COMMUNICATIVE AND ANTICIPATORY DECISION-MAKING SUPPORTED BY BAYESIAN NETWORKS

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Communicative and Anticipatory Decision-Making Supported by Bayesian Networks

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A dissertation

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ABSTRACT

The purpose of this research is to draw up a clear construction of an anticipatory communicative decision-making process and a successful implementation of a Bayesian application that can be used as an anticipatory communicative decision-making support system. This study is a decision-oriented and constructive research project, and it includes examples of simulated situations.

As a basis for further methodological discussion about different approaches to management research, in this research, a decision-oriented approach is used, which is based on mathematics and logic, and it is intended to develop problem solving methods. The approach is theoretical and characteristic of normative management science research. Also, the approach of this study is *constructive*. An essential part of the constructive approach is to tie the problem to its solution with theoretical knowledge.

Firstly, the basic definitions and behaviours of an anticipatory management and managerial communication are provided. These descriptions include discussions of the research environment and formed management processes. These issues define and explain the background to further research.

Secondly, it is processed to managerial communication and anticipatory decision-making based on preparation, problem solution, and solution search, which are also related to risk management analysis. After that, a solution to the decision-making support application is formed, using four different Bayesian methods, as follows: the Bayesian network, the influence diagram, the qualitative probabilistic network, and the time critical dynamic network. The purpose of the discussion is not to discuss different theories but to explain the theories which are being implemented.

Finally, an application of Bayesian networks to the research problem is presented. The usefulness of the prepared model in examining a problem and the represented results of research is shown. The theoretical contribution includes definitions and a model of anticipatory decision-making. The main theoretical contribution of this study has been to develop a process for anticipatory decision-making that includes management with communication, problem-solving, and the improvement of knowledge. The practical contribution includes a Bayesian Decision Support Model, which is based on Bayesian influenced diagrams. The main contributions of this research are two developed processes, one for anticipatory decision-making, and the other to produce a model of a Bayesian network for anticipatory decision-making.

In summary, this research contributes to decision-making support by being one of the few publicly available academic descriptions of the anticipatory decision support system, by representing a Bayesian model that is grounded on firm theoretical discussion, by publishing algorithms suitable for decision-making support, and by defining the idea of anticipatory decision-making for a parallel version. Finally, according to the results of research, an analysis of anticipatory management for planned decision-making is presented, which is based on observation of environment, analysis of weak signals, and alternatives to creative problem solving and communication.

Computing Reviews (1991) Categories and Subject Descriptors:
J.4 Social and behavioural sciences
I.2.1 Applications and expert systems
I.2.8 Problem solving, control methods and search

General Terms:
Theory, Algorithms
Additional Key Words and Phrases:
Management, communication, decision-making, prediction, anticipatory, intelligent systems

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Helsinki, *January* 2009

Pertti Kuokkanen

Contents

List of Tables

List of Figures

Chapter 1

Introduction

1.1 Background to research

This research work has been prepared to outline anticipatory management and managerial communication as part of decision-making in a changing environment and to indicate the basis of Bayesian methods usefulness as an anticipatory decision-making support system. Furthermore, this study focuses on the assessment of the effects of a dynamic environment, factors of critical perception, and preparation of the alternative in the anticipatory decision-making process.

The phenomenon being researched is an everyday one for people in managerial positions within an organisation. It can be assumed that certain factors, such as management principles and communication, the environment, the organisation and its resources (e.g., personnel, information, etc.) have an effect on the decision-making process. These factors change over time. Therefore, the decision-maker constantly has to make new decisions. The phenomenon can be researched with models that are associated with decision-making and support it and by developing new constructs of these models. The goal is to use the results to develop support systems that can be used to aid decision-making in various situations.

The interaction between organisations that operate in a changing environment is a factor not only in organisations' relationships, but also in their success. A strategy is created for the organisation to enable it to succeed or carry out its purpose. This strategy is intended to create order and provide shared objectives, which enable the organisation to succeed in its operating environment. The difficulty in implementing this strategy is that the strategy's planners and implementers work on different issues, think differently and speak different languages. There can be no shared understanding without communication, and no strategy can be implemented without shared operations. (Mantere et al 2006, 10–11.)

Communication has a positive impact on this relationship when leaders lead from the employees' perspective and communicate in ways that make employees feel needed, appreciated, and understood (Grandwell 2004, 2). By communicating planned change effectively, leaders can diminish employee resistance caused by misunderstanding, misinterpretation, anxiety, fear, stress, uncertainty, and adverse reactions to proposed changes (Grandwell 2004, 3).

Changes in the environment lead to a need for the organisation to change. In order to implement organisational changes effectively, it is necessary for the organisation's top management to engage in anticipatory communication, both internally and externally. The objective of proactive communication is to have the organisation use its own communication and management methods to reach objectives and enable personnel to understand and internalise changes before they are actually implemented.

The largest part of any organisation's action (i.e., organisation management and within connected decision-making) is communication. The action of organisation is based on an information exchange and understanding. People communicate with each other in an organisation, because objectives of organisation need communicative relations. Organisation will be build up to achieve people's joint objectives. People produce information and react to it, so structures and systems will be built upon it. Thus, management and decision-making can be examined as a communication phenomenon.

Behind the new leadership behaviour, education, and training program is internationally significant research that can be called the new paradigm of leadership. The new part is the modelling of the "best practices" of the transformational leader that offers a reliable framework for observing, measuring, and conceptualising leadership behaviour (Nissinen 2001, 61). Both research and practical life have revealed risen requirements for leadership that are still extremely challenging. Leaders are required to have skills related to staff commitment, exceptional results, vision building, and changing management, while routines and processes continue working efficiently (Nissinen 2000a, 11).

The newest conceptions and practices of management comprehension favour a leadership-type approach. Vision and mission are emphasized instead of management that focuses on planning. The focus is on anticipatory and fast management (Lönnqvist 1995, 34–35). The ability to anticipate is essential to the leader in all management environments, and the meaning of this ability increases as the level of management rises (Nissinen 2000a, 86). A leader who bases his or her management on images of the past will not succeed in today's fast tempo environment. For this part, the study of management must be firmly connected to those conceptions and visions that plumb future situations (Krogars 1997, 73).

Simultaneously, the future is unpredictable and predictable. Leadership and related decision-making ability are important success factors for every organization. Change has become the essence of management, so in order to survive and prosper in the future, a leader and his or her organization will have to perfect outside-in thinking skills: to relate information about developments in the external world to what is going on internally. The bottom line is whether change occurs as a series of crises, or if a leader uses foresight and anticipation to manage change in a calm, informed, and systematic manner (Ashley and Morrison 2001).

The adaptation of an organization is too often seen as reactive, in which case the organization changes only due to necessity, following change that was begun by others. Adjustment can also be the wise execution of an organization's own competitive strategy, so that its relationship to the environment can be described as proactive and self-motivated to change its operational environment. Good perception of the environment and fast use of one's own advantages create preconditions for success. (Lönnqvist 1995, 9.) It can be argued that the more important changes occur in the operational environment of organizations, the more interest is aimed at leadership and leaders. The question is about the management of change. (Krogars 1997, 60.)

In relation to artificial intelligence research, the closest tendency of psychology is cognitive psychology, which studies the intellectual activity of humans, such as perception, attention, thought, memory, problem solution, and reasoning. When human memory and learning are studied from the cognitive angle, the goal is to draw conclusions concerning human information processing, primarily by modelling the psychological activity of humans and the controlling of this activity under various conditions (Lonka 1993, 38–40). Computer science, artificial intelligence research, and cognitive science have taken advantage of knowledge about human thinking produced by psychology. The complexity of thinking means that there is no one right perspective to human thought (Saariluoma 1995, 15–16). Research on decision-making conducted within the framework of cognitive psychology has contributed to our understanding of how perceptual and cognitive operations affect decision-making. Much of the research on human decision-making, however, involves a single judgment in static environments under certain conditions. Cognitive approaches to decision-making are further limited by the fact that they usually ignore the impact of affective, motivational, and self-regulatory influences on how information is gathered, evaluated, integrated, and used. (Bandura 1998, 451.)

Numerous disciplinary areas have contributed to the development of decision support systems. These include computer science, which provides users with the database design and programming support tools needed in decision support system constructs. The field of management science and operation research has provided the theoretical framework in decision analysis that is necessary to design useful and relevant normative approaches to choice making, especially those that are concerned with systems analysis and model-based management. Background information from the areas of organisational behaviour, behavioural and cognitive science are needed for the design of effective systems for dialog generation and management. (Sage 1991, 2.)

Intelligent systems acting in the real world require the ability to make decisions under uncertainty using available evidence. Over the past decade, probabilistic networks have become the primary method for reasoning and acting under uncertainty. Probabilistic network applications of well-understood techniques are conditioning for incorporating new information and maximizing expected utility for decision-making. They take advantage of the causal structure of domain to allow a compact and natural representation of the joint probability distribution over the domain variables. (Binder *et al* 1997.)

Bayes' theorem is the basic tool for making inferences in probabilistic expert systems (Cowell *et al* 2003, 14). The Bayesian paradigm provides an elegant approach to pursue rational decisions under uncertainty. As its principal ingredient, the approach requires the decision-maker to evaluate his or her subjective probability model, possibly including a large number of variables. Once a model is built, various questions of inference and prediction can be answered from the unifying, decision theoretic perspective. (Koivisto 2004, 22.)

As far as this study is concerned, interesting decision problems are those for which such perfect information is not available, and it must take uncertainty into account as a major feature of the problem. The concern of research is with the logical process of anticipatory decision-making in situations of uncertainty.

This research outlines a process in anticipatory decision-making. This process is developed to respond to decision-making and risk problems that arose during the management process, which authorized only a limited observation of an environment to support anticipatory decision-making. It is an integrated approach that makes use of all applicable evidence and judgment in a disciplined, documented, and structured way to support anticipatory decision-making. This approach has allowed management to identify risk, assess the potential impacts of corrective action, and gain confidence that the end state will satisfy its mission requirements.

1.2 Contributions

This thesis is partly based on the following articles and reports. Summaries and the contribution of these theses are given with respect to context of this thesis. Information about these articles and reports are updated and reused.

1. Anticipatory Management and Constructivism. (Kuokkanen 2006a)
The aim of this article was to present the basis of model making for anticipatory management. In this article, presented principals should be taken into consideration when a management system is built up. Processes of anticipatory management have been clarified and based on these creative models (constructions), taking into consideration management (knowledge, decision-making, including risks, implementation), action, environment, and time.

2. The Basis for Anticipatory Decision-Making. (Kuokkanen 2004)
This research work has been prepared to present an outline of anticipatory management and decision-making in a changing environment, and to indicate the basis for anticipatory decision-making. Furthermore, the study focuses on the assessment of the effects of a dynamic environment, the factors of critical perception, and the preparation of the alternative in the anticipatory decision-making process. The main contribution of the study has been to develop a process for anticipatory decision-making that includes management, problem-solving, and the improvement of knowledge. The study also contributes to decision-making support by providing a description of anticipatory decision-making that is grounded on firm theoretical discussion by demonstrating the idea of anticipatory decision-making for the parallel version.

3. Data Modelling of an Action Environment for Information Warfare. (Kuokkanen 2006c)
This research paper has been prepared to present an outline of an action environment and to indicate the basis for modelling methods. Furthermore, this study produces action environment models for an anticipatory decision-making support system. Much of the research on human decision-making involves discrete judgments in static environments under no taxing conditions. Judgments under such circumstances may not provide a sufficient basis for developing either descriptive or normative models of decision-making in dynamic, naturalistic action environments. In this study, three types of action environment are differentiated: the turbulent, the dynamic, and the stable. For the modelling of the action environment, the four areas of interest are information, resources, liabilities, and environment. The main contribution of this study has been to develop a process for producing a model of an action environment that is useful for practical applications.

4. Risk Consequence Analysis as a Part of Anticipatory Decision-Making using a Bayesian Network. (Kuokkanen 2005)
An anticipatory decision-making process was developed to respond to decision-making and risk problems that arose during the management process, which authorized only a limited observation of an environment. This integrated approach has allowed management to identify risks, assess the potential impacts of corrective action, and gain confidence that the end item will satisfy its mission requirements. A process for anticipatory decision-making that includes risk management is supported by providing a Bayesian application.

5. Anticipatory Decision-Making Support Using a Bayesian Network. (Kuokkanen 2006b)
The changing Information Warfare environment requires that a decision-maker have effective processes to manage situations. This research paper presents an outline of anticipatory decision-making and indicates the usefulness of the Bayesian method for decision-making support. The Bayesian paradigm provides an elegant approach to pursue rational decisions in uncertain conditions. The main contribution of this constructive study has been to develop a network for time expanded anticipatory decision-making for actions of Information Warfare and Security in general.

The contribution of this thesis will be divided into theoretical and practical classes. The theoretical contribution includes the definitions and model of communicative and anticipatory decision-making. The main theoretical contribution of this study has been to develop a process for anticipatory decision-making that includes communication, leadership and management, problem-solving, and the improvement of knowledge. This study also contributes to decision-making support by providing an academic description of anticipatory decision-making that is grounded on firm theoretical discussion by demonstrating the idea of anticipatory decision-making for the parallel version. The theoretical contribution includes the definitions and model of Anticipatory Decision-making.

The practical contribution includes the Bayesian Decision Support Model, which is based on Bayesian networks. The main practical contributions of this research are two developed processes, one for communicative and anticipatory decision-making, and the other for producing a model of a Bayesian network for anticipatory decision-making. These models are tested successfully using a simulated environment and focusing on decision-making and risk consequences.

1.3 Structure of thesis

This thesis is divided into eight chapters and an appendix. The theoretical background is divided into four chapters, and the presentation of results into two chapters. The appendix summarizes the most essential definitions.

Chapter 1 states the purpose of the research in general, offers main results and gives an overview to the structure of the study.

Chapter 2 states the purpose of research, describes research problems and research methods. It also indicates related works and limitations of research.

Chapter 3 includes basic definitions and behaviours of an organisation, leadership and anticipatory management, and managerial communication. The chapter includes descriptions of the research environment and management processes formed. The chapter deals with decision-making from preparation, problem solving, searching for a solution, and both risk management and analysis. The end of the chapter examines the role of the significance of feedback and learning in the process of decision-making. This chapter explains the background to further research.

Chapter 4 inspects methods and principles that support decision-making and gives an outline of the research methods of qualitative and quantitative decision-making. This chapter includes suggestions for communication and a framework of anticipatory decision-making.

Chapter 5 presents the basis for the formation of a decision-making support application using Bayesian method. The chapter examines classification, Bayesian networks, influence diagrams, and the time critical dynamic network's use in the shown environment.

Chapter 6 presents the formation of a solution using Bayesian method. The chapter includes a model of environment behaviour and decision-making supporting intended model specifications. Finally, it will present a solution to the examined research problem.

Chapter 7 examines the usefulness of the prepared model in solving the problem under consideration, and presents the results of research.

Chapter 8 presents the conclusions of research and closes the study by briefly summarising the research.

Chapter 2

Definition of research problem

In this chapter, the research problem is defined and the research approach is given by methods and questions of research. The research process is reviewed and the limitations are discussed.

2.1 Purpose and questions of research

The purpose of this research is to draw up a clear construction of anticipatory and communicative decision-making, and successful implementation of a Bayesian application that can be used as an anticipatory communicative decision-making support system. This study is a decision-oriented and constructive research project, and it includes examples of simulated situations.

This study has the following objectives and research questions:

1. To outline the foundation and models of anticipatory decision-making, their basic assumptions, possibilities, and opportunities to support it. *"How to prepare for anticipatory decision-making and how to support it?"*
2. To find models of communication that support decision-making. *"How to support anticipatory decision-making with managerial communication in management processes?"*
3. To create a functional framework for anticipatory decision-making in a dynamic environment. *"What issues and processes are closely connected to an anticipatory decision-making support system?"*
4. To implement a Bayesian based application as an anticipatory decision-making support system in a dynamic environment. *"How will Bayesian method give support to anticipatory decision-making when based on inaccurate information?"*
5. To draw conclusions from and make recommendations about the model supporting and communicating anticipatory decision-making.

2.2 Strategy and methods of research

Science is a systematic and rational acquisition of new information. This conception of the objective of science is called cognitivism. The opposite view, according to which scientific problems are not questions of information but of decision-making, is called behaviourism. This line of thinking, according to which the "results" of science are not declarative sentences but recommendations of action proposed for solving problems, has gained support, especially after the Second World War. The exact methods of science (operations research, system theory, game and decision theory, linear programming methods, statistics, computer simulation) have been systematically used in both the military and civilian sector (Haaparanta and Niiniluoto 1998, 9–10).

The study of leadership does not have one single paradigm or research tradition. Instead, research must take advantage of the latest knowledge and the most appropriate methods across the field of traditional science. Even the most progressive research can be futile to an organization if the results cannot be used in further research as well as in practical life. (Nissinen 2000a, 16.) Traditionally, communication research has been based on Claude Shannon's approach to the process model, which observes the parts in the process as well as the relationships between them. In this context, communication is the information exchanged between sender and receiver. Another approach is semiotic models, in which the main issue is to pay attention to delivered senses. In the semiotic models approach, communication is the process by which people use messages to create, update, and handle senses. (Åberg 2000, 19–20.)

As the basis for further methodological discussion about the different approaches to management research in Finland, the classification by Neilimo and Näsi (1980, 66–67) is often used. It consists of the following four approaches (Table 1):

– The *conceptual approach*, which is a traditional descriptive approach with a positivist view. It aims to produce exact conceptual systems mainly by the use of reasoning.
– The *nomothetical approach* is also linked to the positivist research tradition, and aims to establish new causal laws and is explanatory by nature. The approach is descriptive and highly empirical.
– The *decision-oriented approach* is based on mathematics and logic, and it is used to develop methods of solving problems. The approach is theoretical and characteristic of normative management science research.
– The *action-oriented approach* is hermeneutic and aims at understanding processes while taking the human aspect into account. This approach is empirical and at the same time both descriptive and normative.

Table 1. Different approaches to leadership research (Neilimo and Näsi 1980, 67) and the approach of this study

The conceptual approach	The nomothetical approach	The decision-oriented approach	The action-oriented approach	This study
Intends to construct systems of conceptions	Task is to explain causal connections	Task is to develop problem solution methods	Intention is to understand, sometimes changing goals	*Firstly, the intention is to construct systems of conceptions and secondly, to develop problem solving methods*
Background in previous research of concept analysis or empirical research	Background in positivism	Background in micro theory, game theory and positivism	Background often in teleological explanation	*Background in positivism supported by previous research of concept analysis*
Uses the method of the thought, New comprehensions with analysis and synthesis	Scientific ideal close to physical science, behavioural science	Scientific ideal adapts to logic and mathematics	Scientific ideal Aristotelian, activity science, anthropology	*Scientific ideal adapts to logic and mathematics and partly behavioural science*
Testing is not real verification, but mainly argumentation	Empirical part has a significant role	Empirical part commonly related to application example	Empiria included usually through few key individuals	*Empirical part related to application example, i.e. Bayesian network*
Research can concentrate on facts, values and norms	Research includes plenty of methodological regulations	Progress follows loosely the axiomatic principle	No stabilized set of methodological regulations	*Progress follows loosely the axiomatic principle*
Research results could be both statements and recommendations	Research results comprised of mainly legal rules	Research results are solutions to explicit problem	Result often appears as concept systems at different levels, ”languages”	*Research results are both statements and recommenda-tions and provi-de solutions to presented problems*

A research approach that uses the methodology of decision-making aspires to mostly develop methods based on mathematics that can be used to assist decision-making. The results are often mathematical or computer science models that give a recommendation for the decision, or that can be used to study the effects of the decision. In a study, material is made up of earlier information on dependency. By combining them with the help of logic, models that describe the phenomenon being studied are formed. This can be considered a reasoning deduction. The empirical approach is used to test how well the solution works in one or more cases. The value of scientific contribution is assessed on the basis of the usefulness of the solution. The benefit can be either a solution to a previously unsolved problem, or a more reliable, faster, or otherwise more economical solution. On the other hand, the value of the contribution depends on whether the development of the decision-making method can be considered creative in a scientific sense, instead of an obvious routine solution. (Olkkonen 1993, 70–71.)

When considering the *constructive approach*, as Kasanen, Lukka and Siitonen (1991, 302) define it, similarities to both decision- and action-oriented approaches are found. The constructive approach is normative by nature and also mainly empirical. The above-mentioned approaches and the constructive approach are located in Figure 1, according to their properties measured along two axes: theoretical-empirical and descriptive-normative.

