Foresight activities have often provided support for priority-setting, networking and consensual vision-building. Drawing on complementary evolutionary perspectives, we discuss these objectives from the viewpoint of diversity which appears vital in contexts characterized by technological discontinuities and high uncertainties. Yet, although the solicitation of weak signals is typically advocated as a suitable methodology for such contexts, we argue that the solicitation of novel ideas about prospective innovations may result in more focused, action-oriented and comparable reflections of future developments that are more amenable to subsequent analysis. Specifically, we extend the recently developed Robust Portfolio Modelling (RPM) methodology and present a new collaborative foresight method called RPM screening which is based on the generation, revision, evaluation and analysis of innovation ideas. We also report experiences from a pilot project where this method was employed to enhance the work of the Foresight Forum of the Ministry of Trade and Industry in Finland. The encouraging results from this pilot project and other recent applications suggest RPM screening holds promise in terms of fostering diversity in a variety of contexts, for instance in the development of shared research agendas and the identification of risks that may be difficult to anticipate.

Keywords: decision support systems, diversity, foresight, incomplete information, innovation studies, internet-based participation, multi-criteria evaluation, path-dependence.
Diversity in Foresight: Insights from the Fostering of Innovation Ideas

1. Introduction

In the 1980’s, publicly funded foresight activities were largely seen as an instrument for assisting in the development of priorities for S&T resource allocation (Irvine & Martin, 1984). Later on, stakeholder participation and networking have increasingly been regarded as essential dimensions of foresight activities for ‘wiring up’ the innovation system (Martin & Johnston, 1999). Reports from recent participatory foresights, in turn, have emphasized the importance of common vision-building as a step towards the synchronization of the innovation system (Cuhls, 2003).

These overarching trends can be viewed as complementary dimensions of how foresight can strengthen the long-term innovative activities of the innovation system. They are also reflected in the taxonomy of Barré (2002) who distinguishes between the objectives for (i) setting S&T priorities, (ii) developing the connectivity and efficiency of the innovation system, and (iii) creating a shared awareness of future technologies. Yet, because these objectives tend to be inherently consensual, it is pertinent to bring in complementary considerations based on evolutionary perspectives (e.g. Dosi et al., 1988) which acknowledge the historical accumulation of innovation capabilities and stress the importance of evolutionary flexibility and adaptability of innovation systems, particularly in contexts characterized by technological discontinuities and high uncertainties. We consequently posit that a key consideration in the fostering of innovation activities and capabilities is diversity; defined as the condition or quality of being diverse, differerent, or varied; difference, unlikeness (Oxford University Press, 1989).

Thus, we suggest that diversity is a pertinent dimension in the management of foresight activities. For instance, the ability to anticipate and shape different kinds of futures is likely to be enhanced through different manifestations of diversity, such as the consultation of participants representing different stakeholder groups. This is typical in the
methods developed for the scanning of weak signals resulting often a diverse set of signals (Harris and Zeisler, 2002; Mendoça et al, 2004). Here, we suggest that it may be useful to assume a narrower characterization and focus on innovation ideas which, in a sense, can be regarded as more comparable and comprehensible indications of weak signals. We consider also the elaboration of differences in such judgmental statements highly relevant and develop a method that supports the adoption of multiple perspectives in their analysis.

In this paper, we use the generic Robust Portfolio Modeling methodology (RPM, Liesiö et al., 2005) as a framework in the development of a foresight method which consists of phases for internet-based generation, commenting, revision, multi-criteria evaluation and screening of innovation ideas. The resulting method - called RPM screening for short – responds to diversity considerations by engaging different stakeholder groups, encouraging them to submit ideas on prospective innovations and, most notably, by explicating multiple interests and perspectives in the evaluation and analysis of these ideas. We also report experiences from the use of RPM screening in the Foresight Forum (or the Forum, for brevity) that was established by the Finnish Ministry of Trade and Industry in mid-2004. In the Forum, RPM screening was employed to support three expert groups working on the themes (i) nutrigenomics, (ii) health care and social services and (iii) services for the provision of personal experiences. Parallel processes were also conducted with postgraduate students in a course on decision analysis the Helsinki University of Technology. Experiences from these six processes suggest that RPM screening can address several diversity considerations and, moreover, provide support for networking and vision-building, particularly when used in conjunction with workshops and other face-to-face communication activities (Salo et al., 2004).

