at contract research organization, *Technological Analysis & Strategic Management* 21(3), 381-405.

Könnölä, Totti (2006) *Escaping Path Dependence – Essays on Foresight and Environmental Management*, Doctoral Thesis, Espoo: Helsinki University of Technology, Systems Analysis Laboratory.

Lane, P.J. and Lubatkin, M. (1998) Relative absorptive capacity and interorganizational learning, *Strategic Management Journal* 19(5), 461-477.

Liesiö, J., Mild, P. and Salo, A. (2007) Preference programming for Robust Portfolio Modeling and project selection, *European Journal of Operational Research* 181(3), 1488-1505.

Liesiö, J., Mild, P. and Salo, A. (2008) Robust Portfolio Modeling with incomplete cost information and project interdependencies, *European Journal of Operational Research* 190(3), 679-695.

Liesiö J. and Salo A. (2008) *Scenario-based selection of investment projects with incomplete probability and utility information*, Helsinki University of Technology, Systems Analysis Laboratory Research Reports E23.

Linstone, H.A. and Turoff, M. (1975) *Delphi method: Techniques and applications*, Massachusetts: Addison-Wesley.

Linstone, H.A. (1999) *Decision making for technology executives: Using multiple perspectives to improve performance*, Boston/London: Artech House.

Lundvall, B.-Å. (ed.) (1992) *National systems of innovation: Towards a theory of innovation and interactive learning*, London: Pinter Publishers.

Martin, B.R. and Irvine, J. (1989) *Research foresight: priority-setting in science*. London: Pinter Publishers.

Martin, B.R. and Johnston, R. (1999) Technology foresight for wiring up the national innovation system. Experiences in Britain, Austria, and New Zealand, *Technological Forecasting and Social Change* 60(1), 37-54.

Metcalfe, J.S. (1995) Technology systems and technology policy in an evolutionary framework, *Cambridge Journal of Economics*, 19(1), 25-46.

Miles, I., Keenan, M. and Kaivo-Oja, J. (ed.) (2002) *Handbook of Knowledge Society Foresight*, Manchester; Prest. Downlowdable at http://foretech.online.bg/docs/EFL_Handbook_October.pdf.

Orsenigo, L., Pammoli, S. and Riggaboni, M. (2001) Technological change and network dynamics: Lessons from the pharmaceutical industry, *Research Policy* 30(3), 485-508.

Rask, M. (2008) Foresight – balancing ebtween increasing variety and productive convergence, *Technological Forecasting and Social Change* 75(8), 1157-1175.

Reger, G. (2001) Technology foresight in companies: From an indicator to a network and process perspective, *Technology Analysis & Strategic Management* 13(4), 533 – 553.

Rip, A. (2003) Constructing expertise: In a third wave of science studies?, *Social Studies of Science* 33(3), 419-434.

Salmenkaita, J.-P., and Salo, A. (2002) Rationales for Government Intervention in the Commercialization of New Technologies, *Technology Analysis & Strategic Management 14(2)*, 183-200.

Salmenkaita, J.-P., and Salo, A. (2004) Emergent foresight processes: industrial activities in wireless communications, *Technological Forecasting and Social Change 71*, 897-912.

Salo, A. (2001) Incentives in technology foresight, *International Journal of Technology Management* 21(7), 694–710.

Salo, A. and Cuhls, K. (2003) Technology foresight - past and future, *Journal of Forecasting* 22(2-3), pp. 79-82.

Salo, A. and Gustafsson, T. (2004) A group support system for foresight processes, *International Journal of Foresight and Innovation Policy* 1(3/4), 249–269.

Salo, A., Gustafsson, T. and Ramanathan, R. (2003) Multicriteria methods for technology foresight, *Journal of Forecasting* 22(2–3), 235–255.

Salo, A. and Hämäläinen, R.P., (1992) Preference assessment by imprecise ratio statements, *Operations Research* 40(6), 1053-1061.

Salo, A., Könnölä, T. and Hjelt, M. (2004) Responsiveness in foresight management: Reflections from the Finnish food and drink industry, *International Journal of Foresight and Innovation Policy* 1(1), 70-88.

Salo, A. and Liesiö, J. (2006) A case study in participatory priority-setting for a Scandinavian research program, *International Journal of Information Technology & Decision Making* 5(1), 65-88.

Salo A. Mild P. and Pentikäinen, T. (2006) Exploring causal relationships in an innovation program with Robust Portfolio Modeling*, Technological Forecasting and Social* Change 73(8), 1028-144.

Salo, A. and Punkka, A. (2005) Rank inclusion in criteria hierarchies, *European Journal of Operational Research*, 163(2), 338-356.

Salo, A. and Salmenkaita, J.-P. (2002) Embedded foresight in RTD programs, *International Journal of Policy and Management* 2(2), 167-193.

Shim, J.P., Warkentin, M., Courtney, J.F., Power, D.J., Sharda, R. and Carlsson, C. (2002) Past, present, and future of decision support technology, *Decision Support Systems* 33, 111-126.

Schot J. (2001) Towards new forms of participatory technology development, *Technology Analysis and Strategic Management* 13(1), 39-52.

Smits, R. and Kuhlmann, S. (2004) The rise of systemic instruments in innovation policy, *International Journal of Foresight and Innovation Policy* 1(1), 4-32.

Stewart, T.J. (1996) Robustness of additive value function methods in MCDM, *Journal of Multi-Criteria Decision Analysis* 5(4), 301 – 309.

Technological Futures Analysis Methods Working Group (TFAMWG) (2004) Technology futures analysis: Toward integration of the field and new methods, *Technological Forecasting & Social Change* 71(3), 287-303.

Van Aken, J.E. and Weggeman, M.P. (2002) Managing learning in informal innovation networks: overcoming the Daphne dilemma, *R&D management* 30(2), 139 – 150.

Van Der Meulen, B., de Wilt, J. and Rutten, H. (2003) Developing futures for agriculture in the Netherlands: a systematic exploration of the strategic value of foresight, *Journal of Forecasting* 22(2-3), 219-233.

Weber, K.M., Kubeczko, K., Kaufmann, A. and Grunewald, B. (2008) Trade-offs between policy impacts of foresight: Experiences from the innovation policy foresight and strategy process of the City of Vienna, *Proceedings from Third International Seville Seminar on Future-Oriented Technology Analysis: Impacts and implications for policy and decision-making*, October 16-17, Seville, Spain.

Vilkkumaa, E., Salo, A. and Liesiö, J. (2009) Multicriteria portfolio modeling for the development of shared action agendas, manuscript submitted to *Group Decision and Negotiations* journal. Available at http://www.sal.tkk.fi/tutkijakoulu/vierumaki2009files/VilkkumaaEtAl.pdf, visited 20 November 2009.