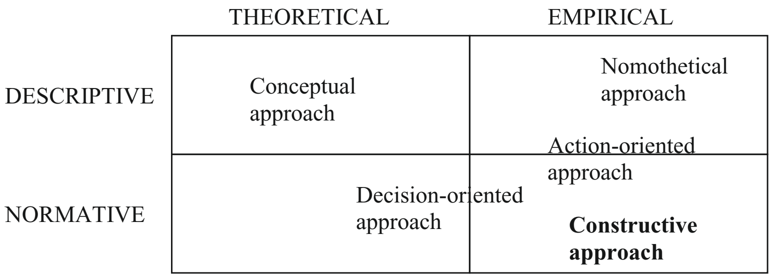

Figure 1. Classifications of research approaches (Kasanen *et al* 1991, 317)

The approach of this study is constructive in the sense described by Kasanen *et al* (1991, 306). The elements of constructive research are practical relevance, practical functioning, theory connection, and theoretical contribution. An essential part of the constructive approach is to join the problem and its solution with theoretical knowledge. The novelty and actual workability of the solution have to be demonstrated as well.

This study concentrates on analyzing the readiness for decision-making, the basis of actual decision-making, its effects in a dynamic environment, and the background of research based on differentiated theories of leadership and differentiated comprehension of communication. A deeper approach for model creation is studied using theories of decision-making and communication methods, as well as theories of Decision Support and Bayesian methods. These theories give a basis for more detailed anticipatory decision-making and communication process analysis. The framework of the study and its information basis are presented in Figure 2.

The multidimensional information base related to leadership and supported decision-making consists of:
– the operational environment, in which leading and decision-making happen
– communication, in which leadership activity and decision-making will be published
– leadership behaviour, or how the leader actually functions in the surrounding environment
– decision-making and how decisions are made in the operational environment
– support to decision-making and how is it solved by Bayesian method

The grid forming the information base in Figure 2 is to be interpreted so that the five previously mentioned factors are simultaneously valid. The combination of these five factors always forms the leadership situation in question. This study uses process models to logically describe things and the connections between them.

In this research, these four issues have been defined and limited as follows:
– the environment behaves dynamically, sometimes in chaos
– the type of communication, based on the decision-making situation, is a managerial communication
– leadership behaviour follows the new paradigm of leadership
– decision-making follows the anticipatory decision-making process

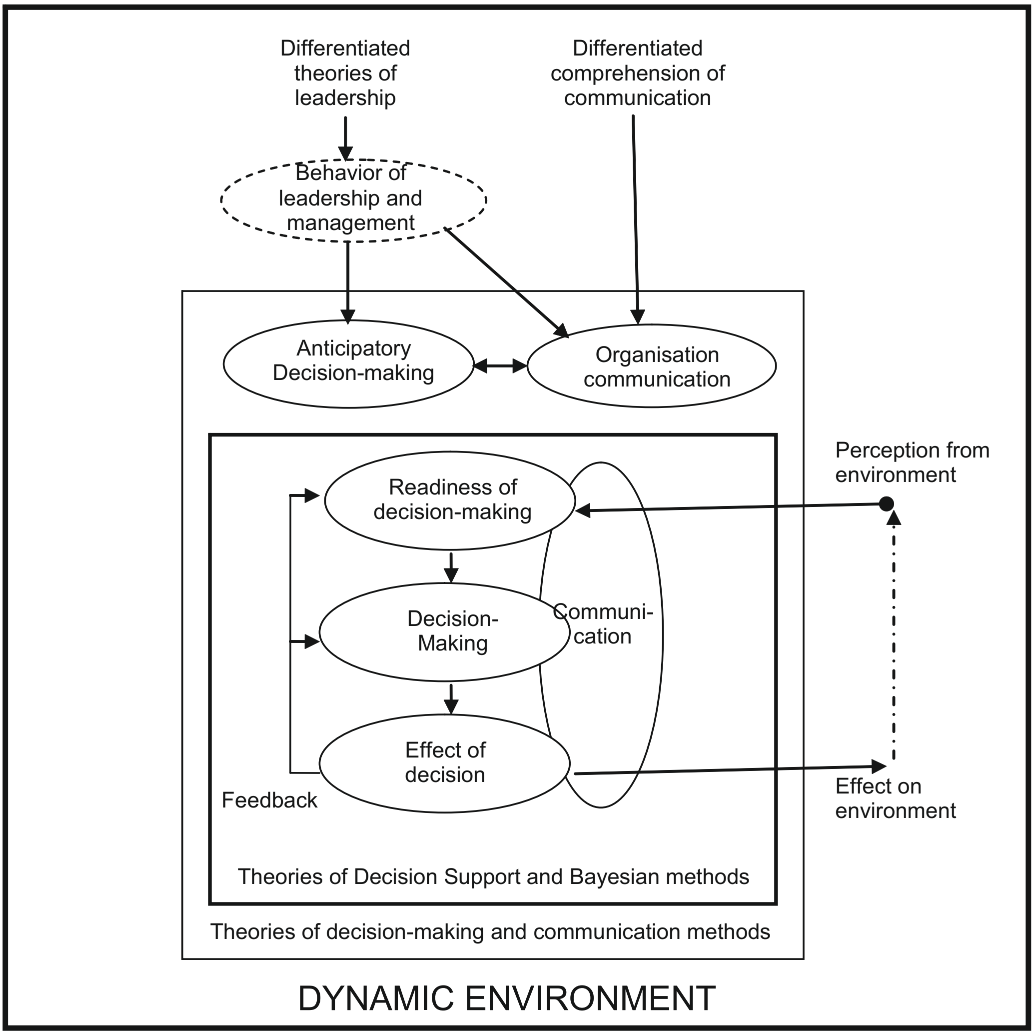

Figure 2. The theoretical framework of communicative and anticipatory decision-making and the basis of research knowledge

2.3 Research process

According to Kasanen *et al* (1991, 306), the characteristics of the constructive approach can be presented as a research process with the following phases:

1. Find a practically relevant problem, which also has research potential.
2. Obtain a general and comprehensive understanding of the topic.
3. Innovate, i.e., construct a solution idea.
4. Demonstrate that the solution works.
5. Show the theoretical connections and the research contribution of the solution concept.
6. Examine the scope of applicability of the solution.

The structure of this research contains all the above listed elements, although the order is different and some of the items are overlapping. A more detailed evaluation of the fulfilment of these requirements is given in the concluding chapter. According to the decision-oriented approach and the constructive approach, the research process has followed a structure, which is shown in Figure 3. This process has also formulated the structure of this thesis and produced publications by the author concerning this research.

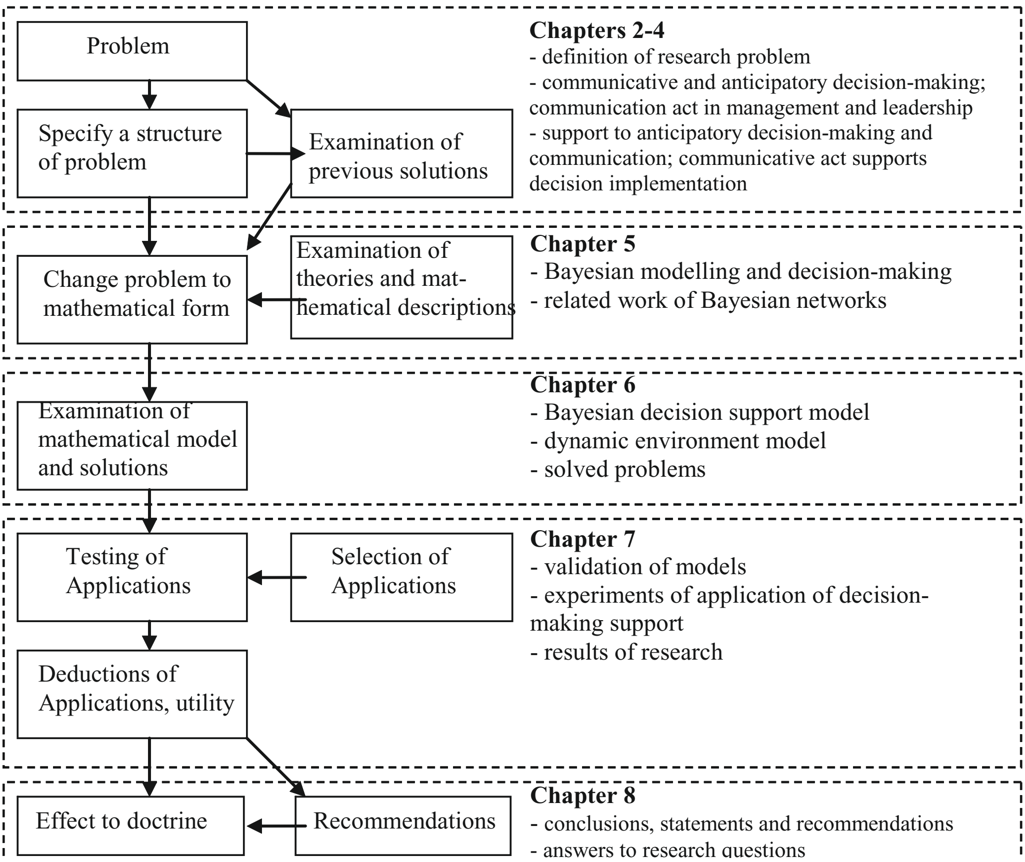

Figure 3. Connections between the research approach and the process and structure of this study.

Literature analysis is the method typically used in research that emphasizes theory. It cannot be defined as a single method with clear criteria of execution. Literature analysis has been a particularly useful way to review what earlier research reports and scientific articles have to say about the research topic in question. Literature analysis produces a good overall picture of the phenomenon being studied. Emphasis has been on the psychology of leadership, creative problem-solving, and chaos methods. In this study, the hermeneutical model of thinking has been used, and so the preliminary understanding of the topic has also guided the process of analysis.

The key sources in defining anticipatory decision-making and creating the process have been: “Viestinnän johtaminen” by Åberg (2000), ”Organisaation kaaos vai kaaoksen organisaatio? Dynaamisen organisaatioviestinnän teoria.” and “Johtamisen kaaos vai kaaoksen johtaminen?”, both by Aula (1999; 2000), and also ”Information Management for the Intelligent Organization” and ”The Knowing Organization”, both by Choo (1998; 2000). In addition, at communication domain, “Strategiaviestintä” by Hämäläinen and Maula (2004), ”Organisaation strategian toteuttaminen”, by Mantere *et al* (2006), and “Johtamisviestintää!”, by Åberg, L. (2006) have also been used. In addition, at management area, ”An Introduction to Management Science” by Andersson-Sweeney-Williams (1997), Lönnqvist’s (1995) ”Johtajan ja johtamisen psykologiasta” and Saariluoma’s (1995) ”Taitavan ajattelun psykologia” have also been used.

Bayesian method’s main reference has been Pearl’s (1988) “Probabilistic Reasoning in Intelligent Systems”. This book was the most influential and widely cited book in the development of belief networks. It is excellent foundational book and has a very mathematical and theoretical orientation. Jaynes’ (2003) “Probability Theory, The Logic of Science”, is also a useful book for basis of probability theory.

In his doctoral dissertation “Intelligent Leadership and Leadership Competencies – Developing a leadership framework for intelligent organizations”, Sydänmaanlakka (2003) has developed a leadership framework for intelligent organizations. This was done by analysing the future working environment of managers, leadership as a phenomenon and as a process, and leadership competencies. Based on this framework, he has developed an intelligent leadership model as a process, not a position. Future leaders are living in a turbulent and chaotic environment, in which the real power to act comes from recognizing patterns of change, and sensing and seizing windows of opportunity.

Nikander (2002), in his doctoral dissertation, “Early Warnings, a Phenomenon in Project Management”, examines the background of Ansoff’s theory, the way in which project theories treat project problems, the causes of problems, and possible early warnings. This study designs a fundamental model for the utilization of the early warnings phenomenon. This model can be used to identify early warnings. The study provides project management and project risk management theories with additional information about the early warnings phenomenon, which has not been extensively studied, but which is widely known among project management specialists.

Chapter 3

Communicative and Anticipatory Decision-Making

This part of the study will first discuss the knowing organisation and organisational decision-making. Second, this chapter includes a short introduction to new leadership and management. A managerial communication in management and leadership is presented as well. Third, preparation to decision-making is shortly illustrated. Fourth, main decision-making is introduced by evaluation of alternatives and timing. Fifth, feedback and learning in process are discussed. Lastly, it will define a concept of anticipatory management processes. This chapter gives the basis and the environmental framework to further research.

3.1 The knowing organisation and models of organisational decision-making

The knowing organisation possesses information and knowledge that confer a special advantage, allowing it to manoeuvre with intelligence, creativity, and occasional cunning. Choo (1998, xi) has defined the knowing organisation as follows:

> "The knowing organisation is well prepared to sustain its growth and development in a dynamic environment. By sensing and understanding its environment, the knowing organisation is able to prepare for adaptation early. By marshalling the skills and expertise of its members, the knowing organisation is able to engage in continuous learning and innovation. By applying learned decision rules and routines, the knowing organisation is primed to take timely, purposive action. At the heart of the knowing organisation is its management of the information processes that underpin sense making, knowledge building, and decision-making."

To fulfil tasks or achieve goals, an organisation uses information. Current thinking in management and organisation theory emphasizes three distinct arenas in which the creation and use of information play a strategic role in determining an organisation's capacity to grow and adapt. These arenas are as follows (Choo 1998, 1–2):

1. The organisation uses information to make sense of changes and developments in its external dynamic and uncertain environment, where messages and signals about events and trends are invariably ambiguous and subject to multiple interpretations. The goals of sense making are for an organisation's members to construct a shared understanding of what the organisation is and what it is doing, and to ensure that the organisation adapts and continues to thrive in a dynamic environment.
2. Strategic information use is when organisations create, organise, and process information in order to generate new knowledge through organisational learning.
3. Strategic information use is when organisations search for and evaluate information in order to make important decisions. In theory, this choice is to be made rationally, based on complete information, feasible alternatives, probable outcomes, and the values of these outcomes to the organisation.

Choo (1998, 24–25) shows how the three modes of information use complement each other by supplying some of the missing pieces necessary for each mode to function. *Sense making* constructs meaning and so expresses what is vital to the organisation and its members. *Knowledge creating* generates new innovations and competences that broaden the horizon of choice. In *choice making*, decision-makers are channelled by routines, rules, and personal heuristics that both simplify and legitimise their action.

Choo (1998, 170) presents and compares four important models of the organisational decision-making process. The *rational model* (developed initially by March and Simon 1993, and Cyert and March 1992) conceptualises decision-making as goal directed and problem driven, and choice behaviour as regulated by rules and routines, so that an organisation acts in a manner that is intended and procedurally rational. The *process model* (exemplified by the work of Mintzberg, Raisinghani, and Théorêt 1976) elucidates the phases and cycles that give structure to apparently complex and dynamic decision-making activities. The *political model* (developed by Allison 1971) sees politics as the mechanism of decision choice when different players occupy different stands and exercise different amounts of influence, so that decisions are less the result of rational choice than the pulling and hauling that is politics. The *anarchic model* is like the garbage can model (proposed by Cohen, March, and Olsen 1972), in which organisations are likened to garbage cans where problems and solutions are dumped by participants, and decisions are the outcomes of the meeting of independent streams of problems, solutions, participants, and choice situations.

Whichever the decision mode is, the organisational environment of decision-making is defined by at least two properties: the structure and clarity of organisational goals that impinge on preferences and choices, and the uncertainty or amount of information about the methods and processes by which tasks are to be accomplished and goals are to be attained. Goals may be fuzzy or clear, and organisational groups may disagree about their relative importance. There is, therefore, a goal ambiguity or conflict about what organisational goals to pursue (political or anarchy models). Uncertainty may arise because organisational tasks or problems are technically complex, and there is not enough detailed information about cause-effect relationships or appropriate approaches to be adopted. There is, therefore, technical uncertainty about how goals and objectives are to be achieved (process or anarchy models).

Organisational decision-making requires information to reduce uncertainty in at least three ways. Firstly, information is needed to frame a choice situation. Secondly, information is needed to define preferences and to select rules. Multiple goals and interests are clarified, reconciled, and expressed as choice criteria. Thirdly, information is needed about viable alternatives and their projected outcomes. In some modes of decision-making, a great part of the information seeking effort is on identifying, developing, and evaluating alternative courses of action. Information needs then depend on whether alternatives already exist, whether existing solutions may be customised or modified, or whether new solutions have to be discovered. A summary of information needs in decision-making is presented in Table 2.

Organisations are networks of decisions, decisions makers, and decision-making. Decisions result in commitment to courses of action. A completely rational decision would require information beyond the capability of the organisation to collect, and information processing beyond the capacity of humans to execute. The knowing organisation is effective because it continually evolves with its changing environment, refreshes its knowledge assets, and practises vigilant information processing in its decision-making.

Table 2. Information needs, seeking, and use in decision-making (Choo 1998, 190)

	Information needs	Information seeking	Information use
Decision-making	* determine problem frame and boundaries * clarify preferences and rule appropriateness * information about alternatives, outcomes, preferences	* guided by heuristics, habits * search is problem driven * satisfying criteria	* limitations in human information processing * structured by routines and rules * many issues compete for attention
Cognitive needs	* phases of decision process: intelligence, design, choice, review * identification and development needs	* multiple managerial decision roles * high-velocity decision-making	* cognitive simplifications and biases * selective information processing
Affective responses	* stress due to complexity, risk, multiple interests, aspirations * affective factors in problem formulation	* conflict model of decision-making: unconflicted adherence or change, defensive avoidance, hypervigilance, vigilance	* pressure to conform in group think * over commitment in escalation situations
Situational dimensions	* programmed and non programmed decisions * tactics to frame decision problems	* types of decision processes: sporadic, fluid, and constricted * structure, incentives, and information access	* information-handling rules: routing rules and filtering rules * uncertainty absorption

3.2 Managerial communication

3.2.1 The principles of new leadership and management

In management operations today, change is part of everyday operations. Leadership and management mean the responsible use of resources, planning that ensures that efforts are directed at the agreed target, as well as implementation of these plans in practice. Leadership and management are always about providing direction and directing resources. The future is emphasised, as is the anticipation of procedures. (Åberg 2006, 63.)

Leadership is the directing and control of change that literature on management theory has aspired to describe, by adding to it the conception of the best methods to control change that have prevailed at different times. In addition to relativity, the part of leadership in the control of change is also closely connected to time and place. Leadership is seldom self-intentional; in most cases leadership aspires to improve the organization's performance. (Krogars 1997, 61.) From this viewpoint, leadership as a concept has often been understood as a set of leader-related means that, when successful, lead to the desired result (Krogars 1998, 28). It is essential to develop the leader's ability to take advantage of visions in leadership. The key requirements of the use of visions are analysis of an organization's operational environment and opportunities, and the ability to convey the vision so that people commit to it and receive new personal motivation from the vision (Lönnqvist 1995, 34).

Sydänmaanlakka (2003, 11) has defined leadership as follows:

> "Intelligent leadership is a dialogue between leader(s) and followers where they try to influence each other in a certain situation in order to achieve shared vision (purpose) and objectives effectively. This process will take place in a certain team and organization in which the same values and culture are shared. The macro environment – industry and society – also affects this process."

Sydänmaanlakka (2003, 72) has tried to summarize reasons for the need for new approaches as follows:

1. In practice, the models used are now old and were developed mainly during the sixties and seventies. The last true invention may have been the transformational leadership developed by Burns.
2. The working environment of leaders has changed dramatically during the last twenty years, but we are still using approaches developed for industrial organizations.
3. The paradigm of science has also changed; the constructivist paradigm is replacing the behaviouristic paradigm. Also quantum physics, self-organizing systems, and chaos theory bring in interesting perspectives to leadership.
4. A move should be made from "one right approach" to several right approaches and perspectives; in an attempt to integrate the best features of old approaches, and even to use those parts that are still valid.

The basic function of leadership is to unite the individual objectives of the leader and subordinates in order to achieve a higher objective or vision. This thought, therefore, includes the possibility that people do not have to agree on everything, but the vision and direction of activity have to unite individuals (Burns, 1979). The vision is an ideal that presents the future and the long-term goal, and helps to evaluate where the organization is in relation to its objective. When functioning in a constantly changing environment, the vision must be continuously adapted to the environment and new conditions (Servan-Schreiber 1990). The construction of the vision needs a functional strategy that states how the objective can be reached. Alternatives are important in situations in which development turns out to be more positive or negative than expected (Krogars 2000, 89).

The leader's task is to transmit and move information. Moving from one situation to another tests the leader's ability to adapt (Lönnqvist 1995, 75). A leader who cares about efficiency has to limit, control, and direct the behaviour of others. The leader must possess more information, abilities, and good ideas than his subordinates or those who are influenced by him (Eskola 1990, 123). People's beliefs about their efficacy influence how they construe situations and types of anticipatory scenarios. Those who have a high sense of efficacy view situations as presenting realizable opportunities. They visualize success scenarios that provide positive guides for performance. (Bandura 1998, 116.)