2. Diversity and Foresight Objectives

Several authors (e.g. Schot, 1992; Weitzman, 1992; Kemp, 1997; Mulder et al., 1999; Könnölä et al., 2005) have stressed that diversity should be fostered in innovation systems. In biology, diversity refers to the individual or species level, stressing primarily a high variety among individuals within a population or different species, whereas variety refers to the propensity of a genotype to vary (Rammel & van den Bergh, 2003). In the context of innovation systems, we use the term ‘diversity’ to encompass the both dimen-
sions; the diversity of innovation activities and the variety of innovation capabilities, which are measured in the extent of technological options and respective visions and value networks (Könnölä et al., 2005). Here, the diversity of technological options consist of both physical technologies in the form of technological artefacts and infrastructures, and social technologies (Nelson and Sampat, 2001) such as routines, hierarchies and institutions. The presence of such diversity in innovation systems enhances the evolutionary flexibility and adaptability with regard to structural changes in economy, the rationale being that drawbacks within one type of economic activities may be complemented or replaced by other activities.

Diversity is particularly relevant in view of the path-dependencies that prevail at different levels of the innovation system, including its organizational, sectoral, regional, national and international dimensions. Both evolutionary and institutional economists (e.g. Dosi et al., 1988; North, 1990) have identified dynamic path-dependent processes that are driven by the economies of increasing returns and institutional acculturation. These processes may lead to ‘lock-ins’ to existing production and social systems (Jacobsson & Johnson, 2000; Unruh, 2000; 2002). Often, such processes are characterized by the emergence of standards, dominant designs and practices that reduce the uncertainties for action while creating stable expectations of the behaviour of others. At the organizational level, such path-dependencies tend to strengthen the surveillance, mental and power filters of information (cf. Ansoff, 1975), which may diminish the organization’s ability to identify signals of change.

While technological and institutional path-dependence may support the efficiency of exploiting present resources, it can also lead to the paucity of technological options and respective alternative visions and value networks. This may ultimately lead to reduced innovation capabilities. Feldman and Audretsch (1999), for example, have found empirical evidence that specialized innovation activities within a narrow industry are far less conducive for innovations than diverse activities across complementary economic activities and industries. In particular, diversity in innovation systems may become crucial in times of discontinuous radical changes that replace existing components or entire systems and, at the same time, destroy old competences and create new value networks (Könnölä et al., 2005).
This suggests that diversity is pertinent to foresight activities, too, as elaborated through the following remarks on three general foresight objectives, i.e., priority-setting, networking and common vision building:

- **Priority setting** supports the identification of common future actions and the efficient resource allocation (Irvine & Martin, 1984). Yet, excessive prioritising decreases the diversity of options that could challenge conventional approaches and dominant designs. This, in turn, may strengthen inertia within existing techno-institutional systems which thus become dependent on their historical paths due to the paucity of available alternatives. In such settings, foresight methods need to support the generation of ideas on new alternatives and the amplification of diverse perspectives in priority-setting (Keenan, 2003).

- **Networking** enhances the connectivity of the innovation system and can improve its performance. However, excessive emphases on the strengthening of present networks and optimising their efficiency may create path-dependencies which, at the extreme, lead to techno-institutional conditions that lock-out alternative technological options (Unruh, 2000). Thus, apart from strengthening existing networks, foresight activities should also contribute to the creative restructuring or even destruction of possible lock-in conditions by engaging different stakeholders in the proactive generation of rivalling visions on the future (Könnölä et al., 2005). This can foster the emergence of competing coalitions based on different value networks and encourage the envisioning of different architectures, configurations, features and standards (Tushman & O'Reilly, 1997).

- **Building a consensual vision** of the future and its technologies reduces uncertainties and helps synchronize the strategies of different stakeholders towards common action. But on the other hand, an excessive search for a consensus on the most probable future and its technologies may lead to conservative and abstract results (Luoma, 2001; Keenan, 2003), and thus lead to a further strengthening of existing path-dependencies. General abstractions are not readily actionable either, especially if the responsibilities are not clearly identified (Salmenkaita and Salo, 2004). The search for a consensual vision of the future should therefore be complemented with – or even be replaced by – the exploration of alternative futures and respective technological arrangements.

In foresight activities, participants are typically first encouraged to put forth diverse viewpoints in relation to the stated foresight objectives (Loveridge, 2004). The Delphi-method
method (e.g. Helmer, 1983), for example, solicits diverse viewpoints at the outset and gradually converges towards more consensual statements through an iterative process of feedback, reflection and revision. This notwithstanding, strong emphases on priority-setting, strengthening of existing networks and common vision-building are often coupled with methodological choices that contribute more to convergence rather than the enhanced diversity of coalitions with rivalling technological options and respective visions and value networks. There is therefore a need for foresight methods that retain diversity considerations as a relevant part of the attainment of the general foresight objectives.

3. Innovation Ideas as Reflections of Weak Signals

The attempt to accommodate diverse perspectives on the future is central to the methods for the scanning of weak signals (Harris and Zeisler, 2002; Mendoça et al., 2004). Ansoff (1975) defined weak signals as “imprecise early indications about impending significant events”. Later on, this definition has been expanded to accommodate additional characteristics, such as new, surprising, uncertain, irrational, not credible, difficult to track down, related to a substantial lag time before maturing and becoming mainstream (Coffman, 1997; Harris and Zeisler, 2002; Mendoça et al, 2004).

