Decision Modelling and Foresight Methodologies
by

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Directed by Prof. Ahti Salo, the research Group on Decision Modelling and Foresight Methodologies is based at the Systems Analysis Laboratory of the Helsinki University of Technology (www.sal.hut.fi). The research and teaching activities of our Laboratory – which is directed by Prof. Raimo P. Hämäläinen – cover a wide range of issues in systems sciences, decision analysis, optimization techniques, game theory, environmental decision making, among others. The Laboratory also coordinates the graduate school on systems analysis, decision making and risk management, run in collaboration with Helsinki School of Economics as of 1995. To-date, more than 40 doctoral degrees have been obtained within this school. The majority of these degrees have been awarded at the Helsinki University of Technology.

At the moment, there are seven full-time doctoral students (Ville Brummer, Tommi Gustafsson, Janne Kettunen, Juuso Liesiö, Pekka Mild, Antti Punkka) and an M.Sc. student (Erkka Jalonen) in our Group on Decision Modelling and Foresight Methodologies. Practically all our activities are enabled through basic and applied research projects that are funded by organizations such as the National Technology Agency (Tekes), the Academy of Finland, Ministries of the Finnish Government, industrial firms and the European Union.

Our focal research topics include (i) the modelling and exploitation of incomplete information in decision support processes; (ii) the development of methods and software tools for the selection and management of project portfolios; (iii) the design and implementation of innovative methodologically structured foresight processes.

For several years, we have been working on the question of how incomplete information can be dealt with in decision modelling. This question is motivated by the realisation that information on the performance of decision alternatives or the relative importance of the decision criteria can be difficult, impossible or prohibitively expensive to acquire; it is therefore pertinent to examine how useful and defensible recommendations can be provided on the basis of the information that can be obtained through reasonable efforts. Specifically, by building on the well-established frameworks for value tree analysis and AHP-like hierarchical weighting models, we have developed methods such as *PAIRS* (Salo and Hämäläinen, 1992) and *PRIME* (Salo and Hämäläinen, 2001) which accommodate incomplete information about the model parameters by way of set inclusion: this means, for instance, the lower and upper bounds may be placed on the alternatives' scores, and that criteria weights may be constrained through linear constraints.

With the help of relevant dominance concepts and decision rules, such information can be synthesised to convey (i) which alternatives can be surely recommended (in the sense that the recommendations are supported by all feasible combinations of model parameters) and (ii) what alternatives are supported by decision rules that transform incomplete information into corresponding decision recommendations (e.g., the max-min decision rule supports the alternative whose least possible overall value is the highest one among all alternatives).

The above methods synthesise incomplete information through interlinked phases of preference elicitation and presentation of intermediate results; we therefore refer to them by the term *Preference Programming* (Salo and Hämäläinen, 1995, 2003). From the viewpoint of decision support processes, preference programming methods are promising as they provide support for interactive learning processes, can reduce the costs of information elicitation, and may increase the DMs commitment to the decision support process (see, e.g., Mustajoki et al., 2004, 2005; Hämäläinen, 2003, 2004).

The recently developed *RICH* method (*Rank Inclusion in Criteria Hierarchies*; Salo and Punkka, 2005) extends preference programming methods to the analysis of incomplete ordinal information. In *RICH*, the DMs may provide incomplete information by associating subsets of attributes with corresponding subsets of rankings (e.g., 'cost and quality are among the top three most important attributes', 'the most important attribute is either cost or location'). We have also implemented a related decision support tool called *RICH Decisions©* which is available in the Internet (www.rich.tkk.fi). To-date, this tool has been employed in the selection of risk management methods at an energy utility (Ojanen et al., 2005) and the development of priorities for a Scandinavian research programme (Salo and Liesiö, forthcoming). Even more flexible preference elicitation modes are offered by the *RICHER* method (*RICH with Extended Rankings*; Punkka and Salo, 2005) which applies the preference elicitation modes of RICH to the comparison of alternatives. Thus, for any given subset of alternatives, the DM may specify a subset of rankings that these alternatives may assume in relation to a single evaluation criterion, several criteria, or even all criteria (whereby the last mode of preference elicitation corresponds to a holistic statement).

Much of our recent work has been at the juncture of preference programming and multicriteria project portfolio selection. This work has resulted in the *Robust Portfolio Modeling* (*RPM*) methodology (www.rpm.tkk.fi, Liesiö et al., forthcoming) which is well-suited to problems where a subset of available projects is to be selected subject to one of several resource constraints, and where there may be incomplete information about (i) the projects' performance with regard to the multiple evaluation criteria or (ii) the relative importance of these criteria.