Burn's main idea is to divide leadership into two forms. *Transactional* leadership is based on reciprocal activity, in which a leader approaches a subordinate in order to exchange something, like a salary for work. In transactional leadership, it is essential that the leader attempt to achieve certain goals by influencing his or her subordinates, irrespective of the objectives of the subordinates. In *transformational* leadership, a leader recognises and exploits the needs and demands of potential subordinates, aims to recognise the motives of his or her subordinates, fulfils their needs at increasingly higher levels, and thus makes the subordinates commit themselves comprehensively. (Nissinen 2001, 66.)

Research of the phenomenon of Burn's excellent leadership behaviour has been produced by several competitive schools. As will be shortly introduced, these schools are divided into three different types: contingency theories of effective leadership, charismatic leadership, and transformational leadership. After considering these three schools, new leadership by visionary management will be introduced.

Contingency theories of effective leadership

Yukl (1990, 265–288) has researched and introduced six contingency theories that prescribe different patterns of leader behaviour traits for different situations. The *path-goal theory* of leadership examines how aspects of leader behaviour influence subordinate satisfaction and motivation. In general, leaders motivate subordinates by influencing their perceptions of the likely consequences of different levels of effort. If subordinates believe that valued outcomes can be attained only by making a serious effort, and that such an effort will be successful, then they are likely to make the effort. The *situational leadership theory* prescribes a different style of leadership behaviour, which depends on the confidence and skill of a subordinate in relation to a task. A leader is encouraged to be flexible in behaviour and responsive to changes in subordinate maturity. In addition, the theory describes how the leader may be able to increase subordinate maturity over a longer period of time. The *theory of leadership substitution* identifies aspects of the situation that make leadership behaviour redundant or irrelevant. Various characteristics of the subordinates, tasks, and organisation serve as substitutes for leadership and/or neutralizers of its effects. Substitutes make some types of behaviour by the leader unnecessary and redundant, whereas neutralizers are constraints that prevent the leader from doing anything to improve the prevailing conditions. The *multiple linkage models* describe how a leader can influence intervening variables to improve group effectiveness. The performance of a group or organisational sub-unit is highest when members have a high task skill and motivation, they are efficiently organised, there is a high level of member cooperation, adequate resources are available, and unit activities are coordinated with those of interdependent units. The *LPC* (least preferred co-worker) *contingency model* deals with the moderating influence of three situational variables on the relationship between a leader trait (LPC) and subordinate performance. The situational variables are leader-member relations, leader position power, and task structure. Leaders with high LPC scores are more effective in moderately favourable situations, whereas leaders with low LPC scores are more favourable in situations that are either very favourable or very unfavourable. *Cognitive resources theory* examines the conditions under which cognitive resources such as intelligence and experience are related to group performance. Situational variables, such as interpersonal stress, group support, and task complexity, determine whether the leader's intelligence and experience enhance group performance. Directive leader behaviour is an intervening variable used to explain how the leader's cognitive resources affect group performance.

According to Yukl, none of the situational contingency theories have been adequately tested. Each theory provides some insights into reasons for leadership effectiveness, but each theory has conceptual weaknesses that limit its utility.

Charismatic leadership

Charisma appears to be an attribution resulting from the interactive process between leader and followers. Some leader traits and skills, such as self-confidence, strong convictions, poise, speaking ability, and dramatic flair increase the likelihood of attributed charisma, but more important is a context that makes a leader's vision especially relevant to follower needs. Commitment is likely to be greater if a leader articulates a compelling vision and increases follower confidence about achieving it.

Charismatic leaders can have a tremendous influence on an organisation, but the consequences are not always beneficial. Many entrepreneurs who establish a prosperous company are tyrants and egomaniacs whose actions sow the seeds for the eventual downfall of their company. The personalised power orientation of these charismatic leaders makes them insensitive, manipulative, domineering, impulsive, and defensive. They emphasize devotion to themselves rather than to ideological goals, which are used only as a means to manipulate followers.

Theories of charismatic leadership provide new insights into the reasons for the success or failure of leaders. However, these theories are conceptualised primarily at the dyadic or group analysis level (Yukl 1990, 319).

Transformational leadership

According to Burns (1979), transformational leaders seek to raise the consciousness of followers by appealing to higher ideals and moral values. He contrasts transformational leadership with transactional leadership, in which followers are motivated by appealing to their self-interest. He also differentiates transformational leadership from influence based on bureaucratic authority, which emphasizes legitimate power and respect for rules and tradition.

Transformational leaders make followers more aware of the importance and value of task outcomes, activate their higher-order needs, and induce followers to transcend self-interest for the sake of the organisation. As a result of this influence, followers feel trust and respect toward the leader, and they are motivated to do more than they originally expected to do. Transformational effects are achieved by using four types of leadership behaviour: individualized consideration, intellectual stimulation, idealized influence, and inspirational motivation (Yukl 1990, 325–326).

An important source of insight into the dynamics of transformational leadership is provided by research on and theory of organisational culture. The basic assumptions and beliefs shared by members of a group or organisation are learned responses to problems of survival in the external environment and problems of internal integration. Culture is influenced by several aspects of a leader's behaviour, including examples set by the leader, what the leader attends to, how the leader reacts to crises, how the leader allocates rewards, and how the leader makes personnel decisions. In general, transformational leaders formulate a vision, develop commitment to it among internal and external stakeholders, implement strategies to accomplish the vision, and embed new values and assumptions into the culture and structure of an organisation.

Visionary management

Opportunistic, strategic, and visionary management are related to each other in an intriguing way. Opportunistic behaviour is to always react in the best possible way to the situation at hand. It is also equal to achieving immediate results: getting orders, supplying customers, making money, and creating cash flow. Because the world changes, strategic management is needed: managers prepare for changes, they look for new constellations, for better ways to reallocate their resources and position the company in the predictable market. The costs incurred in the reallocation process must be balanced against the profit increase and growth from the more efficient opportunistic behaviour that strategic management facilitates. Strategic management decisions are connected to anticipated changes in the business environment, so they response reactively.

In contrast to the two previous forms of management, visionary management is always proactive. Visionary management creates a clear vision to renew strategic options and position the company in the markets of the future. Visionary management is the leadership's response to the fact that the world and the business environment have become more and more complex. Since the 1970s the term *turbulent environment* has been frequently used. A reaction to turbulence has been the emergence of scenario approaches. But in the 1990s, new means and new concepts of management were needed to cope with the new environment and unpredictable changes. (Malaska and Holstius 1999.)

It has already become a precondition for good decision-making to take increasing uncertainty into account. Managers should take advantage of the fact that, at present and in the future, these profound changes in themselves offer more new opportunities than ever before. The task of visionary management is precisely to come to grips with these new future opportunities. The benefits of visionary management will always be realized with successful opportunistic decisions. The key concept in visionary management is the vision itself. A vision is an entrepreneurial perception which reveals and points to something new, and which sees beyond what is already being utilized to what is emerging and becoming invented (Malaska and Holstius 1999).

Management vs leadership

Traditionally management and leadership are differentiated. They are two paths to leading, which have many similarities, but also many differences. Both involve influencing and working with people, and effective goal accomplishment. Management is task-oriented and leadership is people-oriented. Management can focus on different areas of organization: yourself (self-leadership), people (leadership), things and processes (management), technology (technology management), market (market management), and strategy (strategic management) (Sydänmaanlakka 2003, 11).

The concept of management emphasizes continuity and order, whereas leadership is connected to the realization of change (Lönnqvist 1995, 34):

1) management brings forth planning and resource assessment in short-term activity, while leadership directs activity by creating visions and developing strategies to achieve them
2) management progresses according to plan by organizing activity with the help of structures and by manning functions correctly; leadership, on the other hand, attempts to convey the vision so that goals are understood and that a commitment is made to them
3) the control of operations management emphasizes the follow-up of the realization of plans and aspires to the solving of hindrance-forming problems; leadership emphasizes motivation and inspiration as ways to reach goals despite hindrances

The general process of planning, decision-making, and executing is the level of activities usually spoken of as management. Decision-making is the most central concept of management processes. The management of tasks and activities related to a management process requires analytical handling of information, logical assessment of a situation, efficient decision-making and good control of the use of time. Efficient decision-making is based on developed conceptual thinking and a preparation process in which thinking is creative and intuitive (Nissinen 2001, 119–120).

3.2.2 Communication in management and leadership

Managerial communication can be understood as "*sharing of the messages, ideas or attitudes within an organisation between or among managers and associates. The aim is to share the meanings in order to achieve a desired outcome*." Managerial communication can be studied as a type of communication activities (meetings, negotiations) managers are involved in, or focus on the kind of messages managers send or receive, and the people they communicate with. Managers engage in two kinds of communication: interpersonal communication refers to a situation in which two people or a small group exchange messages; organisational communication is the process by which managers transmit information to and receive it from large groups. (Vihakara 2006, 19.)

Management-centred communication is most common in organisations that have put thought into communication and its significance, and created guidelines and strategies for communication. Managers have to decide, on a daily basis, how to spend their time in order to best support an organisation's operations. Among other things, managers are expected to clarify future desired states and explain plans and decisions to employees. Proactive communication means preparing for situations in advance and using communication as a means of controlling change. The purpose of proactive communication is to gain an understanding within an organisation of what it is trying to achieve in the operational environment, and why. (Juholin 1999, 200.)

There is always a human being at an organisation's core, who by thinking and acting, has an impact on how the organisation relates to itself and its environment. Institutional communication situations are often typical integrative communication events. Participants in an organisation's institutional communication events are invited based on their status, hierarchical position, and the organisation's formal rules and practices in order to make various choices (Stacey 1991). Communication processes are built from the top down, and communication takes on a controlled, regular, and literal form. An organisation's spontaneous communication situations are usually unofficial and informal, making it possible to take advantage of dissipative communication.

Interaction with the environment is highly complex, and in order for an organisation to work efficiently, it must concentrate on the key areas of strategic planning, i.e., formulating visions, managing change, and scanning the environment (Stacey 1991). Determining and communicating strategic direction is seen as the most important task of an organisation's management. Management is expected to have a vision of the future and to make the correct choices and decisions to secure an organisation's success. Communication enables the interactive building of information and understanding; management gets feedback from near the customer interface, and subordinate personnel feel that they can influence the strategy's content and the success of its implementation (Mantere et al 2006, 18). Implementing strategy is management in which people are made to work efficiently and purposefully in order to achieve an organisation's goal (Mantere et al 2006, 191).

Many organisations find it difficult to communicate their strategies. Concepts that are clear to all personnel must be agreed upon when planning strategy. Merely communicating strategic decisions does not guarantee that issues will be understood or internalised. In order for people to be able to interpret and understand difficult and abstract issues, they must receive support, for example, in discussions in small groups (Mantere et al 2006, 36–39).

Top management roles are linked across levels, since they all involve the acquisition and exchange of information related to environmental change and an organisation's response to it. Middle management roles focus on communicating information between the operating and top levels of management. Indeed, there are elements of decision-making, communicating and reacting at every level, and there is often considerable overlap. The substance of each role is significant, because it represents the knowledge and information that managers accumulate and communicate in the renewal process. (Floyd and Lane 2000.)

When middle managers provide top management information as a basis for strategic decision-making, feedback assures that top-down strategic plans are rooted in past experience. A key element is an increased understanding of whether past work efforts have been successful. The expectation to facilitate adaptability may allow middle managers a sense of involvement in strategy, in terms of having something to contribute. It may also involve the further enabling aspect of being able to represent one's subordinates. When top managers invite and expect middle managers to participate in planning, middle managers gain more control over the future. (Mantere 2007.)

In the case of an organization engaged in a top-down mode of planning-implementation, it can be argued that an atmosphere in which top managers respect the ability of middle managers as implementers, while middle managers respect top managers as planners and visionaries, enables both planning and implementation in the strategy process. From the dialogical viewpoint, the key is to regard neither task as 'mechanical' or 'replaceable' by nature, but to acknowledge that both depend on each other. (Mantere 2007.)

Bersona and Avolio (2004) found transformational leadership to be associated with careful listener, careful transmitter, and open communications styles. Their exploratory analyses of these research questions produced links between leaders' styles and communication skills and their ability to increase followers' awareness of organizational goals. By being open to others' ideas and comments, especially during times of uncertainty and turbulence, transformational leaders may be better able to determine how well followers understand the strategic goals of an organization.

If there are difficulties putting a strategy into practice within an organisation, it may be that the strategy process has but little significance to supervisors' everyday work. Reasons for this could be their inability to take advantage of the process in their own work, lack of understanding of the process's benefits, unwillingness to participate in the process, or the states of processes are not functioning in a process-like fashion. A strategy process works when it has significance to the members and groups of an organisation. Functionality can be improved by striving for significance, by adding an interpretative element to the process, and developing an organisation's shared process practices as a whole. (Mantere et al 2006, 123.)

When the strategy process is being developed, special attention must be paid to communication. Ensuring efficient communication (e.g., through a communication plan) guarantees that information about good things reaches the target audience and is sufficient and reiterated as necessary. Interaction between management and employees gains a special role when planning and implementing strategy. Any observations and feedback prompted by the interpretation of implementation deserve a response. (Mantere et al 2006, 145.)

A single employee (including the decision-maker) can implement a strategy actively and proactively only if he or she knows and understands the main points of the organisation's strategy and his or her own role in the strategy's implementation. The strategy-based organisational change is explained and its benefits are pointed out by means of communication. Work-related choices are easier when decision-making is based on the organisation's strategy. It's not enough to merely inform people. In order for strategy to be implemented, communication must be bi-directional. By collecting feedback, the employee's views and experiences can be taken advantage of and new information created that can be used to change the strategy as required. Feedback can have a direct or indirect impact on the choice of strategy and its implementation, and consequently on the entire organisation's future (Hamäläinen and Maula 2004, 34–41).

In strategy communication, a supervisor holds a significant position. Therefore, supervisors must have developed communication skills. It is particularly important to have the know-how to pass on a message without altering its content. A supervisor must personally understand an organisation's strategy sufficiently well. Regular meetings between managers and supervisors support and increase a supervisors' readiness to further communicate strategy in their own groups (Hamäläinen and Maula 2004, 108). The ability to successfully communicate change has become an important skill for leaders in all organizations (Grandwell 2004, 161).

A recurring element is the use of oral communication to motivate and arouse followers' emotions. Rafferty and Griffin (2004) suggest that inspirational communication is a distinct construct, defined as: "*The expression of positive and encouraging messages about the organization, and statements that build motivation and confidence*". Expressing positive and encouraging messages about an organization was positively associated with emotional attachment to a firm, individuals' confidence in their capacity to carry out a range of proactive and integrative tasks, and the extent to which people voluntarily helped others with or prevented the occurrence of work-related problems. Inspirational communication seems to be particularly important when expressing a vision for the future. In the absence of encouragement and confidence building efforts, articulating a vision may have a neutral or even a negative influence on employees. (Rafferty and Griffin 2004.)

When the anticipatory decision-making process is visible and continuous, the implementing party has a better understanding of how the decision relates to the greater whole. From the decision-maker's point of view, a functional decision-making process is a tool for directing implementation in order to attain a greater whole, receiving feedback, and tracking the development of operations and the implementation of a decision. In a process-level solution, a central element is the connection between the decision and its implementation. This involves a degree of interpretation on the implementing party's part.

3.3 Preparatory actions for decision-making

3.3.1 Problem-solving and creation of alternatives

Research on psychological thought is divided into three basis types: problem-solving, reasoning, and decision-making. Problem-solving is the thought process that appears in problem situations. The individual strives towards the goal, but is not able to reach it with the immediate means available. The problem situation is the initial situation, and the solution process progresses as a series of transformations in which the initial situation is converted into a solution (Saariluoma 1995, 101).

To a large extent, problem-solving is based on learned and task-orientated solution models that can be combined to form new entities during the solution's construction process. When one has learned some method, he or she has also learned how to manage similar situations in the future (Laarni *et al* 2001, 115; Madsen 1982, 149). The efficient use of models is the key to problem-solving. The situation changes with creative thinking, because there is no ready-made mode of action; rather the solution must be developed for this particular situation (Saariluoma 1995, 142). Creating something new always requires some amount of abnormality, illogicality, and surprise. Creative activity is, thus, thinking by way of imagination, the continuous alternation between imagination and thinking and changing from one into another (Weckroth 1988, 61–62).

The work of making decisions and solving problems is the work of choosing issues that require attention, the setting of goals, finding or designing suitable courses of action, and evaluating and choosing among alternative actions. The first three of these activities – fixing agendas, setting goals and designing actions – are usually called *problem-solving*; the last two, evaluating and choosing, are usually called *decision-making* (Simon 1986).

In cognitive processes, there appears aspiration towards simplicity and clarity. This aspiration is biologically and psychologically expedient, because it eases the functioning of the processes that guide behaviour (Madsen 1982, 99). When interacting with the surrounding world, the individual continuously edits his representation so that he can anticipate, plan, and assess his action. The information agency in human memory is connected to all intellectual activities, such as thinking, problem-solution, and learning (Lonka 1993, 41). Thinking is the production of images. When an individual thinks, he always functions based on logic, rules, grammar, concepts, and definitions, and by following them all he ends up with a particular image sooner or later. Without a doubt, when people create something new by thinking, they create it through old means. When people think, they do not see but look to the future. (Weckroth 1988, 60.)

The process of problem-solving can be divided into seven sub-processes, as follows (see Figure 4) (Anderson *et al* 1997, 2): definition of the problem, identification of alternatives, determine the criteria used to evaluate the alternatives, evaluation of the alternatives, selection of alternative and decision-making, decision implementation, and result evaluation. Decision-making will be a commonly combined process for five first sub-processes. The first three processes shape and define problem resolution, and the last two processes analyze prepared alternatives. Decision-making ends the alternative selection process. To assist decision-making and analysis, qualitative or quantitative methods can be used.

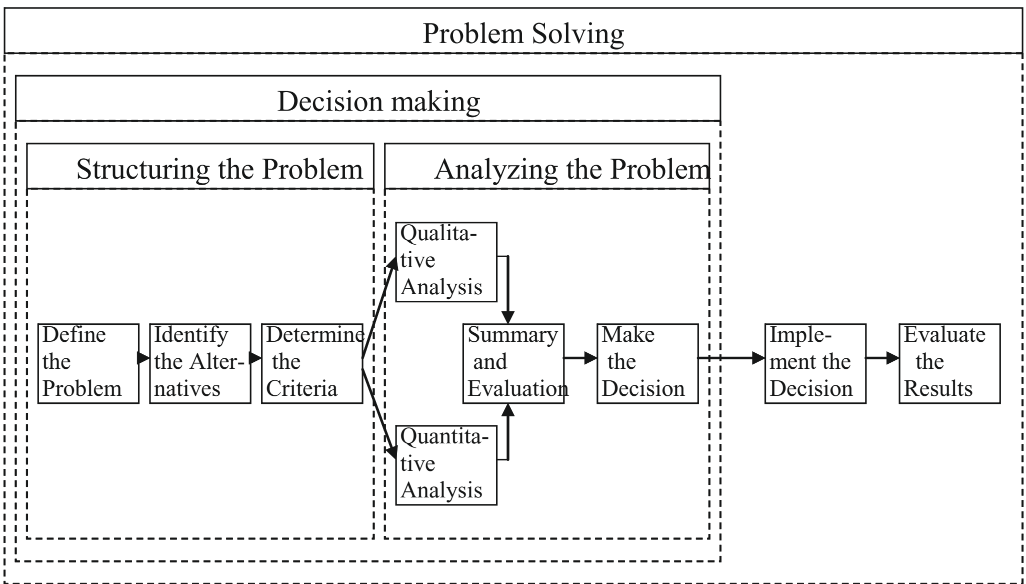

Figure 4. Combination of problem-solving and decision-making (Anderson *et al* 1997, 4).

Information is used in qualitatively different ways during various decision phases and decision routines. For the identification phase, information is used to help frame the problem situation and explain causal relationship. The main purpose is to provide enough comprehension of an issue so that the decision process can start. For the development phase, alternatives and solutions have to be found or generated, and options have to be described in sufficient detail. Development usually begins with a vague image of an ideal solution, which is then progressively fleshed out into one or more specific alternatives. Because the process is iterative and cyclic, information gathering is greatest during development. The main purpose is the design of viable solutions. For the selection phase, the consequences of various alternatives will have to be predicted, and criteria for choosing alternatives will have to be defined, clarified, and reconciled. The main goal is rational evaluation using the best available information, so that the decision is acceptable and can be authorized for action. The manager should be a proactive participant in the decision process, be sensitive to the open, dynamic nature of the decision process, and well prepared to address the different kinds of information needs that characterize each decision phase and routine. (Choo 2000, 47–48.)

Keeney (1998) has discussed two approaches to solving problems. They are Alternative-Focused thinking and Value-Focused thinking. Solving decision problems is the sole aim of alternative-focused thinking. Value-focused thinking is much broader. Alternative-focused thinking is reactive and value-focused thinking is proactive. Alternative-focused thinking follows the same sequences of activities to be presented in Figure 5. In the value-focused thinking process, values will be specified before the alternatives are created.