Yet, the above characterizations are inherently subjective, which is one of the reasons for why the scanning weak signals may result in an extensive and elusive set of fragmental issues that are not amenable to systematic analyses. The absence of a shared interpretative framework, in particular, may make it difficult to see how the signals relate to one another and what they signify to different stakeholders.

This suggests that it may be useful to assume a narrower characterization by devoting attention to signals which contribute the enhancement of innovation activities by presenting ideas about future innovations (instead of stating future-oriented observations with a less specific focus). Indeed, in his seminal discussion, Ansoff (1975) already stressed short descriptions of “issues” that would be focused on the opportunities and threats for an organization. Such issues have also close parallels to the use of miniscenarios – or nodes of discussion – that present alternative future paths (Kuusi & Meyer, 2002).
The focus on innovation ideas is also congruent with the **systemic** and **action-oriented** nature of innovation processes:

- The systemic nature of innovations derives from the recognition that innovations emerge in the wider context of techno-institutional co-evolution of the innovation system (Smith, 2000) where the success of any innovation is influenced by a complex interplay among the supply of S&T knowledge, industrial production and societal demand, among others. Thus, because innovations (and innovation ideas) combine numerous such elements in a variety of ways, they can manifest a much broader set of weak signals, albeit indirectly.

- The action-oriented nature of innovation allows one to pose questions under what conditions and in what ways the envisaged innovation ideas could be best promoted; such an analysis may suggest yet other signals. Furthermore, vivid action-oriented ideas may provide important seeds for a systemic change among fragmental decision-making entities (Smits and Kuhlmann, 2004).

Motivated by the above remarks, our RPM screening method is largely based on the solicitation of ideas on prospective innovations which also serve as indirect indications of the impacts that even other kinds of signals might have. And although the formulation of weak signals by way of innovation ideas may not capture some phenomena (in a direct sense), it is still likely to result in a comparable body of material which can be evaluated with regard to multiple perspectives.

### 4. A Foresight Project with Diverse Perspectives

In mid-2004, the Ministry of Trade and Industry established a Foresight Forum which was conceived as an open-ended instrument which seeks to facilitate the generation, dissemination, and assimilation of information in support of innovation activities. Through this instrument – the second phase of which was started in Spring 2005 – the Ministry seeks to engage a variety of stakeholders by inviting them to theme-specific expert groups, workshops and seminars, and also by supporting the work of these theme area groups through e-mail lists and communication channels among which the website is central ([www.ennakointifoorumi.fi](http://www.ennakointifoorumi.fi), in Finnish). These activities, it is hoped, contribute to an enhanced understanding of technological, societal and economic developments over the next 10 to 15 years so that the participants can respond to them better in their respective organizations.
In the Forum, a six-month pilot project was carried out to assist expert groups on the three theme areas that were addressed by the Forum, i.e., (i) nutrigenomics, (ii) health care and social services, and (iii) services for the provision of personal experiences. Specifically, the pilot project sought to (i) engage a larger number of participants in the theme area work, well beyond the some 10-20 named participants who were closely involved in the work of each theme area, (ii) to develop a systematic foresight method for the scanning, elaboration, assessment and analysis of weak signals in view of multiple perspectives; (iii) to deploy this method for each of the three theme areas and (iv) to disseminate the results to a wider audience. The project was designed and facilitated by the authors in collaboration with the Forum coordinator. Moreover, parallel processes on the same theme areas were conducted with about 60 M.Sc. students in a course on decision analysis at the Helsinki University of Technology. A major result of the pilot project was the development of the RPM screening method which provides support for the collaborative generation, mutual commenting, iterative revision of innovation ideas, as well as the evaluation of such ideas in view of multiple evaluation perspectives.

After two months into the project, the objectives of the pilot project were slightly adjusted, in recognition that responsiveness in foresight management may be beneficial (Salo et al., 2004). That is, instead of scanning across a broad spectrum of all sorts of weak signals, without additional clarification on what kinds of signals would be of most interest, it was deemed pertinent to focus on innovation ideas which, in a sense, can be regarded as more comparable and comprehensible indications of weak signals. We thus provided the following definition for innovation ideas: “Concrete and context-specific ideas for innovations that (i) are related to the chosen issue area (e.g. nutrigenomics), (ii) are new to the participant or received insufficient attention in his/her opinion, (iii) may be related to technological discontinuities, (iv) are interesting in light of present observations (v) may provide an opportunity for the development of an innovation (an applicable new technology, concept, method or practice) within 10-15 years and (vi) may require collaboration among different actors.”

Internet-based decision support tools were employed extensively in the generation and evaluation of innovation ideas. The choice of this technological platform was driven by the realization that the generation of diverse ideas in face-to-face meetings can be difficult and time-consuming for organizers and participants alike (Salo, 2001; Salo et al., 2004). In contrast, Internet-based distributed work can, at best, provide efficient and
systematic support for stakeholder participation while allowing for features such as anonymity and flexibility in terms of time and place (Salo & Gustafsson, 2004).