In *RPM*, the conceptual and computational breakthrough is the determination of all non-dominated portfolios (i.e., portfolios that cannot be improved upon with regard to *all* criteria at the same time). This makes it possible to determine (i) which *core* projects are included in all non-dominated portfolios, (ii) which *exterior* projects are not included in any non-dominated portfolios, (iii) which *intermediate* projects are included in some but not all non-dominated portfolios. Based on this analysis, the DM can be advised to choose core projects and to reject exterior ones. Moreover, subsequent information elicitation efforts can be focused on intermediate projects, which helps reduce the costs of information elicitation.

In comparison with the earlier literature on robustness, *RPM* is unique in that it offers decision recommendations about individual projects instead of offering a 'single' optimal portfolio on some selected robustness measure (e.g., max-min). This makes it suitable for interactive group decision support processes where considerations that are less amenable to formal modelling efforts can be addressed through judgemental considerations (e.g., project interactions). To-date, we have carried out a wide range of applied RPM projects in the contexts of road asset management (Liesiö et al., forthcoming), formulation of a product strategy in a high-technology firm (Lindstedt et al., forthcoming), screening of innovation ideas (Könnölä et al., 2006a), development of a strategic research agenda (Könnölä et al., 2006b), and *ex post* evaluation of an innovation programme (Salo et al., 2005). Our current RPM-related projects are concerned with the selection voluntarily offered forest reserves in a conservation programme, the analysis of patent portfolios in high-technology company, the establishment of a research agenda for an industrial federation, and the development of guiding budgetary principles for road asset management. We are actively working on the development of decision support tools for the computation (*RPM-Solver*©) and Internet-based dissemination of *RPM* results (*RPM-Explorer©).*

Contingent Portfolio Programming (*CPP*; Gustafsson and Salo, 2005) is another recent methodology that we have developed for the management of project portfolio. An important rationale for this methodology is that although decision trees are widely employed in the development of project management strategies, they are not suitable for portfolio problems, because the number of decisions becomes prohibitive if there are many projects. For instance, if there are 10 projects at the initial decision node, there would be as many as $2^{10} = 1024$ alternative decisions. This is far too many for the purpose of building a decision tree, even if many of these decisions may be infeasible due to budget constraints.

In essence, *CPP* is a novel framework for the selection and management of project portfolios in settings where exogenous uncertainties can be captured through scenario trees, and where the DM is interested in maximising her terminal resource position, as captured by an objective function that consists of the expected value of her resources and a modifying risk factor (e.g., lower semi-absolute deviation or expected downside risk). In such settings, *CPP* permits the determination of optimal project management strategies; it also permits the valuation of projects and real options in contexts where marketable securities are available to the investor (Gustafsson et al., 2005). We believe that the *CPP* methodology is a very promising one: for example, on November 14, 2005, the Decision Analysis Society of the Institute of Operations Research and the Management Sciences (INFORMS) recognized the significance of *CPP* by granting the best student paper award to Dr. Janne Gustafsson for our seminal paper (Gustafsson and Salo, 2005). At the moment, we are working on various extension and applications of the *CPP* methodology.

In our applied research projects, have worked extensively on the development of methodologies and approaches for Internet-based consultation processes, particularly in connection with technology foresight which, as an activity, can be defined as "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" (Salo and Cuhls, 2003). In this area, our past projects include, among others, foresight processes for the Finnish Food and Drink Industries Federation (Salo et al., 2004b), Foresight Forum of the Ministry of Trade and Industry (Könnölä et al., 2006), future-oriented evaluation of RTD programmes in electronics and telecommunication (Salo and Gustafsson, 2004), prospective evaluation of the cluster programmes for the forestry and forest-based industries (Salo et al., 2003, 2004a). We have also sought to make conceptual advances concerning the role of systematically structured foresight processes in relation to strategic policy making processes (see, e.g., Salo, 2001; Salo and Kuusi, 2001; Salo and Salmenkaita, 2002; Salmenkaita and Salo, 2002, 2004).

At the moment, we are responsible for the methodological and IT support for FinnSight 2015 (www.finnsight2015.fi) which is the largest foresight process in Finland to-date, run by and on behalf of the Academy of Finland and the National Technology Agency (Tekes). Taken together, these two funding organizations allocate some 600 million Euros for basic research and applied technological research per year. One of the main objectives of FinnSight 2015 – which is a collaborative process involving 120 leading experts from industry and academia – is to address future challenges that the Finnish society and its industries are faced with, and to identify focal competence areas that should be strengthened in view of these challenges. The results of this project will be widely communicated to the highest level of policy making including, for instance, the Prime Minister and other members of the Science and Technology Policy Council.

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