Values come before alternatives in value-focused thinking. Hence, after a decision problem is recognised, the full specification of values is the next step. For many decisions, these values should first be qualitatively explored at length and then possibly quantified. The qualitatively articulated values are then directly used in the creation of alternatives. Values provide the foundation for interest in any decision situation. The process of identifying objectives requires significant creativity and hard thinking about a decision situation. Existing alternatives are a useful source of objectives.

3.3.2 Defining selection factors and values of the decision

The decision-maker has a goal, but he also has alternative courses of action. Because the alternatives are often of different values, they can be arranged in an order of preference, according to their advantages and disadvantages. Preference measurement on the distance scale level is called utility, and it is often defined with the help of the properties of those alternatives that are essential to decision-making. If the decision is based on only one attribute, the decision is one-dimensional. In multi-dimensional decision-making, the alternatives are given values with several attributes. (Laarni *et al* 2001, 111; Saariluoma 1995, 104.)

Decision-making always includes uncertainty, because the decision-maker is not always clear about the consequences of different alternatives. Usually, the probability or likelihood of a consequence is known. In a risk decision, the utility has to be built on the probability of a favourable event, i.e., the likelihood of a negative consequence. The entity formed by the alternatives and their attributes is called decision-making space. (Laarni *et al* 2001, 112.)

Rationality means the extent to which a decision follows a carefully defined norm that guarantees the success of the selection. A decision is rational if the selected act maximizes utility; otherwise the decision is irrational. Psychological decision-making does not obey normative principles, because situations become too complicated too quickly due to people's capacity to act. When people simplify situations, they often outline situations incorrectly. The result is that they form simplified decision-making spaces (illusions) and lead themselves astray, far from the correct perception of the situation. (Laarni *et al* 2001, 112.)

The basic assumptions of decision-making theory define an ideal decision-making situation and decision-maker as follows (Lounamaa and Nurminen 1987, 35):
– behaviour is making choices and implementing them
– the act of selection is essential, implementation is only realization of the selection
– behaviour of the individual is goal-oriented, the goal of every selection is to maximize the expected "happiness" (utility)
– condition of the world can be defined with a finite number of (continuous) variables
– a selection is giving value to a finite number of selection / decision variables
– the world's condition is functionally dependent on selection variables; this dependency is described by conditional likelihood distribution
– all these functions and variables are fully known by the individual
– the individual's data processing capacity is unlimited and faultless.

The process that leads to decision-making can be directed with the help of assessing the sufficiency of goal efficiency, sensitivity, and measures. When assessing goal efficiency emphasis is on the defining of goals and the efficiency of alternative courses of action as well as the controllability of development. If it is possible to clarify and justify those goals, appreciations, actors with their development designs, possibly diverging forces that maintain change, and those external pressures for change that are behind a certain development path, a "self-realizing prediction" of coming events is created. In the assessment of sensitivity, emphasis is on the goal's absoluteness, uncertainty, and sensitivity to economic fluctuations. The purpose of the plan is not to be right, but to describe possible development paths to support decision-making. In the assessment of the sufficiency of measures, emphasis is on the sufficiency of means and the defining of the correct goals. Implementation must progress in phases. A goal and the related plan is impossible if the development of the means of implementation is not complete.

3.3.3 Risk management

Risk estimates are related to decision-making. Recognizing and evaluating risks is included in planning as early as in the preliminary planning phase and takes a more definite form during implementation planning at the latest (Nikander 2002, 14). The danger in crisis situations is that a single event and the reactions it causes may be exaggerated, and rapid, sketchy generalizations are made before a sufficient amount of research information is obtained about the causes and long-term effects of the event. In every situation, the threat analysis should be done from one's own starting point (Visuri 2001, 47).

The assessment of threats and weaknesses progresses to risk analysis, whereby risks caused by possible successful outside effects are taken into consideration. Instead of the complete removal of risks, one must often settle for risk management. In this way, it is possible to try to limit possible damages to an acceptable level. The ultimate goal of securing activity is to improve the opportunities to carry out a given task. The way to do this is to recognize the critical information that describes one's own operating and prevent the environment from acquiring them. This activity can be described as a process in Figure 5.

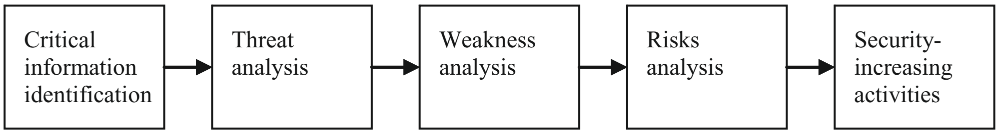

Figure 5. The process of securing activity (Jurvelin 2001, 42).

Identification of critical information aims to find the information the decision-maker requires for decision-making. Critical information is organization, time, and situation dependent, so it is not universal and continuously critical. Threats are assessed on the basis of threats from the environment. When assessing weaknesses the entire operating sequence of planned activity will be examined. The aim is to discover the phase in which indications harmful to one's own activity are created. Risk analysis is done on the basis of threat and weakness analysis. Adequate measures are selected to remove or lessen each weakness. These measures diminish the probability that the environment will observe or interpret correctly those points that are critical to one's own activity. (Jurvelin 2001, 41–42.)

The risks taken by a leader are often not fatal. Common sense urges a leader to prepare for the need for extra time and other measures. Even though risks vary from situation to situation, questions relating to the idea of operating, personnel, resources, and time must be answered before decision-making. The leader's unquestionable basic right is to take a risk when the situation demands it (Servan-Schreiber 1990, 77). A risk situation is the entity formed by the opportunities of harmful effects (Kamppinen and Ruohonen 2001, 256). The risk situation of decision-making can be analyzed following dimensions and questions:

– What is the distribution of the harmful effects and benefits of operating in time and space?
– What is the controllability of the risks of operating, and to what future views do catastrophes belong?
– What is known of operating right now and possibly in the future?

Risk management is a methodical activity that controls the risks occurring during the implementation of change. The phases of risk management are risk identification, mapping, analysis, and documentation, as well as the prevention of the realization of risks during the change process. In practice, these phases can be seen as a list of the goals of risk management (Prosessikäsikirja 2002, Appendix 1):

– to ensure that the goals set to the change are achieved and expectations are fulfilled
– to recognize essential risks from the viewpoint of the change's realization
– to minimize the risk that the change doesn't stay in the schedule or budget
– to estimate the likelihood and seriousness of risks
– to plan and realize improving measures that help to prevent risks or minimize their effects

3.4 Decision-making

Formal decision-making in organisations is structured by procedures and rules that specify roles, methods, and norms. The assumption is that rules and routines would lighten the information processing required of complex problems, embody efficient or reliable techniques learned from experience, and coordinate the actions and results of disparate organisational groups. When the decisions to be made are highly consequential and visible, the organisation may attempt to manage the process more closely through an elaborate system of checks and controls. (Choo 1998, 155.)

Decision style is a term used to describe the manner in which a manager makes decisions. The manager's design style is reflected in the way he or she reacts to a given decision-making context, what is believed to be of value or importance, how information is interpreted, and how externalities and forces are dealt with. Four distinct categories of decision style can be identified as follows (Marakas 1999, 43–46):

– the *directive* decision style combines a high need for structure in the problem context with a relatively low tolerance for context ambiguity. Decision makers possessing these characteristics tend to focus on decisions of a technical nature and often do not require large amounts of information or consider multiple alternatives.
– *analytical*-style demonstrates a much greater tolerance for context ambiguity and tends toward the need for greater volumes of information and the consideration of large sets of alternatives. Decision makers are best at coping with new, often unexpected, situations and problem contexts. In contrast to the directive style, analyticals prefer written communication and are not quick to reach a decision or solution.
– the *conceptual* manager demonstrates a high tolerance for ambiguity but tends to be more of a people person. Conceptualists display openness with their subordinates and tend to be driven by an idealistic emphasis on values and ethics. This type of decision maker is a long-term thinker and is generally strongly committed to the organization.
– *behavioural* types display a deep commitment to the organization and are very employee oriented. This style requires a relatively low amount of data input and, as such, tends to display a relatively short-range vision.

Optimization is considered a rational decision-making behaviour that suggests that the decision maker will choose the alternative that is clearly the best one providing the best overall value and outcome. In another view, using satisfying strategy, the decision maker tends to find the first acceptable solution that meets his or her preconceived notion instead of looking for the optimal solution (Marakas 1999, 67).

A decision is a choice between different options. Traditional decision-making theories assumed that the decision-maker is looking for the perfect solution. Nowadays, the decision-maker can never know all of the factors that affect the decision, or all of the available options. The decision-making situation is constantly changing (Åberg 2006, 66). Efficient decision-making necessitates that: problems can be anticipated and detected at the earliest possible phase, there are suitable arenas where the level of objectives is set and options for a solution are discussed, the decisions and the related operating plans are understandable and can be committed to, and that there has been discussion about the information required to implement supervision.

According to Åberg (2007, 67–68), planning is decision-making that precedes action, outlines a potential chain of decisions, and attempts to influence the future according to the planner's wishes. In strategic planning, the operational resources have not been committed, and the strategy sets guidelines and provides direction. Tactical planning is about committing resources from planning in order to reach goals and about the effects of allocating resources. Operative planning is about planning operations with committed resources.

3.4.1 Evaluation of alternatives

The analytical phase of the decision-making process may take on two basic forms: qualitative and quantitative. Qualitative analysis is based primarily on the leader's judgment and experience; it includes the leader's intuitive "feel" for the problem and is more of an art than a science. If the leader has had experience with similar problems, or if the problem is relatively simple, heavy emphasis may be placed upon qualitative analysis. However, if the leader has had little experience with similar problems, or if the problem is sufficiently complex, then quantitative analysis of the problem can be an especially important consideration in the leader's final decision. (Anderson *et al* 1997, 3–4.)

In systematic forming, it is possible to use clear questions to guide anticipatory measures. Table 3 presents one way of outlining anticipatory alternatives.

Table 3. The elements of anticipatory systematics (Jones and Twiss 1978)

Element	Description of method	What question is answered
1. Qualitative methods	Results in futures without temporal dimensions, information about predicted events	Which phenomena are likely to affect the organization's plans?
2. Quantitative methods	Focuses on the qualitative prediction with the goal of determining the degree of occurrence	How can phenomena be measured and what degree of occurrence is significant as proportioned to the organization's technological or action goals?
3. Timing methods	Deepens the prepared qualitative prediction with the goal of timing the appearance	When will a significant degree of occurrence be achieved?
4. Probability assessments	Compiles a subjective assessment of the degree and timing of presentation	How probable is the degree of occurrence and can the predicted timing be trusted?

The reasons why a quantitative approach might be used in the decision-making process are as follows (Anderson *et al* 1997, 5):
– the problem is complex, and the leader cannot develop a good solution without the aid of quantitative analysis
– the problem is very important, and the leader desires a thorough analysis before attempting to make a decision
– the problem is new, and the leader has no previous experiences on which to rely
– the problem is repetitive, and the leader saves time and effort by relying on quantitative procedures to make routine decision recommendations

The leader's own personal line of policy and his long term point of view can affect decisions quite powerfully, but by concentrating on the views of others and by respecting them, the leader gets others to adopt decisions and participate in the implementation of decisions (Virkkala 1994, 117). Decision-making and its manner should not cause confusion in the target group (Adair 1989, 53). When people assume organizational positions, they adapt their goals and values to their responsibilities. Their decisions are influenced substantially by patterns of information flow and other communications among various organization units (Simon 1986). Fast decisions are often is demanded, and a leader may make the decision alone. In this case, for this person, orientated responsibility increases. (Toskala 1989, 67.)

If the utility of decision alternatives is misevaluated, the cause is the representation of the other alternatives (Saariluoma 1995, 113). Analytical decision-making compares several alternatives, whereas intuitive decision-making concentrates on the deepening of a few alternatives. Intuitive decision-makers accept their own decisions more easily. Analytical decision-makers are more likely to trust linear programming, whereby all negative factors are cut out. Analysis is often formal and time-consuming (Saari 1998, 40). The abundance of information may harm decision-making. Collected information has to be shared and used flexibly. The leader must be able to determine those points that, if affected, can produce an advantage for the organization and make it easier to achieve objectives. (Saari 1998, 48.)

Logical problem-solving is one of the basic elements of decision-making. Decision-making must always take into account the temporal permanence and duration of a decision. The screening and updating of available information always forms the foundation for decision-making. (Nissinen 2000b, 44.) The entity formed by decision alternatives and attributes can be called decision space. A perfect decision space includes all logically possible alternative courses of action (Saariluoma 1995, 105). For the perfect presentation, the decision-maker must know the decision alternatives, necessary attributes, related uncertainty factors, and at least one rational rule of decision-making. In a multi-dimensional, multi-level decision-making situation that includes several alternative functions, the work memory of the decision-maker faces strong requirements during the decision-making process. It is probable that mistakes are made because the decision-maker cannot properly utilize all the information available about the situation. (Saariluoma 1995, 129–130.)

A decision is often based on subjective assessments justified with various expressions of belief and probability: "gives reason to suspect", "increases the belief", and "seems probable". These expressions that describe uncertainty have been presented with the help of the concept of uncertainty. Often, the question is about subjective probabilities an expert interprets and produces on the basis of his own knowledge. The expert can also speak of "probabilities" using the word as a linguistic expression, when he is not really referring to probabilities. (Rantanen and Nykänen 1989, 49.)

Because different approaches sometimes lead to different decision recommendations, the decision maker needs to understand the approaches available. The optimistic approach evaluates each decision alternative in terms of the best payoff that can occur. The decision alternative that is recommended is the one that provides the best possible payoff. The conservative approach evaluates each decision alternative in terms of the worst payoff that can occur. The decision alternative recommended is the one that provides the best of the worst possible payoffs. Minimax regret is an approach to decision-making that is neither purely optimistic nor purely conservative. Selecting the decision alternative with the minimum of the maximum regret values – hence, the name minimax regret – yields the minimax regret decision. (Anderson *et al* 1997, 578–580.)

For the basis of decision-making, it is possible to model a so-called double-sided situation game. The game aims to achieve a finish advantageous to the decision-maker, on the basis of which the effects of the decision on the environment are estimated, as are the effects of the environment on one's own operating or situation. Anticipatory decision-making must pay close attention to the evaluation of these critical factors. Traditionally, critical factors that support preconceptions have been presented as the foundation for decision-making, thus confirming earlier information. In anticipatory leading, the search must be focused on those critical factors that can prevent or otherwise harm decision-making, i.e., risks are mapped and their size estimated.

The conflict of deciding is that all consequences can never be known. At the decisive moment, all figures are not known, only parts of an entity. Furthermore, there is no time to put all the pieces together, to assess them, to analyze alternatives and consider them. In addition, some of the uncertainty factors are permanent. All alternatives must of course be analyzed, and as much information should be collected as possible. Intuition enters the picture, because decisions are not based solely on information. (Servan-Schreiber 1990, 55.) The final decision must be made critically. Fatal factors can hide behind ideas. Ideas or alternative courses of action are usually complex, and the weakest spots of such entities are the most crucial (Virkkala 1994, 126).

3.4.2 Timing and implementation of decision

The objective of the management process is to prepare as good a plan as possible for implementation. The maturing of the operation thought included in the decision requires information. The operation thought loses its importance if it is not proportioned to the time available. (Toveri and Välivehmas 1996, 120.) Because information increases as a function of time, and similarly, the time available decreases at the same time, management activity must be based on a functional period of time that contains the optimal moment of decision-making. The length of this period and the moment of decision-making depend on the organization's task, performance capability, and the decision-maker's ability to take risks.

Life is series of repetitions. Future orientation is simple; everything is repeated according to the cyclic movement. The natural system is characterized as cyclic. This cyclic movement is determined by the behaviour of nature, not clocks. (Julkunen 1989, 11.) New time is mechanical, it is clock time. In clock time, time is not proportioned to activities; activities are proportioned to the shared, abstract, determined course of time. Linear time is the time of an individual who is aware of his or her history and whose future is open, different from the past or the present. Linear time is the time of an individual who operates on long time horizons, anticipates the future and makes plans, and whose world view is dynamic. (Julkunen 1989, 15.)

A realistic interpretation explains time through other temporal courses of events and rules that apply to mental events. It also explains our tendency to have a different attitude towards the past than towards the future by seeking from the events of reality those features that determine the direction of time (Siitonen 2000, 150). In a guide book of military leadership, it can be seen that leading and executing a task must take place at the right time, because a situation is difficult to stop (Sotilasjohtaja 1990, 48). Time affects surprise and initiative. Decisions can be said to improve with the availability of information, but they also weaken if the time used is longer than the optimal time for information acquisition and preparation for a decision (Sotilasjohtaja 1990, 59). In anticipation, it is necessary to know what kinds of operating logics are possible. The conceptions of time and causality are central to the preparation and ensuring of conditions. These conditions are objectives that create the tension which makes possible the anticipation of operation. (Eskola 1989, 193–194.)

Research on actual decision-making shows that people are frequently inconsistent in their choices between the present and future. Additional problems arise because human tastes and priorities change over time (Simon 1986). As a traditional time series, the management process is too slow; it can support only reactive management. The management process is examined as a time space, the dimensions of which are the phases of the traditional management process. In theory, decision-making can occur on any part of this time space. In practice, this means that the entire management process should progress one unit of time ahead of actual events. (Kuokkanen 2004, 87.)

The moment (in this case a decision-making) is a special period during which events take place that are notable or anticipatory in themselves (Kamppinen 2000, 268). In a startling situation, a decision must be made on the basis of the best information available. Target output directed activity is emphasized, which requires rational control. In this context, uncertainty in the surrounding environment should also be noted. This is why it is not always necessary to strive towards a decision made on the basis of perfect information; the goal is a solution better than the environment's regarding information and time. Thus, the moment of decision-making would seem to mean a relatively short period of time that is intensively dedicated to the decision (illustrated in Figure 6).

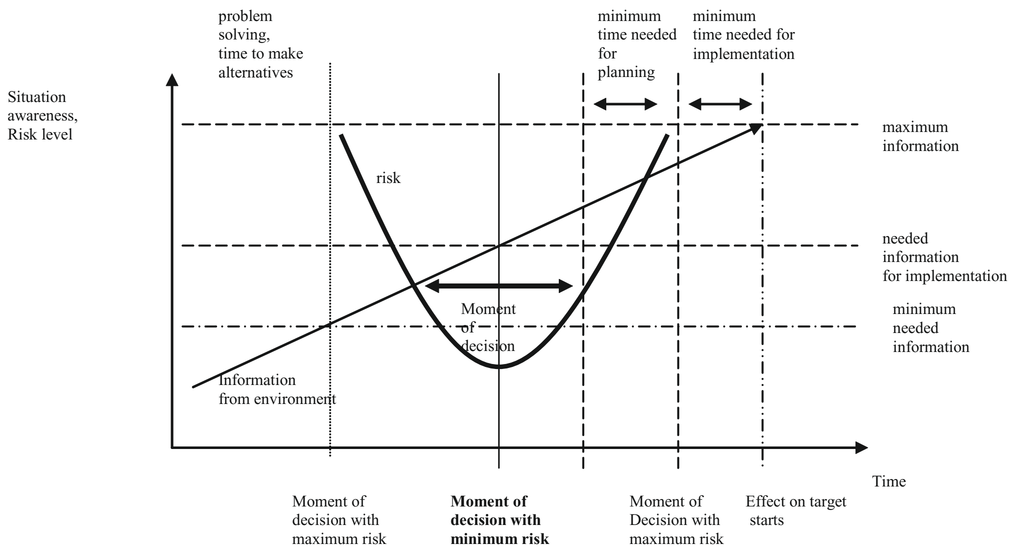

Figure 6. Assessing the moment of decision-making in relation to time and risk level (Kuokkanen 2004, 89)

Actual decision-making is preceded by the preparation of decision alternatives. After this, decision-making can be seen as a social process affected by (Grönlund and Guohua 1993, 179):

– the organization's social situation in general
– the position in the organization of those individuals who are connected to the situation (decision-maker or makers)
– the special features associated with the initial situation (the effect of the preparation phase)
– outlined lines of activity
– decisions associated with coming activity

The normal planning point of view requires that final decisions and implementation are not commenced until complete plans have been made and management has approved them. Parallel decision-making requires another point of view. At the end of each phase, it becomes clear that certain measures must be taken regardless of the decisions made in the following planning phases (Ansoff 1984, 294). In practice, the implementation of a decision is usually considered the most time-consuming phase of the management process. The responsibility for implementation must be defined clearly, and it must be certain that those involved have goals that are in accordance with the task. It is implementation that makes the decision efficient. (Sotilasjohtaja 1990, 64.)