Owing to the limitations of the Internet as a platform for social interaction, the Internet-based process was run in close connection with workshop meetings: that is, the activities in the Forum consisted of Internet-activities, based on RPM screening, and face-to-face meetings among the invited experts in the three theme areas. However, because the novel aspects in the pilot project pertain to methodological advances, we focus on the Internet activities and the use of RPM methodology (Liesiö et al., 2005) in the analysis of innovation ideas.

4.1 Phases of the Project

For each theme area, an Internet-based process was carried out with the aim of engaging diverse participants, including developers, researchers, users and students, among others in the collaborative generation, revision and evaluation of innovation ideas. Towards this end, the project website was set up to solicit new ideas with the help of Opinions-Online© decision support tool. In the later phases, the evaluation results were analysed and synthesised with a PRO-OPTIMAL software based on the RPM framework (Liesiö et al., 2005). Within each theme area, the process was structured in the following four phases:

(i) Generation of innovation ideas

The Forum coordinator sent an e-mail to about 50 selected participants, requesting them to read instructions on the project website and to generate 1-7 innovation ideas. It was estimated that writing the innovation ideas (max. 250 words per idea) would take about 15-20 minutes. This website for providing these ideas was open for two weeks. The participants were able to add new ideas in several separate sessions.

(ii) Commenting and elaboration of ideas

In the second phase, the participants were invited to work with the help of two websites. The first of these provided support for commenting other participants’ ideas and for improving one’s own ideas, while the second website made it possible to study comments
that provided by other participants. Again, the websites were open for two weeks. The participants could visit them as often as they wanted to, or at least twice: first, in order to comment ideas put forth by others and, second, in order to revise their ideas in view of comments expressed by the other participants.

**(iii) Evaluation with regard to multiple criteria**

In the third phase, the participants were asked to evaluate submitted ideas with regard to the following three criteria using the Likert scale 1-7: (i) Novelty – How new is the idea? (ii) Feasibility – How feasible is the idea? (iii) Societal relevance – How extensive and desirable impacts the innovation could lead to?

The number of criteria was limited in three in order to keep the workload of participants manageable. The evaluation criteria were selected in a way that they would be general enough to be applicable for widely different ideas and comprehensive enough to describe future potential of ideas from diverse dimensions. The participants could freely choose which ideas they evaluated, in order to ensure that the evaluation task would not call for an excessive effort while evaluations would be obtained on those ideas that the evaluators were most interested in (which, in itself, gave some interesting information). The evaluators were also encouraged to augment their numerical statements with written comments and, in particular, to provide suggestions for actions through which the ideas could be promoted.

**(iv) Multi-criteria portfolio analysis**

After the internet-based participatory phases, the results were analysed with PRM software tools (Liesiö et al., 2005). This methodology was employed to synthesize the multi-criteria evaluations and to identify subsets of innovation ideas that seemed particularly interesting in view of different diversity considerations. The results of this analysis were finally discussed in workshops for the different theme areas.

**4.2 Analysis with Diverse Perspectives**

Following Ansoff’s idea of weak signals, an innovation idea must be supported by at least some respondents in order to be treated as a reflection of a weak signal. But if an idea
receives consistent and extensive support, it is more probably a trend than a weak signal. And at the other extreme, if an idea receives no support at all, it can be regarded as noise and can thus be deemed as irrelevant for further analysis (see Figure 1 for three types of signals).

(Figure 1 around here)

More formally, one can outline archetypal categories by using the means and variances of the evaluation scores provided by the participants. That is, when an idea has a high mean and low variance it is likely to reflect a trend; and when it has a low mean (and hence low variance, too), it may be considered as noise. But when an idea has a sufficiently high mean but a high variance, too, it may qualify as a weak signal, because it is strongly supported by some experts while others regard it as irrelevant.

These notions are illustrated in Figure 2 where the vertical axis corresponds to the mean and the horizontal axis to the variance. Here, prospective trends with a high mean and low variance are positioned in the upper left quartile, while weak signals whose mean exceeds the threshold level with a high variance are located in the upper right quartile. Noise signals whose mean below the threshold level are in the lower quartiles.

(Figure 2 around here)

While the above discussion parallels much of the earlier literature, our case was different because innovation ideas were evaluated with regard to one but three criteria (novelty, feasibility and societal relevance), resulting in six criterion-specific measures for each innovation idea (three means and three variances based on the participants’ ratings on each criterion). This explication of multiple criteria did bring in additional perspectives into the analysis. It also raised the question of how the different criteria should be weighted: for example, innovation ideas that are not very novel may still be societally relevant and hence interesting.