Implementation could be seen as an effect life-cycle. It is of great benefit for an organisation if it has enough resources to adjust activity during the cycle. The action's effect life-cycle consists of various phases, which place different demands on action (Duro 1989, 39–43), as follows. The *introduction phase* involves creating oneself a bridgehead for a powerful offensive later on. The main idea is that the introduction should be a rapid one, so that the function and quality of the action are experienced by the environment as 'right' or 'effective'. If volume can be generated quickly and at a low cost, and so lowering the total cost level per unit, then this should be done. What is achieved by this is that combat potential increases and the environment's eagerness to enter the same area diminishes. In the *expansion phase*, one concentrates forces on becoming the action leader. Success will be so obvious in the expansion phase, that even if the environment has not reacted before, it will do so now. Thus, it is important, during the earlier phases, to have built up an environment observing organisation that can indicate what the action doing. The expansion phase requires a high degree of flexibility and creativity if one is to keep the lead. Correct action during the other phases of the action's effect life-cycle means that one can now reap the harvest of one's efforts. Economy of action forces, cost-effectiveness, rationalization – this is the main rule for success in the *stagnation phase*. In the last phase, the *rundown phase*, by planning a retreat carefully, thinking through what we must tell the troops and how we fulfil the requirements of an orderly retreat.

3.5 Feedback and learning in the decision process

Learning is one part of the management process, in which existing data structures unite with gained experiences (= feedback) on both the individual and organization level. The learning of organizations has resulted in extensive theoretical discussion in which two ways of achieving change can be distinguished. The first learning phase is characterized by the effects of information from feedback on action strategies while the norm foundation remains the same. In the second learning phase, the effects of feedback reach the norm foundation, making the changes more profound (Argyris and Schön 1978; Sarala and Sarala 2003, 33).

Following Åberg's idea of quality of communication (2000, 268), the quality of decision-making can be assessed if it is impossible to assess the effectiveness of operating. Quality assessment can be carried out from the viewpoint of production, planning, the finished product, the customer and the system, as well as the environment. An example of the points of emphasis in quality assessment is presented in Table 4.

In the learning process, an individual selects information and interprets it on the basis of his or her experiences, expectations, and goals. The ability to anticipate requires experience gained from several real situations or real-like exercises. Actively taking advantage of experiences by looking for general principles and by applying them to new situations is essential. In connection with learning, thought has to be given to what kinds of information structures give learners the best preconditions to manage new situations, and what capabilities of acquiring new information and thought entities learners need to develop as leaders and to develop their subordinates. (Saari 1998, 78.)

Table 4. Points of emphasis in assessment of quality of decision-making (Åberg 2000, 273, based on Lillrank 1998)

Perspective	Focus	Assessment
Production-centered	Efficient use of the resources of decision-making	Things are done correctly the first time
Planning-centered	Functioning of various models of decision-making	Things are planned well and preparations for different decision-making situations are made
Product-central	Quality of plans and commands	Quality of prepared documents
Customer-centered	Satisfaction of cooperation and target groups with decision-making	Satisfaction of the receiver of the decision
System and environmental-centered	Extensive assessment of the effects of decision-making	The quality of decision-making is mutual satisfaction and the responsible increasing of the organization's effectiveness

According to Mezirow (1991), theories concerning adult learning lack a central element, the meaning of phenomena (meaning), and how the meaning of phenomena is construed, assessed, and reshaped. Mezirow thinks that a transformative theory of learning is needed to explain how an adult learner gives meaning to his own experiences, how he structurally construes them, forms meaning to things, and solves conflicts of meaning. (Nissinen 2000, 57.)

The management of entities, understanding complexities, and efficient decision-making require the combining and understanding of concrete phenomena at a conceptual level. Conceptual thinking creates a foundation for the ability to examine. It also creates a basis for the ability to vision and lead anticipatorily. Conceptual thinking is the management of information at a level characterized by the synthesizing of information, logical intuition, and the creation of new information.

Organisational learning takes place when members respond to changes in the environment by detecting errors and correcting the errors through modifying strategies, assumptions, or norms. Two modes of organisational learning are possible. Learning is single loop when the modification of organisational action is sufficient to correct the error without challenging the validity of existing norms. It is single loop, because a single feedback loop between detected outcomes and action is adjusted so as to keep performance within the range set by organisational forms. The goal of single-loop learning is, therefore, to increase organisational effectiveness within current norms for performance. The goal of double-loop learning is to ensure organisational growth and survivability by resolving incompatible norms, setting new priorities, or restructuring norms and their related strategies and assumptions. While single-loop learning is adaptive and concerned with coping, double-loop learning is generative learning and creates new private images and public maps. (Choo 1998, 221–222.)

Renewing learning helps the individual to become more aware of his or her assumptions, and to have a more critical attitude towards them, so that he or she could then actively begin to change ways of thinking that are inadequate for efficient problem-solving. The model of reflective thinking describes changes in hypotheses that concern the sources and certainty of information as well as how decisions are justified (Kitchener and King 1996, 180). Renewing learning means that learners make well-founded decisions about how and when to act on the basis of new perspectives. This may also mean new ways of understanding and using information, and using this information in a new way to understand one's own activity in relationships among individuals. (Mezirow 1996, 378.)

Research on the model of reflective thinking has shown that when individuals representing different age groups and levels of education enter the learning environment, they have clearly different assumptions about what can be known and how, and how different things should be evaluated in light of these assumptions. Some believe they can reach absolute knowledge through concrete observation, while others admit that there are several problems that do not have absolutely true answers. These kinds of problem-solvers see it as their task to construct a solution that can be justified after various evidence and interpretations have been taken into account (Kitchener and King 1996).

3.6 The concept of anticipatory management process

According to Ansoff (1984, 38), anticipatory management was developed when non-continuity started to appear, but changes were still so slow that organizations could anticipate a coming situation on time and adjust to it. Leadership based on flexibility and adjustment forms in conditions in which many essential challenges develop too quickly to allow time for systematic adjustment.

In many organizations, anticipatory management is an essential part of a developed management process. It requires an organization to have a standard of activity in which the intellectual resources of at least some key individuals are directed toward the future. From a leader, decision-making related to anticipatory management requires the intuitive ability to outline entities and changes. Intuition does not mean that information is surpassed. It means a large amount of information and related modelling and simulation, as well as the visualization of results, the task summary, entirety, and expanded information.

The anticipatory management process is based on the 'scanning' of both internal and external operational environment. Scanning is used to recognize changes that can then be prepared for. In an effectively reacting community, each individual should be able to scan even the weak signals of a changing situation (Nissinen and Seppälä 2000, 40). Follow-up of the situation includes the acquisition, checking, and shaping of information so that it is in an assessable form. The acquisition of situation information is continuous, active, and immediate. The goal of decision-making is to find the most advantageous end-state for an organization's activity, within the framework of the borderline conditions and limits that have been defined. This activity includes the definition of factors critical to activity. The critical factors form a basis for alternatives. The analysis of these factors brings forth risk associated to the activity, their permanence, and change (Esikuntaohjesääntö 1998, 23–28).

The leading of tasks and operating included in the management process requires analytical handling of information, logical, and, if necessary, intuitive decision-making and good control of the use of time. Task analysis creates a basis for the assessment of the operational environment and situational development that includes the anticipation of the speed and direction of change. The handling and analysis of information must be organized in such a manner that available information allows the comparison of alternatives drawn up for the realization of a task. The key sector of the management process is decision-making that also acts as the dividing point of the process, separating leadership into the preparation for decision-making and the realization of the decision (Nissinen 2000a, 84–85).

The most efficient leader controls the management process so well that he can flexibly introduce or leave out parts of the process within the time available. When preparing a decision or building a vision, it is always advantageous to make use of an organization's ideas and creativity (Nissinen 2000a, 15–16).

It is somewhat a custom to describe the management process as a simple time series, in which preparation of activity, decision-making, execution, and supervision are the most notable parts of the process, and those processes follow each other as a cycle. Gollwitzer (1993, 144–147) and Nissinen and Seppälä (2000, 34) separate decision-making into four phases: the phase preceding the decision, the phase of decision-making, the realization phase, and the assessment of activity. According to Aula (1999, 200-201), the phases of organizational change can be described in several ways, but most include the following phases: noticing the problem, i.e., pressure for change, planning the change, making decisions concerning the measures required by the change, and implementing those measures.

John Boyd's most important contribution to business and science was the "OODA loop" (observe-orient-decide-act) (Figure 7). The model's most important part is the shaping phase (orient), in which cultural background, genetic genotype, new information, earlier experiences, and the analysis-synthesis process are recognized. The goal is to penetrate the thinking and decisions of an opponent. In many publications, the OODA loop has been incorrectly simplified, and it has been assumed that the decisive factor is speed throughout the chain. Understanding and internalizing the OODA loop gives the decision-maker the opportunity to shorten the time between observation and implementation, and as a consequence, he can select a more surprising alternative course of action, instead of the alternative estimated to be the most efficient. (Lindberg 2003.)

In order to shape the operational environment, one must exploit four factors: changeability, speed, harmony, and initiative. The decision-maker should have a series of ready-made countermeasures he can implement quickly: he must harmonize his actions but never wait passively. After the OODA loop process has been started, it must not be slowed down. Instead, one must exploit the environment's confusion and be active. The result of a faster decision-making cycle is that one's own activity appears to be unclear in the environment, because a new decision has been made before the environment's decision, and the environment cannot react to it, but instead, gets more and more behind. (Lindberg 2003.)

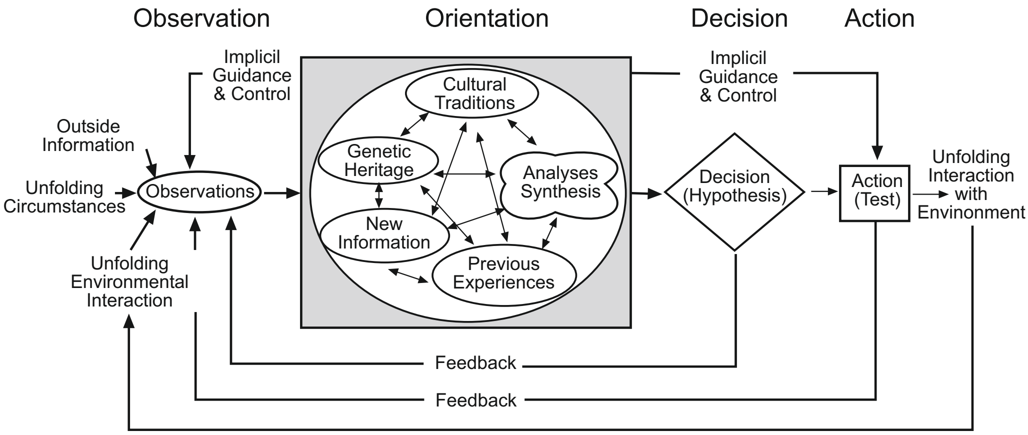

Figure 7. Boyd's OODA Loop (Boyd 2004)

The model of anticipatory management can be considered a kind of ideal that is impossible to realize in practice. Linear progress taking place in stages from the realization of the problem to controlled change is disturbed by the instabilities and imbalance of the surrounding system. In other words, the linear model is not suited to a non-linear reality. As an alternative to the model of controlled change, the model of chaotic change is born (see Table 5). (Aula 1999, 201.)

Instead of the organization remaining to wait for the collection of a sufficient amount of information, it has to determine which ones of the increasingly extensive phases of planning and operating are possible as more information is acquired concerning the development of threats and opportunities (Ansoff 1984, 212). Identification of weak signals means that those responsible for identifying challenges must begin to listen even more carefully then before for the early warnings of threats and opportunities. Noticing weak signals requires sensitivity and professional expertise from the observers. Nets have to be cast over a wide area, and many individuals have to be engaged to supplement the corporate staff responsible for challenges. (Ansoff 1984, 217.)

Table 5. A comparison of the controlled change model and the chaotic change model (Aula 1999, 202, based on Zuijderhoudt 1990)

CONTROLLED CHANGE MODEL	CHAOTIC CHANGE MODEL
1. Awareness	1. Uncertainty
- report	- paradox
- risk management	- disturbances
- timing	- risks
2. Planning	2. Rambles and coalitions
- empirics	- losing of areas
- new information	- disorder and uncertainty
- piloting	- signals of chaos threshold
3. Decisions	3. Emergence of ideas
- observing	- old rules give way to new rules
- selection	- bifurcation point
4. Implementation	4. New structuring
- execution	- forget what has been learned, new learning
- observing	- explanations
	- stabilization of new attractors

Leadership on the basis of weak signals first requires that people become sensitive to receiving signals and that they are trained to follow them. Furthermore, signals have to be classified based on the level of information, and the probable effect and timing of challenges must be estimated as accurately as possible. The lower the level of information, the more extensive is the dispersion of the effect and timing of the assessment. (Ansoff 1984, 230.)

Weak signals and leadership based on them are only one of three choices an organization can choose from when responding to the challenges of the environment. The other two are leadership based on strong signals and periodic planning. When the speed of a threat of an opportunity is so great that it can no longer be controlled with periodic planning, the follow-up of strong signals has to be added to systems. When this too becomes too slow, it must be replaced with the follow-up of weak signals. (Ansoff 1984, 230.)

The anticipatory management process used to carry out several separate tasks is based on several serial models (Ashley and Morrison 2001; Aula 1999, 201; Böhret 1993; Lönnqvist 1995, 66; Pirnes 1995, 122; Simon 1986; Sotilasjohtaja 1990, 40; Åberg 2006, 65–69). A parallel model of these processes has been prepared (Figure 8). The model includes the same main processes as the serial model, but their relation to each other has changed temporally. The processes include, for example, the following sub-processes (Kuokkanen 2004, 50–51):

1) *Situation formation and updating (uncertainty)*: mapping of the general situation, mapping of one's own situation, mapping of the competition's situation, assessment of the development of the situation

2) *Planning (coalitions)*: analysis of the task, definition of the desired end state or situation, condition analysis, mapping of possibilities, identification of the alternative, situation analysis or situation playing between alternatives

3) *Decision-making (emergence ideas)*: formation of decision-making criteria, comparison of alternatives, making the decision and publicizing it

4) *Implementation (new structuring)*: planning of operation in accordance with the decision, planning of execution, execution.

In the parallel process, all sub-processes operate temporally parallel with the situation follow-up. Changes to the situation can cause, either separately or simultaneously, changes and measures in other sub-processes. This means that in addition to the situation follow-up, preparation, decision-making, and implementation are also active functions throughout the entire management activity. Only their activity level or readiness changes during operating. Sub-processes overlap and form a network for the duration of the most active operating.

Acquisition and analysis strive for a situation in which the acquired results are reflected in practical management activity, and especially in decision-making. It is only human that every decision-maker tries to place the acquired information into a larger information structure, in which case the acquired information either supports it or a conflict will arise. Excessive leaning on an earlier information structure may bring about effective filtering. It prevents the decision-maker from seeing the importance of information analyses, and in some cases may lead to analyses being left unnoticed.

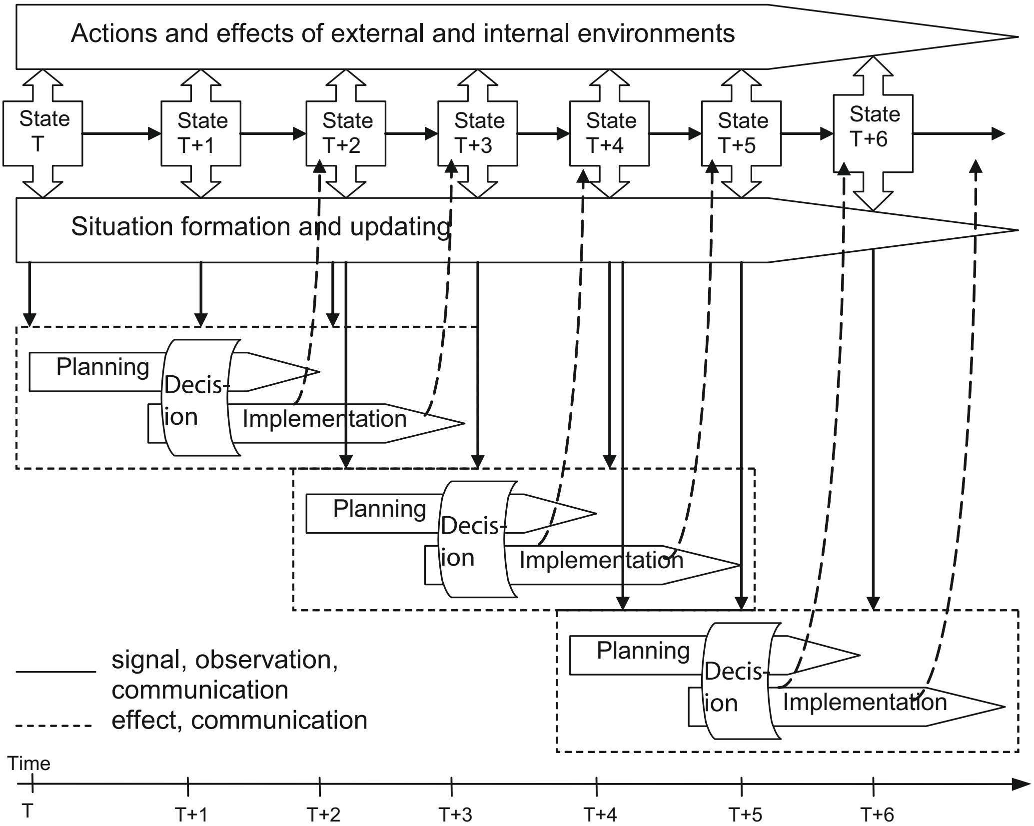

Figure 8. Anticipatory management process (Kuokkanen 2004, 52). The dotted lines from the planning-decision-implementation complex to state T+x illustrate the effect of implementation on the environment and communication act, while the solid lines from the situation picture to the planning-decision-implementation complex illustrate observations of the environment to the decision-making process and communication act.

3.7 Conclusions

The knowing organisation is well prepared to sustain its growth and development in a dynamic environment. By sensing and understanding its environment, the knowing organisation is able to prepare for early adaptation. By applying learned decision rules and routines, the knowing organisation is primed to take timely, purposeful action. The organisation uses information to make sense of changes and developments in its external environment, and searches for and evaluates information in order to make important decisions.

The process model elucidates the phases and cycles that give structure to apparently complex and dynamic decision-making activities. Decisions result in commitment to courses of action. The knowing organisation is effective because it continually evolves with its changing environment, refreshes its knowledge assets, and practises vigilant information processing in its decision-making.

Change does not conform to earlier borders. It changes the environment, forming new combinations of the dynamic and static areas. The speed of change may lead to a disjointed state of chaos. Interaction with the surrounding environment is extremely complex, and in order for the organization to operate effectively, it must place emphasis on the key sectors of strategic planning, such as visioning, changing management, and environment scanning.

Leading an organization means to guarantee that the interpretations people make about the organization are integrated enough for cooperation and successful operating. One task of leading the organization is to create conditions that support and further interaction throughout the organization. In order to succeed, the organization has to tolerate mistakes, faults, accidents, silly questions, and opinions far from conventional. Leadership is the control of conflicts. Chaos, development, mistakes, and faults are included in the natural life of the organization. Nothing is as sure in present-day organizations as uncertainty. The future is unpredictable; only undeveloped and developed, intellectual or unintelligent guesses can be made. (Aula 2000, 10–11.)

Inspected methods of leadership and management show that they can be divided into two classes: based on vision or conception, and based on implementation or action to be effective. New ideas expand transformational leadership principals. They can be seen updating and giving new meaning to traditional processes, especially to observing and planning. Also, they try to encourage leaders to perform their actions individually and to trust themselves.

Transformational leaders make followers more aware of the importance and value of task outcomes, activate their higher-order needs, and induce followers to transcend self-interest for the sake of the organization. Transformational leaders formulate a vision, develop commitment to it among internal and external operators, implement strategies to accomplish the vision, and embed new values and assumptions in the culture and structure of the organization. Differential methods of leadership and management with orientations to anticipatory management are summarized and illustrated in Table 6.

Table 6. Orientation of methods to anticipation

Method of leadership and management	Idea or purpose of method	Orientation to decision-making	Orientation to time	Support to anticipatory decision-making
Transactional	Command, control, correct	Rational	Present	No
Charismatic	Command, guide, (support)	Intuition, emotional	Present or future	Unclear
Transformational	Delegate, follow, be available	Rational, emotional, discussion	Future, short-term	Yes
Visionary	Visioning	Intuition	Long-term	Yes, for planning
Management	Planning, command, control	Rational	Present, short-term	Only in case of short-term

The fragmented nature of managerial activity reflects the fact that many interactions are initiated by others, and much of a manager's behaviour has to be more proactive than reactive in nature. Operating in a complex environment requires continuous changes in standards of activity, as well as operating at different volumes and risks. Success is concealed in complexity and in doing several things at once along various fronts.

An organization cannot operate efficiently without a functioning feedback system. When an organization is able to anticipate changes occurring in the environment, it can try to adjust to them in advance. In unstable conditions, both the environment and various factors of the organization behave unpredictably, and negative feedback is not enough. In order for organizations to be able to prepare for changes, they have to be capable of recognizing their internal changes and the environment's dynamic and periodic changes, and in that way develop further (Aula 1999, 103).