Because it may be difficult to justify ‘true’ or precise criterion weights, it seems that analyses for identifying ‘most interesting ideas’ should accommodate different interpretations of which criterion weights are feasible. This was why we adopted the RPM framework (Liesiö et al., 2005) in the analysis of innovation ideas, for this framework readily admits incomplete information about criterion weights. Thus, apart from the consultation of multiple stakeholder groups, diverse perspectives could be brought into the
analysis of innovation ideas not only through the consideration of multiple criteria (means and variances of the participants’ evaluation ratings), but also by incorporating different interpretations of how important the criteria were relative to each other.

### 4.2.1 Robust Portfolio Modelling

In its standard formulation, the RPM methodology (Liesiö et al., 2005) supports the selection of project portfolios in the presence of resource constraints and possibly incomplete information about (i) the relative importance of evaluation criteria and (ii) the projects’ performance with regard to these criteria. In the Forum, the RPM methodology was employed by regarding innovation ideas as ‘projects’ and collections of ideas as project portfolios, respectively. The task of identifying subsets of most promising ideas for subsequent workshop discussions was hence modelled as a project portfolio selection problem with incomplete information about the relative importance of evaluation criteria.

In the RPM framework, the overall value of each idea is stated as the weighted average of its criterion-specific scores; moreover, the total value of a portfolio is obtained by summing the overall values for the ideas that are contained in it. The identification of ‘most interesting’ ideas (or projects) is based on the computation of non-dominated portfolios (i.e., portfolios such that there does not exist any other portfolio with a higher total value with regard to all feasible criterion weights). Thus, a key feature of RPM is that it provides measures for the attractiveness of individual ideas derived from analyses that are carried out at the portfolio level.

In technical terms, the portfolio selection problem can be formalized as follows. Let \( X = \{x_1, \ldots, x_m\} \) denote the \( m \) ideas that are to be evaluated with regard to the \( n \) criteria. The score of the \( j \)-th idea with regard to the \( i \)-th criterion is \( v_{ij} \geq 0 \), while \( w_i \) denotes the relative importance of the \( i \)-th criterion. Following the usual convention in multi-criteria decision analysis, the components of any feasible weight vector \( w = \{w_1 \ldots w_n\} \) are non-negative and add up to one, i.e., they belong to the set \( S = \left\{ w \mid \sum_{i=1}^{n} w_i = 1, w_i \geq 0 \right\} \).

The overall score of the \( j \)-th idea can now be defined as the weighted sum of its scores
A portfolio is a subset of all ideas $X$ (i.e. $p \subset X$). The total score of portfolio $p$ can be obtained by summing the overall scores of the ideas in it, that is

$$V(p, w) = \sum_{x_j \in p} V(x_j, w) = \sum_{x_j \in p} \left( \sum_{i=1}^{n} w_i v_{ij} \right).$$

In the Foresight Forum, we sought to identify subsets of most interesting innovation ideas, the resource constraints were largely implied by the question of how many ideas from each theme area could be taken forward for further analyses. This requirement corresponds to the observation that if no more than $R < m$ ideas can be taken forward, only the portfolios that include at most $R$ projects are feasible. The set of feasible portfolios is therefore $P_F = \{ p \mid |p| \leq R \}$ where $|p|$ denotes the number of ideas in portfolio $p$.

For the formalization of optimization problems in RPM, it is useful to define integer variables $z_j$ such that $z_j$ gets value one if the idea $x_j$ is in the selected portfolio and zero if this is not the case, i.e.,

$$z_j = \begin{cases} 1, & \text{if } x_j \in p \\ 0, & \text{if } x_j \notin p \end{cases}.$$  

Multiplying the overall value $V(x_j, w)$ for each idea by the corresponding integer variable $z_j$, the total portfolio value can be defined as the sum $\sum_{j=1}^{m} z_j \left( \sum_{i=1}^{n} w_i v_{ij} \right)$. When the feasibility constraint $\sum_{j=1}^{m} z_j \leq R$ is also accounted for, it follows that for a given weight vector $w = \{ w_1 \ldots w_n \}$, the portfolio with the maximum total value is obtained as a solution to the problem
With incomplete weight information, the weight vectors are constrained so that they belong to a feasible set $S_w \subset S$ in accordance with the given preference statements. In this case, portfolio $p$ dominates portfolio $p'$, denoted by $p \succ p'$, if and only if (i) the total value of $p$ is higher than or equal to that of $p'$ for all feasible criterion weights $w \in S_w$ and (ii) its value is strictly higher for some feasible weight vector $w \in S_w$ (i.e. $p \succ p' \iff V(p, w) \geq V(p', w)$ for all $w \in S_w$ and $V(p, w) > V(p', w)$ for some $w \in S_w$). The set of non-dominated portfolios $P_N$ contains the portfolios for which there does not exist any other portfolio with a higher total overall value for all feasible criterion weights (i.e. $P_N = \{p \in P_f \mid \exists p' \in P_f \text{ s.t. } p' \succ p\}$).

Information about the desirability of each idea can now be provided by examining in how many different non-dominated portfolios it is contained. This information is conveyed by the Core Index values $CI(x) = \{p \in P_N \mid x \in p\} / |P_N|$, defined as the ratio between (i) the number of the non-dominated portfolios the idea belongs to and (ii) the total number of non-dominated portfolios. Thus, if an idea belongs to all non-dominated portfolios, it has Core Index value 100 %; and conversely, if it does not belong to any non-dominated portfolios, it has a Core Index value 0 %. Ideas with a Core Index value 100 % are consequently worthy of further scrutiny, since they would, in view of the given evaluation scores, belong to the optimal portfolio of ideas even if additional information about the relative importance of criteria were obtained. Likewise, ideas with a Core Index value can be disregarded, because they would not belong to the optimal portfolio even if additional information is obtained.

### 4.2.2 Complementary Approaches for Screening Innovation Ideas

Early on in the process, we anticipated that the participants in each theme area would generate about 50 ideas, of which some 15-20 (or approximately one third) could be
taken into the further discussion. The size of feasible portfolios was therefore constrained by putting an upper bound \( R \approx m/3 \) on the number of ideas in portfolios.

In the screening of innovation ideas, Core Index values were used as a measure of how interesting the ideas were in view of the participants’ evaluative statements. However, realizing that, in addition to the participants’ mean ratings, the variability in these ratings can also be of interest, we developed two complementary approaches to capture different notions of what can be meant by the notion of ‘most interesting’.

1. The consensus-oriented approach sought to identify ideas that performed rather well with regard to the specified criteria (i.e., novelty, feasibility, societal relevance) in view of their criterion-specific means and incomplete information about the relative importance of these mean values.

2. The dissensus-oriented approach served to highlight ideas on which the participants had differing viewpoints, as captured through the introduction of additional criteria based on criterion-specific variances.

In technical terms, when criterion-specific means and variances based on the participants’ ratings are denoted by \( \bar{a}_{ij} \) and variances \( \sigma_{ij}^2 \), respectively, these two approaches can be stated as follows.

**Consensus-oriented approach: Maximize criterion-specific means**

\[
\max_{z_1, \ldots, z_m} \sum_{j=1}^{m} z_j \left( \sum_{i=1}^{n} w_i \bar{a}_{ij} \right)
\]

\[
\sum_{j=1}^{m} z_j \leq R
\]

\[
z_j \in \{0,1\} \forall 1 \leq j \leq m
\]

**Dissensus-oriented approach: Maximize criterion-specific means and variances**

\[
\max_{z_1, \ldots, z_m} \sum_{j=1}^{m} z_j \left( \sum_{i=1}^{n} w_i \bar{a}_{ij} \right) + \left( \sum_{i=1}^{n} w_i \sigma_{ij}^2 \right)
\]

\[
\sum_{j=1}^{m} z_j \leq R
\]

\[
z_j \in \{0,1\} \forall 1 \leq j \leq m
\]
The consensus-oriented approach helps identify innovation ideas that, on the average, perform consistently rather well in view of the participants’ ratings across all the criteria. The approach is therefore suitable for promoting ideas about which there is a reasonably high degree of consensus among the participants. In the case of fostering innovation ideas, the inclusion of dissensus approach was considered highly interesting as, indeed, our intention was not only to foster the generation of new innovation ideas but also consider the respective diverse interests of different participants.

Apart from distinguishing between dissensus-oriented and consensus-oriented approaches, the analysis enabled us to look at the ideas with multiple criteria and their different weightings. By changing the feasible weight region, $S_w \subset S$ through the introduction of different constraints on the weights, it was possible to identify innovation ideas that were interesting and popular from different perspectives. For example if we define $w_i > w_j$ we state that criteria $i$ is more important than $j$ and we identify innovation ideas that emphasized the criteria $i$ more than the criteria $j$.

As described in the beginning of Section 4.2, we calculate both the means and variances for the idea specific criteria, resulting in six independent portfolio criteria. We use them to produce several analyses by emphasizing different criteria at the same time or separately. Here, we describe the application of the consensus and dissensus approaches as well as three examples of the criterion specific analyses. In the formulas below, the linkage between indices and criteria is defined as follows: Novelty = 1, Feasibility = 2, Societal relevance = 3. Moreover, $w_i^{d}$ refers to the mean of i-th criteria and $w_i^{v}$ refers to the i-th variance.