One of the greatest challenges facing an organization is to understand how the external environment is changing, what the changes mean, and how the organization can best respond to the new conditions. An organization scans conditions continually. By scanning weak signals of change as early as possible, corrective measures can be taken in time.

By anticipating changes occurring in the environment, an organization aspires to adjust to them in advance. In unstable conditions, the behaviour of various factors of both the environment and the organization is unpredictable. As an organization prepares to develop, it must recognize its internal changes, and the environment's dynamic and non-continuous changes.

Decision-making ends the selection of alternatives. Qualitative or quantitative methods can be used in the selection process. Decision-making always includes some degree of uncertainty, because the decision-maker is not always fully clear about the consequences of different alternatives. Usually, consequences are expressed with some degree of probability.

If one wishes to anticipate problems and reach a desired objective in the future, one mustn't limit oneself to the assumption that current trends will continue in the future. In proactive operations, one should outline desired futures and identify turning points and mechanisms of change, in order to find measures and decisions that help to steer operations in the desired direction.

The ability to quickly combine available information, use it to form the correct situational picture, and gain the necessary understanding to make a decision are basic requirements for success in one's own operations. The correct timing of decision-making in the management process makes it possible to reach significant operational advantages and benefits in terms of the environment. The correct timing of decision-making is always gauged in relation to events in the surrounding environment and estimates of how they will develop. A time advantage can be achieved by shortening the planning phase and creating the possibility of making the decision during the planning phase.

Concerning one's own operating, it is important to recognize threats and to be aware of one's own weaknesses. A risk can be divided into two factors: the likelihood of the realization of the threat, and its consequences. The economic and functional consequences of threats are more easily defined if it is possible to determine the worst ways in which the threat can be realized.

If no methods are used to illustrate the situation, two kinds of harmful effects easily result. When the decision-maker does not control a new complex situation, he has to simplify it by leaving some issues without attention. This may worsen the quality of the decision, even if the decision-maker were able to subconsciously take into account all viewpoints appropriately weighted. If others do not see this, the credibility of the decision may weaken, resulting in less commitment than otherwise would have been possible.

The management of entities, the understanding of complexities, and efficient decision-making require the combining and understanding of concrete phenomena on a conceptual level. Conceptual thinking creates a basis for the ability to vision and lead anticipatorily. Anticipatory management is an essential part of a developed management process, in which resources are directed toward the future. Decision-making related to anticipatory management requires that the leader be able to outline entities and change. The anticipatory management process is based on the scanning of both the internal and external operational environments, and to recognize change and prepare for it.

The management process enables all sub-processes to operate simultaneously with the follow-up of the situation. Changes in the situation can cause either separate or simultaneous changes and measures in planning, decision-making, or implementation. It is particularly important to find weak signals related to vision and anticipation, so that it is possible to anticipate changes. Attempts are made to actively anticipate the activities of the environment, in which case it is possible to seize the initiative and create preconditions for success. The increased speed of activity emphasizes the importance of anticipatory management and the need for information.

Even a good strategy cannot be implemented and turned into action if communication is inefficient and responsibilities and decision-making authority are unclear. A strategy must be made into a concrete action programme which includes communication. Lack of communication may prevent full-fledged support from personnel when a strategy is being implemented. Communication must work both ways. One-sided communication will not ensure that the receiving party understands the issue in the way intended by the communicating party. (Hamäläinen and Maula 2004, 144–145.)

Clarity and simplicity make a strategy easier to understand, but they do not guarantee that employees will see the connection between the strategy and their own work. It is the supervisor's job to link the strategy to team operations and each employee's personal goals. Bersona and Avolio (2004) believe that effective dissemination of organizational goals also depends on the communication skills of leaders. Transformational leaders are expected to use their communication skills to articulate organizational goals more effectively than other leaders.

Communicating strategy makes it easier to coordinate operations and make necessary choices in everyday work. The decision-maker can implement a strategy actively and independently only if he or she knows and understands the main points of the organisation's strategy and his own role in the strategy's implementation. One goal of communication is to justify strategic choices and to offer personnel the opportunity to ask questions about the strategy and discuss it. Knowing and understanding these justifications makes it easier to accept changes. By collecting feedback, employees' views and experiences can be taken advantage of, and new information can be created to clarify the strategy as required.

The proactive communication of decision-making has an important role in a situation of change. As an organisation changes, an anticipatory decision provides a basis for a change and makes it easier to see the reasons behind the change. An important purpose of communication is to identify any issues that might be unclear to personnel, to discuss them and perhaps find answers.

The decision-maker and implementing parties see the problem of understanding differently. The decision-maker's primary concern is ensuring that everyone is informed about a decision and ready to implement it. The implementing party's concern is determining what to do. The implementing party needs feedback from the decision-maker, in order to learn whether an implementation supports a decision. In communication, dialogue is used to ensure that objectives are met.

In a process-level solution, a central element is the connection between a decision and its implementation. This involves a degree of interpretation on the implementing party's part. When the anticipatory decision-making process is visible and continuous, the implementing party has a better understanding of how the decision relates to the greater whole. From the decision-maker's point of view, a functional decision-making process is a tool for directing implementation, in order to attain a greater whole, receive feedback, and track the development of operations and the implementation of a decision.

Successful implementation of decision-making doesn't necessarily mean that the decision will be implemented. Evaluating the implementation of decision-making, i.e., whether the work to implement the decision has been successful, is actually slightly different than evaluating how the decision itself has been implemented, i.e., whether the objectives and choices contained in the decision have actually been realised. When the overall implementation of the decision is being evaluated, the decision itself must also be evaluated, in addition to the implementation and realisation of the decision.

For managerial personnel within an organisation, factors that influence decision-making are management principles, available resources, environment and communication. The choice of the right management process supports an organisation's proactive behaviour. The factors that impact decision-making change over time. Therefore, the decision-maker constantly has to make new decisions. In a changing environment, it is essential to make an organisation implement decisions in the desired way by means of communication. In the next chapter, these phenomena are studied with models that are associated with decision-making and support it, and by formulating new constructs of these models. The goal is to use the results to develop support systems that can be used to aid decision-making in various situations.

Chapter 4

Support to Anticipatory Decision-Making and Communication

The previous chapter discussed the knowing organisation, leadership, and management. The main benefit was as introduction to the anticipatory management processes. This chapter first focuses on environmental scanning and weak signals, and second, on support for decisions from environmental observations to predictions. Third, support for the principles of decision-making will be introduced. Fourth, communication support for decision implementation will be presented. Fifth, this chapter reviews useful methods to support evaluation in the decision-making process, and examples of quantitative and qualitative methods. Finally, a structure of decision-making support system will be presented. Information is an organisation's strategic resource. Information is the resource that enables the effective combination and utilisation of other factors of production – it is, in effect, the meta-resource that coordinates the mobilisation of other assets in order for an organisation to perform. Competition is the consequence of the unequal distribution of information among organisations and their differential abilities to acquire, absorb, and actuate information. To become strategic, information must be galvanized into knowledge that can guide action. This transfiguration into knowledge is the goal of information management (Choo 2000, ix).

4.1 Environmental scanning and weak signals

One of the greatest challenges facing the intelligent organisation is to understand how the external environment is changing, what changes mean, and how the organisation can best respond to new conditions. The process of learning about external milieu is environmental scanning, the art of gathering and interpreting information about the environment, so that the organisation has the knowledge to develop effective courses of action (Choo 2000, xi).

An intelligent organization continuously scans surrounding conditions. To a large extent, conditions determine the activities and objectives of the organization. An even more dynamic ability to change is required. A threshold of chaos arises from locality (Aula 2000, 31). Scanning should be planned and managed as a strategic function, much like a research and development program that is given the critical mass of resources to pursue activities with the potential to deliver high payoffs. Scanning should be implemented as a formal, structured, continuous system that maximizes and integrates the information gathering and value-adding capabilities of an organisation. Scanning should be supported by a coherent set of information management strategies that enable an organisation to systematically collect, coordinate, store, analyse, and distribute information (Choo 2000, xii).

A weak signal is an idea or trend, which affects the organization or the operational environment. It is a new and surprising signal from the receiver's perspective, and it can be a threat or a possibility. The management of an organization is about scanning weak signals, interpreting them, and reacting to them. Scanning means the observation of weak signals of change as early as possible, so that adequate action can be taken in time. A delay (latency) is the reaction time required from the first observation of a signal of change to reaction. If the delay is shorter than that of the competition, the organization has a comparative advantage. Delay is a relative concept. Because rapid decision-making can also lead to mistakes, the organization must possess tolerance, the ability to tolerate incorrect decisions, and the ability to repair them as soon as possible. (Åberg 2000, 74–75.)

When scanning the environment, observed challenges differ according to how much information is available about them. Some challenges stand out clearly, and their effect on an organization can be assessed so accurately that required action can be planned. These are called strong signals. Other changes to the environment cause only weak signals that are vague, early signals of coming events that have significant consequences. Weak signals usually get stronger and eventually become strong signals. In an environment with high levels of interference, the organization must begin adjusting to a challenge when the signals from the environment are still weak. (Ansoff 1984, 47–48.)

From an information perspective, every change or development in the external environment creates signals and messages. Some of the signals would be weak (difficult to detect), many would be confusing (difficult to analyse), and other would be spurious (not indicative of a true change). In seeking information, an organisation would have to attend selectively to a flood of signals created by a dynamic environment, interpret often confusing messages, and make sense of clues in relation to goals and activities.

A summary of environmental scanning may include the following observations (see Figure 9) (Choo 2000, 103–104):

1. Situational dimensions: the effect of perceived environmental uncertainty. Managers who perceive the environment to be more uncertain will tend to scan more. Environmental uncertainty is indicated by the complexity, dynamism, and importance of the sectors comprising the external environment.
2. Organisational strategy and scanning strategy: the organisation's overall strategy is related to the sophistication and scope of its scanning activities. Scanning must be able to provide the information and information processing needed to develop and pursue the elected strategy.
3. Managerial traits: unanswered questions. Little is known with confidence about the effect of a manager's job-related and cognitive traits on scanning. Upper level managers seem to scan more than lower level managers. Functional managers scan beyond the limits of their specialisations.
4. Information needs: the focus on environmental scanning. Business organisations focus their scanning on market-related sectors of the environment. In industries where developments in other environmental sectors are considered highly strategic, these sectors would be scanned intensively.
5. Information seeking: source usage and preferences. Although managers scan with a wide range of sources, they prefer personal sources to formal, impersonal sources, especially when seeking information about developments in the fluid market-related sectors.

6. Information seeking: scanning methods. Organisations scan in a variety of modes, depending on the organisation's size, dependence on and perception of the environment, experience with scanning and planning, and the industry within which the organisation operates.
7. Information use: strategic planning and enhanced organisational learning. Information from scanning is increasingly being used to drive the strategic planning process. Choo's research indicates that effective scanning and planning is linked to improved organisational learning and performance.

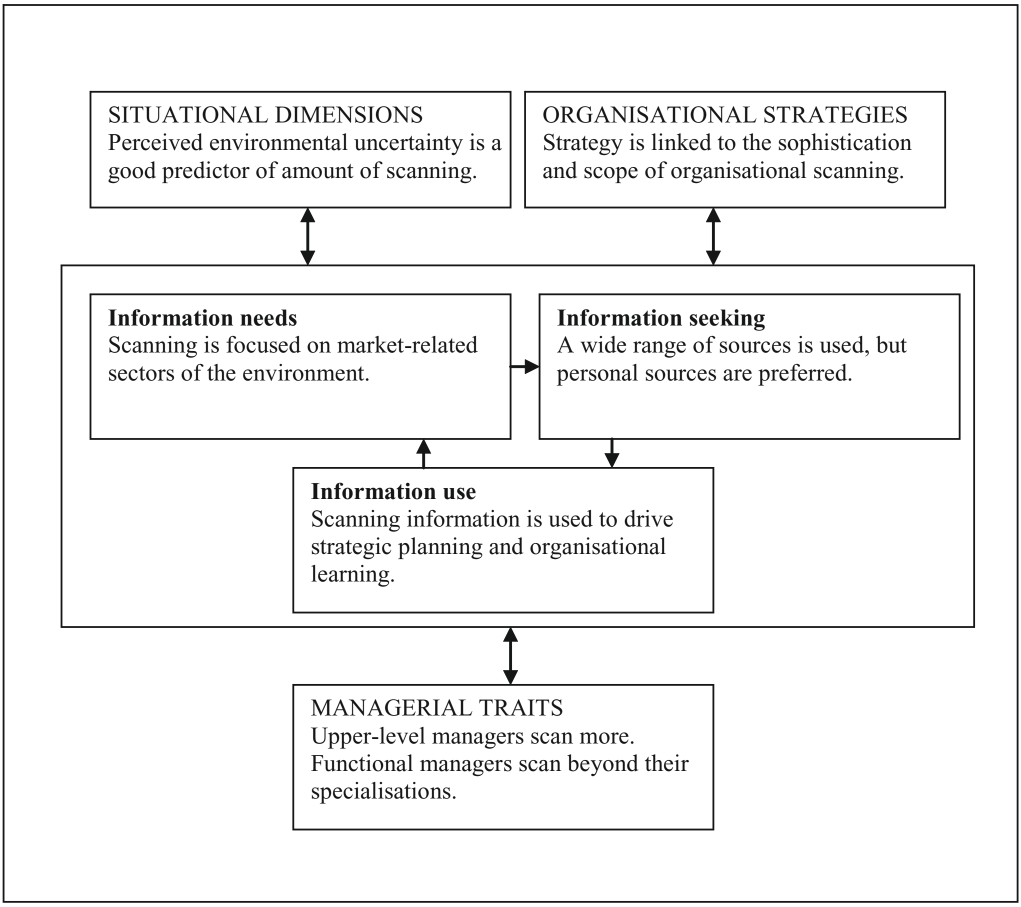

Figure 9. Summary of the principal findings from Choo's research on environmental scanning (Choo 2000, 103)

4.2 From observation to predictions

Information existing in the world is either physical, i.e., natural, or caused order of material, or linguistic, i.e. the expressive power and use of human-created language. The concept of information must be distinguished from the classic concept of information (information is a well-justified true belief), because the information contained in a sentence is completely neutral in relationship to its truth value (Niiniluoto 1992, 39). A sentence (for example, an absolute value theorem or a norm) that has no truth value is not cognitively meaningful, i.e., it has no informative meaning because it does not make any claims concerning the world. Nevertheless, a sentence like this can have emotive meaning related to the expression or awakening of feelings.

In order to understand a particular thing, it is important to create a model of the concepts related to information. Figure 10 presents a three-level information hierarchy that the views presented in this study are based on. Information is one key resource of leadership, and by using and applying information it is possible to try to achieve set goals.

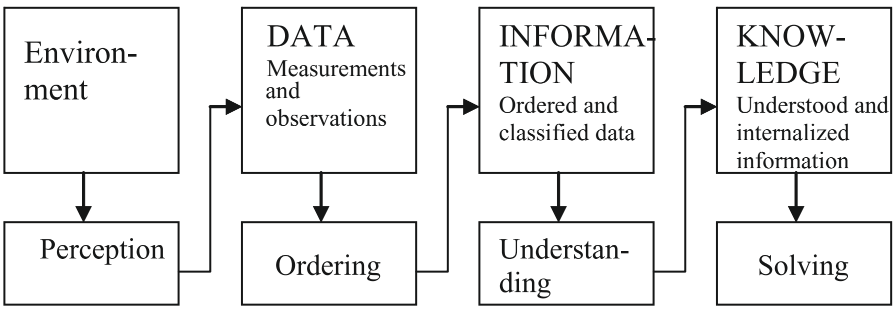

Figure 10. Information hierarchy and information refining process from observing the environment to the application of know-how (Jurvelin 2001, 17)

Halonen (2000) has defined information processes using Waltz (1998) as follows:
- observation is a physical process, in which an individual perceives, collects, measures and analyzes acquired data. It is the collecting and marking of quantitative measurement, and sending it to further processing.
- measurements and observations of data are arranged by preconditioning, calibrating, filtering and indexing the acquired data. Information elements will be focused, converted, filtered, sorted, indexed and stored for further processing.
- information is produced by binding indexed and organized data to context by focusing, correlating, and generalizing as well as by removing contradictions.
- knowledge is produced with the help of understanding and explanation using reasoning and justifications, and by controlling the uncertainty connected with information. When knowledge is efficiently applied to realize plans or operations in order to achieve a desired goal, we speak of having a point of view.

Choo (2000, 19–20) has defined the organizational intelligence process as a continuous cycle of activities that include sensing the environment, developing perceptions and generating meaning through interpretation, using memory about past experience to help perception, and taking action on the interpretations developed (Figure 11). *Sensing* is collecting information about the external and internal environment. Because an organization cannot attend to every event or development, it must select areas of priority, filter incoming data according to its interests, and sample events for learning. *Memory* is derived from the experiences of an organization in interacting with the environment, and is expressed formally (documents, procedures) and informally (beliefs, stories). Experience develops rules that are used to match situations with appropriate responses, and frames that are used to define problems and their salient dimensions. *Perception* is the recognition and development of descriptions of external events and entities using the knowledge that is available in memory. Perceptual strategies include developing a representation of an external scene, classifying objects and events according to categories that are known or have been encountered before, and recognizing the identity and main attributes of interested objects. *Interpretation* is at the centre of the intelligence cycle, as it attempts to explain, “What is really going on here?” in terms that are meaningful to the organization. Interpretation leads to understanding and creative insight by which future consequences and opportunities are anticipated and evaluated according to preferences. It is the making of meaning about where the organization was in the past, what it is today, and what it wants to be in the future. Finally, *adaptive behaviour* initiates a new cycle of learning, as an organization makes decisions and takes actions that result in effects and outcomes. These are feedback into the loop by modifying strategies, frames and rules in memory.

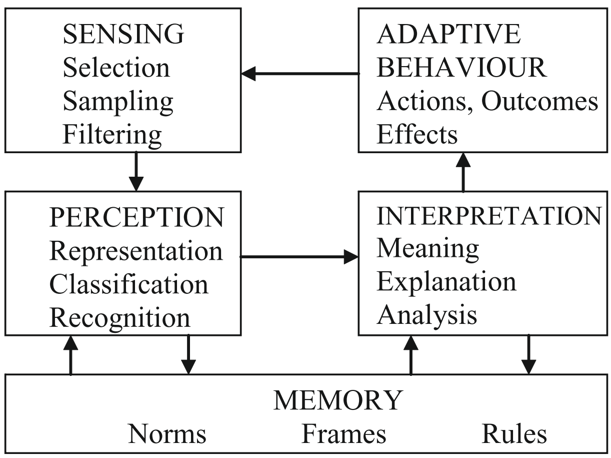

Figure 11. An organizational intelligence cycle (Choo 2000, 19)

According to the classic definition, knowledge is a well-justified true belief. Knowledge is semantic information contained in declarative sentences that fulfils the justification condition and the truth condition. Sceptics have argued that knowledge, in the classic definition of the word, is not possible for human beings. On the other hand, rationalists have argued that humans can, with their common sense or intellectual intuition, acquire reliable knowledge about mathematical truths and the higher principles of nature. Empiricists have traditionally considered the source and basis of reliable information to be sense perception purified of faulty sources. The empiricists of the new era have had to admit, though, that sense perception is always more or less uncertain. Good justification means that the available observation material, or “evidence”, supports the truth of the claim presented with the requirements of knowledge, making it “probable” in the epistemic sense. (Niiniluoto 1992, 58.)

The syntactic conception of knowledge does not pay attention to such semantic concepts as truth and non-truth (Niiniluoto 1992, 40). Syntactical knowledge may be connected to an organization's routine activities and stored in a measurable form (Aula 1999, 194). But also, in the theory of semantic information, the knowledge content of the declarative sentence and its amount are independent of the truthfulness and non-truthfulness of the sentence (Niiniluoto 1992, 40). Semantic knowledge can be characterized as qualitative information that somehow changes the interpreter's observations and actions. The world of semantic knowledge is associative, networked, and heuristic. From the viewpoint of self-directing, successful change in an organization depends on whether the change processes results in semantic knowledge and the organization can produce and process this semantic information (Aula 1999, 195).

Science is not a monolith entity. Instead, it is possible to speak of empiricist ontology, conception, and formation of information that leans on external reality, hermeneutical ontology that leans on understanding, and pragmatic ontology that leans on action. Nowadays, our thinking is directed by *empiricist conception of information*. The formation of information is so powerfully based on factors outside human beings that a mental system is not seen to have any other function but to receive and remember information and produce correct answers. The *hermeneutic conception of information* takes into consideration the individual's manner and ability of interpreting the future and his own observations. Knowledge is just understood information that also has to be defended and developed further. According to the *pragmatist conception of information*, the individual's own activity affects the formation of knowledge, not just what he factually knows or whether he understands what he knows. Those skills that are improved through practice and the individual's participation in events, in fact, all that the individual experiences, is considered to be the most central basis for the formation of knowledge. (Venkula 1993, 6–7.)