**Analysis with consensus-oriented approach**

Innovation ideas were analysed by maximizing criterion specific means of innovation ideas. All the criteria were considered equally important, and thus the feasible set of criterion weights was defined as

$$S_w = \left\{ w \mid \sum_{i=1}^{3} w_i^{d} = 1, w_i^{d} \geq 0 \right\}.$$
**Analysis with the dissensus-oriented approach**

In the dissensus-oriented approach, explicit attention was given to the variability in the ratings that provided by the participants, in order to highlight ideas about which they had expressed different statements. Specifically, for all three criteria, variance measures were considered more important than the respective means; moreover, novelty was considered more important than feasibility which, in turn, was considered more important than societal relevance. To ensure the relevance of all criteria (in terms of attaining a strictly positive weight), the weight of each criterion was contrained from below by the bound $1/36$ (i.e., one sixth of the average component of any feasible weight vector):

$$S_w = \left\{ w \left| \sum_{j=1}^3 \left( v_{ij} + w_{ij} \right) = 1, w_{ij} \geq 0, v_{ij} \geq 0, w_{ij} \geq w_{ij}^d \text{ ja } w_{ij}^d \geq w_{ij}^d \right. \left. \geq w_{ij}^d, w_i \geq \frac{1}{36} \right\}$$

**Analyses with specific criteria**

In order to explore alternative ways in which the consensus and dissensus oriented approaches might be combined, we also performed three additional analyses, based on different constraints on the criterion weights associated with the means and variances derived from the participants’ ratings. In the first of these, anlaysis, only variance criteria were accounted for, without additional statements about which variances were more important than others. Second, attention was given only to the novelty and feasibility, of which novelty was treated as the more important criterion while the variances were considered more important than means. Third, the same analysis was carried out in view of novelty and societal relevance, with societal relevance replacing the role of feasibility in the second analysis.

- **Maximize variances:** $S_w = \left\{ w \left| \sum_{j=1}^3 w_{ij}^v = 1, w_{ij}^v \geq 0 \right\}$$
- **Maximize novelty and feasibility:** $S_w = \left\{ w \left| w_{ij}^d + w_{ij}^v + w_{ij}^d + w_{ij}^v = 1, w_{ij}^d \geq w_{ij}^d \right\}$$
- **Maximize novelty and societal relevance:** $S_w = \left\{ w \left| w_{ij}^d + w_{ij}^v + w_{ij}^d + w_{ij}^v = 1, w_{ij}^v \geq w_{ij}^d \right\}$$

The purpose of these additional analyses was that two analysis was that the two first analysis were considered a basis of analysis and the three last ones to support them, i.e. with the analysis with consensus and the dissensus approach we created a framework for expert workgroup discussion and with the analysis with specific criteria we identified
innovation ideas that the two basic analysis didn’t identify. Thanks to the supporting analysis, we could identify not only those innovation ideas which were interesting from many different perspectives but also those which were interesting with regard to a a specific criterion.

The five different analyses described above are largely illustrative. Still, the idea of using RPM is that defining feasible set of weights i.e. emphasizing different weightings in numerous different ways, once the criterion-specific means and variances have been derived from the participants ratings. At the moment, we are developing an Internet-based software which will allow the stakeholders to specify their own preferences for the users, and to examine which ideas will be highlighted, in view of their preferences.

4.3 Results of the Process

The Internet-based process supported the objective to engage stakeholders into the work of the expert groups. About 50 participants per theme were invited resulting in the following dispersion of participants among different stakeholder groups:

- industry ~ 10 %,
- government ~ 40 %,
- research ~ 30 %,
- commerce and non-governmental organizations ~ 10 %, and
- technology entrepreneurs and investors ~ 10 %.

The participation in the RPM screening was quite active, although the theme on ‘services for the provision of personal experiences’ suffered from the lack of participation, mainly because of the busy holiday season for entrepreneurs in the tourism services. Overall, the process resulted in a total of 166 prospective innovation ideas, of which many were considered sufficiently interesting for further elaboration: for example, such ideas were adopted into the Delphi-process of a regional foresight project. The ideas were also disseminated to a large number of enterprises, universities, research centres, ministries and regional development centres through websites, workshops and seminars. Table 1 summarizes the participant contributions in the different phases of the internet-based consultation process. Overall, the feedback that was collected from the participants by e-mail and face-to-face discussions in different phases of the project was positive about the process at large.
To provide a better picture of the results, we describe an example of the analysis. Figure 3 shows the results for the “Health care and social services”, in which innovation ideas are sorted in a descending order according to their Core Index values.

With consensus approach, the innovation idea number 18 became the first in order with the Core Index 100 and the idea 23 became 18-th with the Core Index 7. Correspondingly, with dissensus approach the idea 18 became 14-th with the Core Index 26 and the idea 23 became the first with the Core Index 100. Thus, the two different approaches identified also different innovations as the most interesting ones. Also the contents of innovation ideas differed from one another. The idea 18 described the role of the third sector and voluntary organizations in the supply of health care services and the idea 23 proposed that the linkage between the municipality of a resident and the right to health care in other municipalities could be eliminated. Furthermore, in the workshop participants considered the idea 18 clear and ready for use, whereas, while the idea 23 was promising, the implementation was considered difficult and even controversy (whereby its variance scores were higher). In general, the workshop participants considered that calculated core indices for ideas were in line with the contents of the innovation descriptions.