The behaviour of an individual has abilities and readiness called skill or know-how. Human beings have been able to create a constantly renewing system of improving skills that is transferred to future generations by way of language, education, and teaching. Skill can be considered the pre-phase of information. In part, human know-how does not require the ability to understand or linguistically describe the activity in question or its rules. Learning such skills is based on trial and error, imitation, or "model learning". The know-how of expert systems is, on one hand, scientific factual information; on the other hand, it is heuristic rules of action, heuristic activity rules, and therefore know-how. The compilation of know-how into computers may be a useful accessory to a decision-maker – as long as it is remembered that it is not "higher" information, only fallible human information. (Niiniluoto 1992, 64.)

An organisation works with three classes of knowledge: tacit, rule-based, and cultural. *Tacit knowledge* consists of hands-on skills, special know-how, heuristics, intuitions and the like, that people develop as they are immersed in the flow of their work activities. The transfer of tacit knowledge is by tradition and shared experience. Whereas tacit knowledge is implicit, *rule-based knowledge* is explicit knowledge that is used to match actions to situations by invoking appropriate rules. Rule-based knowledge is used in the design of routines, standard operating procedures, and the structure of data records. Rule-based knowledge enables an organisation to ensure a high level of operational efficiency, coordination, and control.

Cultural knowledge is part of an organisation's culture, and is communicated through oral and verbal texts, such as stories, metaphors, analogies, visions, and mission statements. Cultural knowledge includes the assumptions and beliefs that are used to describe and explain reality. (Choo 2000, 11–12.)

Information subject to management generally refers either to the information itself or to broader know-how and expertise about certain subjects or issues. Information and expertise have varying content and properties (Vanhala et al 2002, 223–225):
– there are different levels of information; in practice, information relates either to an individual or to an organisation; it is a feature of a specific organisation and tied to it
– the form of the information subject to management varies depending on the nature of the information, which ranges from simplified data, such as databases or statistics, to more complex sets of information, and may include expertise and actions
– information can be codified, i.e., presented in forms that enable communication and storage; what is important is that the information can be transferred from one person or organisation to another
– information involves the possibility to influence others and cater to various interests.

To summarise the main contingencies that characterises the information use of managers (Choo 2000, 54):
1. Most managerial work is action-oriented. When leaders make a decision, they are actually making a commitment to action. When leaders make sense of a situation, they are actually interpreting a context for negotiating the possibilities for action.
2. Both the internal and external environments of the leader's work unit are complex and dynamic. Internally, organisational action is played out in an intricate web of personalities, interests, and long-held beliefs. Externally, the organisation joins an environment in which competitors, customers, suppliers, stakeholders, regulators and others manoeuvre for advantage or control. The trajectories of cause and effect are hidden in a crisscross of relationships and dependencies that are never revealed.
3. The need to take prompt action in the rapid stream of an ill-defined situation challenges the capacities of individual leaders. Each leader copes by making simplifications and applying heuristics. They do not try to develop a complete representation of the problem situations they face, but work with a simplified model that captures the most salient features.

The orientation of leaders towards action suggests that they prefer concrete information to abstract information. Concrete information about specific individuals, organisation, or relationships provides leaders with the details and nuances that they need to evaluate the relevance and applicability of information. The complexity of the work environment and the need to respond quickly often mean that leaders cannot afford a thorough or systematic search of the available information. Information search starts with the recognition that a problem exists, and ends when sufficient alternatives have been found. (Choo 2000, 54–55.)

4.3 Methods to support evaluation in the decision-making process

4.3.1 Quantitative methods

The basis of the processes of classification, reasoning, and interpretation are similar in qualitative and quantitative research. Quantitative analysis operations are more unambiguous than qualitative methods. Furthermore, quantitative research divides into more distinct phases than qualitative research. The reason for this is the simple fact that computation requires carefully limited data. No matter what the type of data is, attention has to be paid to its significance, sufficiency, extent, evaluation, and repetitiveness. (Mäkelä 1990, 45.)

In statistical analysis, it is possible to calculate the size of the needed data beforehand so that code numbers can be estimated at sufficient accuracy and certain differences are revealed in a statistically reliable manner. Similar figures are not available for qualitative data. The extent of the analysis means that interpretations are not based on random compilation. The evaluation of the analysis means the ability to follow up on the reasoning, so that one can either accept the interpretations or argue against them. The repetitiveness of the analysis refers to the unambiguousness of the rules of classification and interpretation, so that their application results in similar results (Mäkelä 1990, 52–53).

Quantitative analysis compels reality to answer set questions. After this, it is easier to analyze how qualitative analysis tries to do the same. Quantitative analysis argues with figures and systematic, statistical connections. It is based on presenting the data in a chart form. Argumentation is done with average connections, and the basis for this is the search for differences among units in relation to different variables (Alasuutari 1995).

The following management science techniques are useful in quantitative analysis (Anderson *et al* 1997, 14–15):

a) linear programming techniques
- linear programming is a problem-solving approach that has been developed for situations involving maximizing or minimizing a linear function subject to linear constraints that limit the degree to which the objective can be pursued
- integer linear programming is an approach used for problems that can be set up as linear programs with the additional requirement that some or all of the decision recommendations be integer values
- goal programming is a technique for solving multifactor decision problems, usually within the framework of linear programming

b) techniques for scheduling time and activities
- network models: a network is a graphical description of a problem consisting of circles called nodes that interconnect by lines called arcs. Specialized solution procedures exist for these types of problems, enabling us to quickly solve problems in such areas as transportation system design, information system design, and project scheduling
- project scheduling (PERT/CPM): in many situations, leaders are responsible for planning, scheduling, and controlling projects that consist of numerous separate jobs or tasks performed by a variety of departments, individuals, and so forth. The PERT (Program

Evaluation and Review Technique) and CPM (Critical Path Method) techniques help leaders carry out their project scheduling responsibilities
– inventory models are used by leaders faced with the dual problems of maintaining sufficient inventories to meet the demand for goods, and, at the same time, incurring the lowest possible inventory holding costs

c) simulation techniques
– waiting-line or queuing models have been developed to help leaders understand and make better decisions concerning the operation and perform simulation computations
– computer simulation is a technique used to model the operation of a system. This technique employs a computer program to model the operation and perform simulation computations
– Markov-process models are useful in studying the evolution of certain systems over repeated trials

d) decision analysis techniques
– decision analysis can be used to determine optimal strategies in situations involving several decision alternatives and an uncertain or risk-filled pattern of events
– analytical hierarchy process: this multifactor decision-making technique permits the inclusion of subjective factors in arriving at a recommended decision
– forecasting methods are techniques that can be used to predict future aspects of a business operation
– dynamic programming is an approach that allows us to break up a large problem in such a fashion that once all the smaller problems have been solved, we are left with an optimal solution to the large problem

Multifactor analysis examines the regularities in multifactor decision-making, and aspires thus to assist in finding the ranking order of alternatives evaluated with several criteria (Jaakkola 2000, 1). The preferences or appreciations of the decision-maker have a central role in multifactor decision-making, for example in sociology, psychology, economics, and the insurance trade. The alternative's pre-eminence is based on the decision-maker's personal liking. Appreciations model the decision-maker's participation in the decision-making process. In multifactor decision-making, linear programming is in practice impossible. (Jaakkola 2000, 18.)

To forecast is to anticipate or predict some future event or condition. An explicit probability statement may be associated with a forecast. Forecasting plays an important role in the planning process. It helps to identify limits beyond which it is not sensible to plan, it can suggest rates of progress, and it can indicate possibilities that might be achieved (Quade 1989, 152–153).

In the analysis of an organization's self-direction, it would be useful to resort to simulation. The information obtained with simulations can be used to focus the verbal descriptions of organizational models. The decisive thing is to recognize the system's structural, causal, and functional mechanisms, and factors relating to feedback, self-regulation, autocatalysis, bifurcation, and bifurcation chain. Successful and creative systems do not function like machines or organisms that adjust by degrees. Instead, they develop and survive with the help of unpredictable, creative, spontaneous, and self-directing processes that are naturally dependent on chaotic factors. (Aula 1999, 193.)

As a method, simulation is relatively popular, but nevertheless, the real value of simulation research is in human research remains problematic. Simulation has been considered biologically unbelievable. There is no empirical proof that computers would work like the human brain in any sense, or that humans would obey the behaviour model that follows a particular order like computer programs. Both arguments can be countered. The biological argument concentrates somewhat on issues that are secondary to cognitive science. Cognitive simulation is interested in information and data content construction, and this information level cannot be returned to biology that works according to its own laws. The argument about following orders is also suspicious, because it is apparent that there are regularities in human behaviour (for example movement and the speech). (Saariluoma 2001, 36.)

The use of simulation requires simplification. Simulation does not preserve the causal relations of the modelled system. Thus, simulation can imitate only those behavioural habits of the system that were taken into account when building the model (Heinämaa and Tuomi 1989, 246).

4.3.2 Qualitative methods

In qualitative analysis, data is often analyzed as an entity. Analysis demands extraordinary absoluteness that differs from statistical research. All points that are considered reliable or belonging to the figure or mystery being resolved have to be clarified, so that they are not in conflict with the presented interpretation. Qualitative analysis consists of the simplification of observations and the solving of a mystery. (Alasuutari 1995, 29.)

The starting point for the combining of observations is the idea that data contains examples or samples of the same phenomenon. However, the goal of combining and simplification is not to find average individuals or typical cases. In qualitative analysis even one exception disproves the rule and shows that the entire issue needs to be thought over. By combining observations, the produced observation must be valid for all raw observations. (Alasuutari 1995, 31–33.)

In qualitative analysis, next phase is resolving the mystery. This means that on the basis of the produced clues and available hints, a meaningful interpretation of the examined phenomenon is made. At this stage data, based on statistical analysis can be used, as well as qualitative data that has been quantified and used to form statistical connections. The more clues appropriate for solving the mystery that can be found, the more correct the answer is likely to be (Alasuutari 1995, 34–39). The sense of impression of qualitative analysis can be reduced, and at the same time improve its assessment and repetitiveness by cataloguing data, separating interpretation operations into smaller segments, and particularizing rules of interpretation (Mäkelä 1990, 57).

The development of all deterministic systems cannot be predicted, because they are too complex for computational methods. However, it may be possible to use some kind of qualitative method that would not predict a phenomenon's future, but instead would categorize different alternatives (Ekeland 2001, 123). From everyday life, we know that experts are not unanimous when it comes to complicated problems on the strategic level.

Solutions are often based on subjective preferences and values. Thus, in problem-solving systems, there is a most apparent need to include a value perspective and the special features of human decision-making. (Hämäläinen 1989, vii.)

The following methods can be used in qualitative analysis: scenario writing, group judgment technology or Delphi, and operational gaming and simulation. A scenario is most often a description or prediction of the conditions under which a system or policy that is to be analyzed, designed, or evaluated is assumed to perform. *Scenario writing* is the preparation of a logical sequence of credible (but hypothetical) events leading from the present to some future time. Scenario writing is both a way of using expertise individually, as scenarios can be written by one person, and also a way of using experts collectively, because scenarios can and often are written by group of people. A scenario can also be generated by a computational model or through the sequence of plays in an operational game. (Quade 1989, 192.)

The traditional method of using *a group* of experts to arrive at a *judgment* is to conduct a round-table discussion among them, and having them eventually agree on a group position. The resulting judgment is very likely to be a compromise between divergent views, often arrived at under the influence of certain psychological factors, such as specious persuasion by the member with the greatest supposed authority or merely the loudest voice, a reluctance by certain of the participants to abandon positions that they might have taken publicly, and the bandwagon effect of a majority opinion (Quade 1989, 196).

Delphi is an iterative procedure for eliciting and refining the opinions of a group of people by means of a series of individual interrogations. Originally, this was done by written questionnaires. In practice, the group consists of experts or especially knowledgeable individuals, possibly including a responsible decision-maker. The idea is to improve the panel or committee approach in arriving at a forecast or estimate by subjecting the views of the individual participants to each other's criticisms in ways that avoid the psychological drawbacks associated with unstructured face-to-face confrontation. The Delphi procedures – anonymous response, iteration, controlled feedback, numerical estimates, and statistical "group response" – promise to become a highly effective means of group information processing. Delphi is not without its critics, because the procedures are often inappropriately used (Quade 1989, 210).

In addition to scenarios, "partially quantitative" techniques may be employed to overcome difficulties that cannot be handled by the use of computers and mathematical models. They still provide the basic requirements for using expertise efficiently: context, communication, and feedback. *Operational gaming* exercise, *simulation* with human participants, is a first step away from computers and mathematical models. Its predictive quality is very clearly a function of the intuitive insight provided by the participants. Because it allows the participants to introduce their judgments at every stage, a game provides an opportunity to consider intangibles often seen as beyond the reach of analysis. Both experts, who control the game, and the players, can let their decisions be influenced by their appraisal of the effects of the simulated environment. (Quade 1989, 201.)

4.4 Communication supports decision implementation

Decision communication routines gather as well as distribute information as part of the decision process. They consist of exploration, or the general scanning for information and passive review of what becomes available, investigating, or the focused search and research for information on a specific issue, and disseminating, or the distribution of information about progress of the decision process to interested parties (Choo 1998, 178).

Decision-making in a group or organisation is different from individual problem solving because of interpersonal relations. Whenever two or more people come together to handle a problem, interpersonal obstacles arise. As such, the decision-maker needs to make ideas clear to others and manage differences. (Littlejohn 2001, 264.) Communication is a means of sharing information, it is a way members explore and identify errors in thinking, and it a tool of persuasion. People use communication to share resources in solving problems, and communication becomes not only an instrument for accomplishing tasks, but also a means of organisation maintenance and cohesion. Communication can be viewed as a system of inputs, internal processes, and outputs. In decision-making, the inputs include information, resources, and task characteristics. The process includes interaction and decision development, and the outputs include tasks and decisions. (Littlejohn 2001, 277.)

According to Granwell (2004, 103), about communication process, in most instances participants believed a well structured, well orchestrated, multichannel communication process was critical for supporting the change and for increasing the leaders' credibility. Face-to-face, follow-up meetings helped to reinforce the change and were perceived by most participants as significant in increasing leadership credibility.

An organisation is a group of people that systematically attempts to reach certain objectives by adjusting the resources at their disposal. An organisation's operations are foreseeable to a certain extent. The possibility to anticipate operations is based on an organisation's shared view of how to allocate resources. This view is based on attaining benefits by sharing work and authority and structuring activities. (Åberg 2006, 51–52.)

A basic requirement for successful communication is that the sender has formulated the message in a way that enables the receiver to understand it. Management communication is receiving, producing, and sharing information (decisions) (Åberg 2006, 93):

> "Management communication is management work that takes place within an organisational framework which emphasises interpreting issues, producing and sharing information required for operations, directing the work of individuals and the group, organising, supervising, motivating and encouraging as well as interaction and a community spirit."

In the field of management, there exist a number of concepts, which are used by members to discuss such future-oriented behaviour. Mantere and Sillince (2007) have positioned strategic intent among two of the most relevant of these, goals and visions. They have argued that, in the creation of strategic intent, the sharing of an obsession, strategy intent is a rhetorical tool for achieving coherence between multiple intents. Rhetoric offers a way to explore the potential of an organization-level statement of strategic intent of bridging between multiple intents held by individuals and groups through a process of creating coherence. For instance, in very dynamic environments, the concept of strategic intent may have little use. Exploring the potential liabilities associated with the building of a strategic intent, or appropriate and inappropriate contexts for such pursuits, is left for future inquiries, preferably empirical ones. Therefore, it must be kept in mind that while the development of a widespread strategic intent is potentially beneficial for an organization, it is at the same time a problematic task because it may result in ideological control.

Communication is an organisational resource, which must be planned, directed, and supervised, just like all other resources. For its part, communication helps to reach an organisation's objectives and make a profit. Without communication, those who are part of an organisation don't know what its goals are, how work is shared, or how to succeed in their work. Channels related to personal supervisor/employee interaction are important in internal communications. Sender-based models have been replaced by interactive and receiver-considerate models. A subordinate has the right to information and the obligation to obtain it. (Åberg 2006, 96.)

Anticipatory decision-making is based on the appropriate interpretation of strategy and mission. Then, operations and available resources can be directed correctly. Jointly discussed and internalised values guide decision-making in the direction approved by an organisation and help personnel accept decisions.

The community can do some scanning to detect external and internal changes relevant to operations in time and take them into account in the decision-making process (Åberg 2006, 126). The Choo model is well suited to describing the scanning process. The first cycle is sense making. Weak signals are interpreted using existing expertise, which starts knowledge creation. Once an interpretation has been generated, new knowledge and expertise are created and decisions can be based on them. If these cycles function well, the decision results in goal-oriented operations that are adjusted to the new situation. Constant scanning is required to ensure that the decisions are correct and that operations change flexibly along with the operational environment.

The supervisor is the work community's most important communicator (Åberg 2006, 109). With proactive management communication, the supervisor can work on his personnel's attitudes, knowledge, motivation, commitment, and behaviour, to prepare them for an upcoming new decision and its consequences. Knowledge and opinions are the primary targets. Situations are different, and therefore, the targets being influenced change according to the situation. The hardest things to change are values, attitudes, or permanent behaviour. To that end, performance review discussions can be used as a part of genuine management. Based on these discussions, the supervisor can proactively prepare his personnel for the future based on the information available.

In motivational communication, the decision-maker must know what he wants the end result to be. Decisions must be linked to the unit's and the entire work community's objectives and needs. In motivational communication, interaction is of particular importance, in order to discover motivation-related factors. A motivated and committed person feels that his or her work is important and its objectives are worth attaining (Åberg 2006, 163).

A decision-maker isn't alone. He gets things done with the help of the organisation. This is why managerial communication emphasises the need to publish decisions and to direct, organise, and supervise implementation. A decision-maker who is a good communicator can foresee and quickly interpret the communication requirements set by the situation and knows how to flexibly use different methods of communication and make the communication situation more open to interaction (Åberg 2006, 204).

With respect to anticipatory management and managerial communication, it is important to be aware of the factors that direct an organisation's operations. They guide and influence not only every decision-maker, but also every implementing party. Values, motivation, and commitment are important cornerstones of management.

Managerial communication can be examined from the management and leadership points of view, in accordance with the duality of management. The former emphasises communication as a system composed of different channels and related rules and procedures. The decision-maker is a part of the work community's communications system. Managerial communication guides operations, which means that communication attempts to change information, attitudes, the individual's and group's behaviour, and even the individual's values and the organisational culture. An organisation must have procedures, such as scanning, used to detect and interpret weak internal and external signals of change. The leadership aspect emphasises the ability to lead an organisation's members according to the situation. Motivating members and encouraging commitment and creativity in them are challenges. (Åberg 2006, 206.)

Traditional deterministic models presenting system processes are not sufficient to explain changes and the multiform dynamics of change. These models assume that a system's processes of change are predetermined and stable, and that the system's behaviour is controllable. Another view, based on the concept of balance, explains that a system always strives for balance. This view has often been used to describe the adaptive properties of a system. Models based on the dissipative view describe change that occurs when a system's internal or external circumstances are unstable enough to tilt the system out of balance. The shape and structure of the system are broken and seek new shapes and structures. (Aula 1999, 127–129.)

According to the dissipative model, turbulence within the environment causes increasing structural instability, loss of control, or lack of resources, which create a critical state or circumstance characterised by a loss of symmetry or bifurcation in the system. This model describes the system as dynamic, open, complex, and unstable. It sees the system as being in a constant state of interaction with the environment and the uncertainty factors caused by the environment. (Aula 1999, 129.)

An organisation's behaviour is directed by human action taken in response to the challenges brought on by change. Logical decision-making and the drive to rationally balance and improve actions prevent, for their part, the impact of instabilities in the bifurcation point. The bifurcation point provides a chance to create a new dynamic order that enables one to successfully deal with increasing uncertainty. At the bifurcation point, an organisation uses communication to minimise instabilities and chooses the right path of development. Each realised choice takes an organisation towards a new point. Therefore, an organisation tries to choose the correct option so that actual development is as beneficial as possible for the organisation. (Aula 1999, 130.)

Together, integrative and dissipative communications form a double function in communication. An organisation's development is described using the concept of bifurcation, whereas integrative communication directs the organisation towards order. Integrative communication attempts to preserve existing structures and repeat them. Dissipative communication changes the choices made at an organisation's bifurcation point. Dissipative communication is useful when problem-solving requires innovative, creative, and interactive approaches. It leads to anticipation and to the birth of new structures.

There is a clear role for this double function in anticipatory decision-making. Integrative communication is emphasised in decision implementation, whereas dissipative communication refers to the environment's communication to the organisation and enables the creation of disorder, or it could be the product of failed implementation.