In summary, the process was quite successful as a new method for the generation, commenting, evaluation and analysis of novel ideas on prospective innovations. The application of the RPM approach in the analysis of innovation ideas also proved useful: the participants in the final workshops noted that the analysis with regard to multiple criteria both novel and informative, and that some of the identified ideas were not only interesting but even surprising.
5. Discussion

Foresight activities have often sought enhance the performance of innovation systems by emphasizing consensual priority-setting, networking and vision-building. But just as in the case of scenario work (Bunn and Salo, 1993), the elaboration of controversial and even conflicting ideas can be helpful in preparing for alternative futures. Indeed, consensual foresight objectives and diversity considerations can have complementary roles in enhancing the performance of innovation systems: for example, the implementation of S&T priorities may be best pursued through the concerted efforts of rivalling coalitions that reflect different competences and technological arrangements (Tushman & O'Reilly, 1997). This also means that the fostering of diversity need not be aligned with ‘anything goes’ type of fragmented approaches; rather, it calls for the ‘wiring up’ of the emerging coalitions based on new value networks and visions, with the aim of securing that these will offer viable alternatives for existing dominant designs. Arguably, such evolutionary flexibility and adaptability is best supported through foresight methods that recognize diversity considerations.

Motivated by the above discussion, we have developed the RPM screening method which engages participants from different stakeholder groups into successive phases for the collaborative generation, revision, analysis of innovation ideas. In effect, RPM screening method is aligned with several diversity considerations. It explicates multiple evaluation perspectives (by way of a multi-criteria model), it admits different interpretations about the importance of these perspectives (by way of incomplete information about criteria weights) and it emphasizes the variability of the participants’ ratings (by way of using variance measures as a criterion). Still, the mapping of innovation ideas and the visions that they embody also calls for interpretative work with the aim of laying the foundations for new value networks, architectures and agendas. This is why RPM screening is best deployed in conjunction with face-to-face deliberative activities, such as workshops and seminars where the results from distributed work can be taken forward through informal networking activities, among others.

Although we have focused on the generation and screening of innovation ideas, RPM screening seems suitable in other contexts as well. In the European Forest-Based Sector Technology Platform (www.forestplatform.org), for instance, RPM screening has been employed for shaping the Finnish priorities for the Strategic Research Agenda (see the project website www.sra.tkk.fi) through which this sector’s future R&D roadmap is to be im-
implemented. In WoodWisdom-Net (www.woodwisdom.net) – which is one of the ERA-NETs for building the European Research Area – analogous processes are being carried out with the aim of developing an international research agenda which will be implemented through later Calls-for-Proposals and joint projects on wood material science and related sciences. More generally, decisions concerning societally warranted technologies and organizational responses are often complicated by high uncertainties, inability to obtain complete information on available options, and cognitive bounded rationality limitations (Kline, 2001). In such contexts, RPM screening holds promise as a systematic method in fostering the diversity considerations in the discussions, thus helping prepare for alternative futures.

6. Acknowledgements

This research has been supported by the Ministry of Trade and Industry of Finland. We wish to thank Risto Louhenperä and Seppo Kangaspunta for their considerable contribution to the design of the foresight process. We are also grateful to Eija Ahola, Jyrki Kettunen, Osmo Kuusi, Torsti Loikkanen, and Margareetta Ollila for their constructive comments in the different phases of the pilot project.

7. References


Figure 1  Three types of signals

Figure 2  Signals with regard to means and variances
<table>
<thead>
<tr>
<th>Themes</th>
<th>Participants</th>
<th>Generated Innovation ideas</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Phase 1</td>
<td>Phase 2</td>
</tr>
<tr>
<td>Services for the provision of personal experiences</td>
<td>2</td>
<td>-</td>
</tr>
<tr>
<td>Health care and social services</td>
<td>11</td>
<td>16</td>
</tr>
<tr>
<td>Nutrigenomics</td>
<td>7</td>
<td>2</td>
</tr>
<tr>
<td>Services for the provision of personal experiences (Students)</td>
<td>9</td>
<td>8</td>
</tr>
<tr>
<td>Health care and social services (Students)</td>
<td>8</td>
<td>7</td>
</tr>
<tr>
<td>Nutrigenomics (Students)</td>
<td>6</td>
<td>6</td>
</tr>
<tr>
<td>Total</td>
<td>43</td>
<td>39</td>
</tr>
</tbody>
</table>

Table 1 Participation in the internet-based process and the number of generated ideas.
Diversity in Foresight: Insights from the Fostering of Innovation Ideas

To be submitted to the International Journal of Foresight and Innovation Policy (IJFIP)

Consensus approach

Dissensus approach

Figure 3: Core indices of ideas within the theme “Health care and social services” with regard to consensus and dissensus approaches