4.5 Basis and Structure of Decision Support System

It is often the case that a relatively simple model with only a few parameters can be found that closely represents the real world problem. The need for this is particularly important in decision modelling. The obvious but often forgotten fact is that decisions are made by decision makers. A decision model is not intended to replace the decision maker. Its usefulness is limited to aiding this person to understand the structure and implications of alternate decision choices. If the model is so complex or contains so many parameters and built-in dependencies that the decision maker finds it difficult to understand, it will probably have no impact on the decision-making process. (Marshall and Oliver 1995, 134.)

According to McCosh and Scott-Morton (1978, 3):

> "The decision support system (DSS) is supporting the decision processes of managers with flexible access to models and relevant information". This approach emphasizes the analysis of key decisions with the aim of improving both effectiveness and the efficiency of decision-making.

The information systems of an organisation will be required to help it analyse the business, along with its environment, and formulate and check that it achieves its goals. The information system may help the organisation to achieve improved efficiency of its operations and effectiveness through better managerial decisions. Information systems include transaction processing systems, decision support systems, expert systems, and office automation systems, all of which are outlined below (Avison and Fitzgerald 1995, 3). Decision support systems aid the decision-making of management. Such systems may use the whole range of facts about an organisation, or part of an organisation, or sometimes relate to aspects external to an organisation, that is, its environment, to provide information to aid the decision maker.

The decision-support system theme has a number of variants. Management information systems concentrate on summary information, executive information systems stress the presentation of information to senior managers, information retrieval systems usually provide information from one database source, but provide it quickly and efficiently, and use computer supported co-operative work, which supports collaborative decision-making. (Avison and Fitzgerald 1995, 5.)

Leaders, such as heads of department, who check the summary information to ensure that the weekly objectives of the business are being met, might be typical users of management information systems. Top management interested in using information for long-range planning might use executive information systems. Secretaries producing documents might be users of office information systems. Problem-solvers will use the expert systems available. These people are all 'users', but very different ones. (Avison and Fitzgerald, 1995, 6.)

Decision support systems are designed, built, and used to assist in the activity that they are named for: supporting the decision-making process. A decision support system is a system under the control of one or more decision makers that assists in the activity of decision-making by providing an organized set of tools intended to impart structure to portions of the decision-making situation and to improve the ultimate effectiveness of the decision outcome. The effectiveness of a given decision is an essential element in the decision-making process. Common DSS characteristics are (Marakas 1999, 3):

- intended to support decision makers rather than replace them
- is under control of the DSS user
- uses underlying data and models
- is interactive and user-friendly
- is generally developed using an evolutionary, iterative process
- can provide support for multiple independent or interdependent decisions
- provides support for individual, group-, and team-based decision-making context

Potential benefits of use of DSS can be seen as follows (Marakas 1999, 5):

- extent the decision maker's ability to process information and knowledge
- extent the decision maker's ability to tackle large-scale, time-consuming, complex problems
- shorten the time associated with making a decision
- improve the reliability of a decision process or outcome
- encourage exploration and discovery on the part of the decision maker

Limitations of use of DSS can be seen as follows (Marakas 1999, 5):

- DSSs cannot yet be designed to contain distinctly human decision-making talents such as creativity, imaginativeness, or intuition
- the power of a DSS is limited by the computer system upon which it is running, its design, and the knowledge it possesses at the time of its use
- DSSs are normally designed to be narrow in scope of application, thus inhibiting their generalisability to multiple decision-making contexts

In very general terms, a decision support system (DDS) is a system that supports technological and managerial decision-making by assisting in the organisation of knowledge about ill-structured, semi-structured, or unstructured issues. The primary components of a decision support system are a database management system (DBMS), a model-base management system (MBMS), and a dialog generation and management system (DGMS). Emphasis in the use of a DSS is on provision of support to decision makers in terms of increasing the effectiveness of the decision-making effort. This involves the formulation of alternatives, the analysis of their impacts, and interpretation and selection of appropriate options for implementation. (Sage 1991, 1.)

The extent to which a support possesses the capacity to assist a person or a group to formulate, analyse, and interpret issues will depend on whether the resulting system should be called a management information system (MIS), a predictive management information system (PMIS), or a decision support system (DSS) (Figure 12). Fundamental to the notion of decision support system is assistance provided in assessing a situation, identifying alternative courses of action, formulating a decision situation, structuring and analysing a decision situation, and then interpreting the results of analysis of the alternatives in terms of the value system of the decision maker. (Sage 1991, 5.)

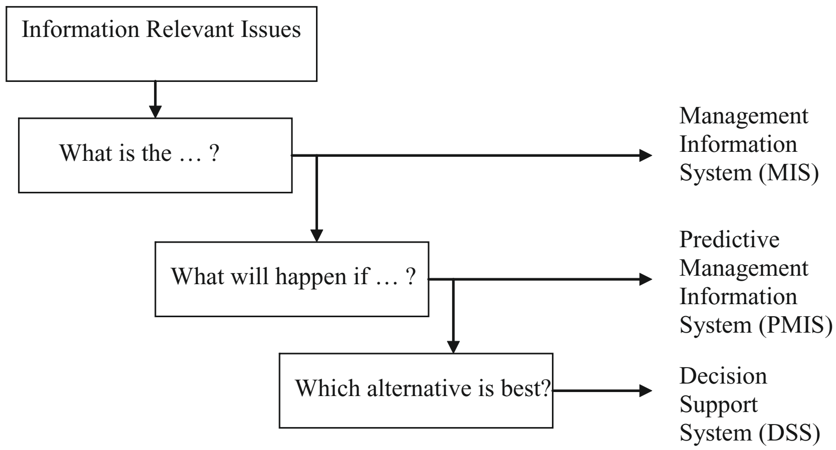

Figure 12. Conceptual differences between MIS, PMIS, and DSS (Sage 1991, 6)

Sage has discussed three previous principal components of a decision support system, DBMS, MBMS, and DGMS, and an appropriate decision support system design framework will consider each of these three component systems and their interrelations and interactions. The interconnection of these generic components and the interaction of the decision maker with the system through the DGMS is illustrated in Figure 13.

A *database management system* (DBMS) is one of the three fundamental components of a decision support system. An appropriate DBMS must be able to work with data that is internal to the organisation and data that is external to it. Some of the desirable characteristics of a DBMS include the ability to cope with a variety of data structures that allow for probabilistic, incomplete, and imprecise data, and data that is unofficial and personal, as contrasted with official and organisational. The DBMS should be capable of informing the support system user of the types of data that are available and how to gain access to them.

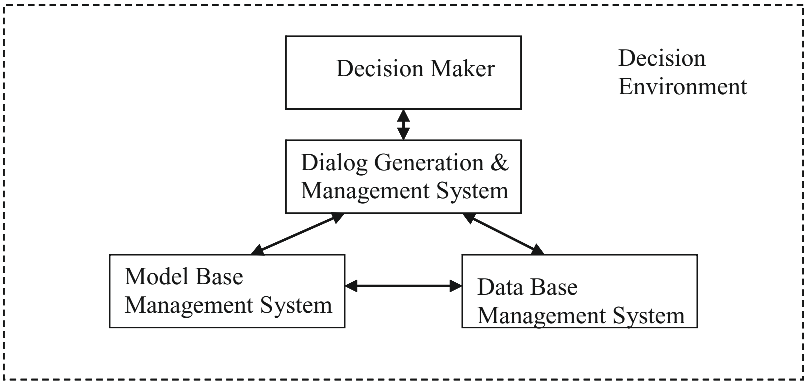

Figure 13. Generic components in decision support system (Sage 1991, 7)

The *model-base management system* (MBMS) that Sage is able to provide for sophisticated analysis and interpretation capability is a decision support system. The single most important characteristic of a MBMS is that it enables the decision maker to explore the decision situation through the use of a database by a model base of algorithmic procedures and associated model management protocol. The subject of model-base management, and its use in managing decision models, is a very important one for decision support systems development. Among the developments in this area are the use of expert systems for rapidly constructed models, the use of heuristic search techniques for selection and integration of models in to the DSS, and the development of approaches for interpretation of the analysis results of model use.

The *dialog generation and management system* (DGMS) portion of a decision support system is designed to satisfy knowledge representation, and control and interface requirements of the DSS. It is the DGMS that is responsible for presentation of the information outputs of the DBMS and MBMS to decision makers and for acquiring and transmitting their inputs to the DBMS and the MBMS. The DGMS is responsible for producing DSS output representations, for obtaining decision maker inputs that result in operations on representations, for interfacing to memory aids, and for explicit provision of the control mechanisms that enable the dialog between user input and output and the DBMS and MBMS.

4.5 Conclusions

People must be able to quickly, efficiently, and reliably gather pre-determined signals and signs and react to them. Instead of a temporally and locally defined physical space, people must operate in multi-dimensional spaces of signs and symbols. Expert systems contain scientific factual information and heuristic rules of activity, i.e., know-how. Assembling knowledge into computers is a useful accessory to the decision-maker.

In order to introduce an anticipatory influence to an artificial decision-making system, it is necessary that anticipations are learned and presented in some form. People have certain beliefs about how the world works and how they are able to influence their environment.

However, it is not clear how their model of the world is formed and modified by life experience, nor how exactly knowledge is structured in the brain (Butz 2002, xix).

The processes of classification, reasoning, and interpretation have the same basis in both qualitative and quantitative research. The use of these two types of methods aims for logical justification and objectivity on the basis of observation data. Qualitative and quantitative analysis can be applied in the same study and in the analysis of the same data. Quantitative analysis argues on the basis of figures and the systematic and statistical connections between them.

The three techniques that stand out as consistently being at the top of the list include statistical methods, linear programming, and simulation (Anderson *et al* 1997, 15). Computer simulation is possible only if the object of the simulation can be described as an accurate logical structure. The use of simulation requires simplification of the environment, i.e., modelling.

Anticipatory management responds to changes, weakening predictability of events, and shortened planning of the current operational environment. Thinking is focused on the creation of potential solution alternatives and purposeful selection between them. The creation of solution alternatives takes advantage of previously learned models, but emphasizes their rejection in situations in which they can be a hindrance to operating (Kuokkanen 2004, 115).

In anticipatory management, it is essential to form clearly defined goals for activities and selection criteria for alternatives in advance. In a complex and dynamic environment, the information related to decision-making has to be analyzed, the risks of the activity have to be assessed, and forming uncertainties have to be weighted appropriately. The decision's temporal permanence and duration must be given attention in the planning phase. This responds to constant change in the operational environment and, thus, to the weakening of predictability. In addition to situation follow-up, a continuous readiness in preparation, decision-making, and implementation is maintained. These functions are firmly networked to each other.

Anticipatory management includes the processes of problem-solving (Figure 14). With management measures, an organization takes advantage of the operating sequence of structured problem-solving, while increasing its knowledge and know-how at the individual and organizational levels. Knowledge and know-how that are in accordance with a decision are actively used during implementation. Knowledge and know-how acquired through rejected alternatives remain in individuals' and the organization's information structures of decision-making, and have a later influence either as active or tacit information. (Kuokkanen, 2004, 116.)

Both the decision-making and interpretation perspectives are complementary ways of understanding information seeking and use in organisations. Rational, systematic decision-making is probably better suited to solving problems in which issues are clearly identified. On the other hand, collective interpretation may be needed in dealing with problems in which issues are unclear and information is ambiguous. Any attempt to study the use of information in organisations would benefit from applying the two points of view. (Choo 2000, 8.)

Regulating the interaction between an organization and its environment is an essential part of leadership. The goal of the interaction is to ensure that an organization's internal activity is based on a realistic conception of the outside world. Outlining surrounding conditions is important, because they contain the basic task, the acquisition of resources, several limitations on activities, as well as most threats and opportunities (Lönnqvist 1995, 49). The environment must be continuously scanned, and a realistic image of it formed. The environment must be made favourable to one's own operating by increasing its disintegration and then assembling it into a form that is controllable in light of one's own operating. As the situation develops, the relationship between an organization and the environment must be constantly evaluated.

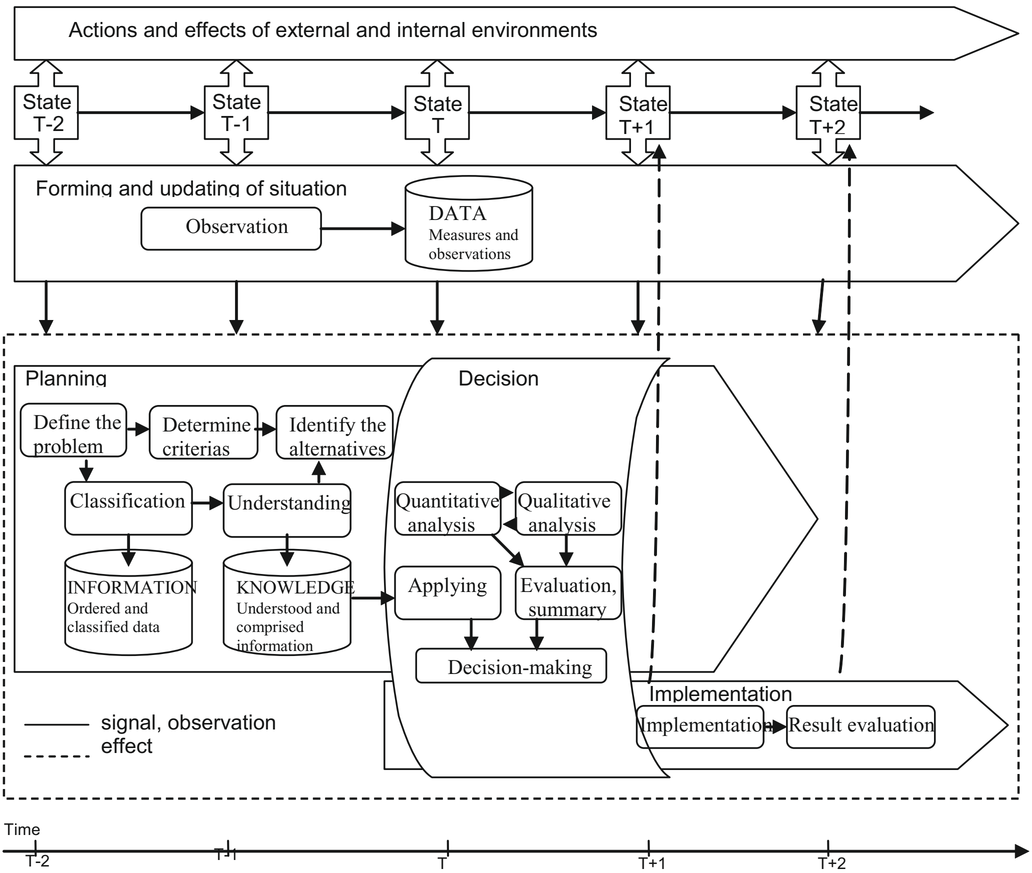

Figure 14. The connection between anticipatory management and problem-solving processes and the development of information. The dotted line illustrates the effect of implementation on the environment and an integrative communication, while the solid line illustrates observations of the environment to the decision-making process and dissipative or integrative communication.

Anticipatory decision-making is based on models prepared of the environment, which include presentations of situation picture, statistics, situation maps, and so on. They describe a "real" situation in which a decision will be made. Thus, the decision-maker works in an environment created by the models, not in a real environment.

From the decision-maker's point of view, the environment's communication can be either dissipative or integrative, or possibly both. The decision-maker is not necessarily in active interaction with the environment. In these cases, some of the information coming in from the environment is interpreted by the decision-maker and may thus be unconfirmed. The information is unclear or may lack contributory factors and their values, meaning that options and decisions are prepared in a state of uncertainty.

The decision-maker's communication during implementation of the decision has to be integrative in order to outline the correct direction and reach the desired state. Interactive communication must be used in order to ensure that the implementing parties truly understand a decision's contents and its significance to an organisation's everyday activities.

In accordance with the basic communications paradigm, communication has a goal or an objective, and by communicating in a certain way, that goal or objective can be reached. Correspondingly, decision-making may be positioned in the communication chain as follows: A → B → C = X, where A is the environment, B is the decision-maker, C is the implementing party and X is the result (desired or otherwise). The decision-maker receives feedback on the result by observing and interpreting changes in the environment.

Management takes place within the framework of the organisational strategy. In order for a decision to have an impact, it has to be formulated into a message and communicated so that meanings can be produced for the decision and it can be shared and interpreted. The decision-maker implements decisions with his group; therefore, managerial communication highlights the directing, organising, and supervising of work.

In accordance with Åberg's (2006, 98) principles of result communication, the model can also be applied to decision-making and its communication as follows:

- operations are supported, communication is required to produce decisions and transfer them to implementation
- the work community is profiled in order to create a clear long-term operational decision-making profile
- sharing information; communication is required to inform about decisions and related events
- communication is required to familiarise the members of the work community with the decisions and the decision-making system.

Anticipatory decision-making is based on appropriate interpretation of strategy and mission. Then, operations and available resources can be directed correctly. With proactive management communication, the supervisor can work on his personnel's attitudes, knowledge, motivation, commitment, and behaviour, in order to prepare them for an upcoming new decision and its consequences. Knowledge and opinions are the primary target. Situations are different, and therefore the targets being influenced change according to the situation. The hardest things to change are values, attitudes, or permanent behaviour. Based on performance, review discussions, and the information at his disposal, the supervisor can proactively prepare his or her personnel for the future.

A decision-maker gets things done with the help of the organisation. This is why managerial communication emphasises the need to publish decisions and to direct, organise, and supervise implementation. A decision-maker who is a good communicator can foresee and quickly interpret the communication requirements set by a situation and knows how to flexibly use different methods of communication to make the communication situation more open to interaction.

With respect to proactive management and managerial communication, it is important to be aware of the factors that direct an organisation's operations. They guide and influence not only every decision-maker, but also every implementing party. Values, motivation, and commitment are important cornerstones of management.

Models that are associated with decision-making and support it are used to develop new constructs. The use of a decision support system (DSS) is a provision of support to decision makers, in terms of increasing the effectiveness of the decision-making effort. This involves the formulation of alternatives, the analysis of their impacts, and interpretation and selection of appropriate options for implementation. When factors that influence decision-making are modelled in line with managerial principles, available resources, environment, and communication, the overall model supports the chosen decision-making model. Computer science provides users with a database design and programming support tools that are needed in a decision support system. A decision support system is assistance provided in assessing the situation, identifying alternative courses of action, formulating the decision situation, structuring and analysing the decision situation, and then interpreting the results of analysis of the alternatives in terms of the value system of the decision maker. In the next chapter, these models are examined using mathematical models related to and supporting decision-making, and new constructs are created from these models.

Chapter 5

Probabilistic Decision-Making and Bayesian networks

The previous chapter discussed anticipatory decision-making, and how to prepare for, to carry out, to communicate, and to learn about decision-making. This chapter focuses first on the possibilities of probabilistic decision-making. Second, this chapter reviews classification, Bayesian belief networks, influence diagrams, qualitative networks, and time-critical Bayesian belief networks. Finally, conclusions of these methods are presented.

5.1 Basis for probabilistic decision-making

5.1.1 Problem of decision-making

Probabilistic methods provide coherent prescriptions for choosing actions and meaningful guarantees of the quality of these choices. The prescriptions are based on the paradigm that normative knowledge – judgments about values, preferences and desirability – represents a valuable abstraction of actual human experience, and that like its factual-knowledge counterpart, it can be encoded and manipulated to produce useful recommendations. Whereas judgments about the likelihood of events are quantified by probabilities, judgments about the desirability of action consequences are quantified by utilities (Pearl 1988, 289).

A decision problem shall be described as any situation in which choices are to be made among alternative courses of action with uncertain consequences. A structure of decision problem is determined by four basic elements (Bernardo and Smith 2003, 16):

- a set $\{a_i, i \in I\}$ of available actions, one of which is to be selected
- for each action a_i, a set $\{E_j, j \in J\}$ of uncertain events, describing the uncertain outcomes of taking action a_i
- corresponding to each set $\{E_j, j \in J\}$, a set of consequences $\{c_j, j \in J\}$
- the relation $\leq$, which expresses the individual decision-maker's preferences between pairs of available actions, so that $a_1 \leq a_2$ signifies that a_1 is not preferred to a_2.

Suppose action a_i will be chosen, then one and only one of certain events E_j, $j \in J$, occurs and leads to the corresponding consequence c_j, $j \in J$. Each set of events $\{E_j, j \in J\}$ forms a partition of the total set of possibilities. Within the relation, it is possible to compare some or all the pairs of available options and put them in a preferred order.

A formal definition of a decision problem is written as follows. This will be presented in a compact form, detailed elaboration is provided in the remarks following the definition.

Definition (Bernardo and Smith 2003, 18–19). A decision problem is defined by the elements ($\mathcal{E}$, $\mathcal{C}$, $\mathcal{A}$, $\leq$), where:
- $\mathcal{E}$ is an algebra of relevant events, E_j
- $\mathcal{C}$ is a set of possible consequences, c_j
- $\mathcal{A}$ is a set of options, or potential acts, consisting of functions which map finite partitions of Ω, the certain event in $\mathcal{E}$, to compatibly-dimensioned, ordered sets of elements of $\mathcal{C}$
- $\leq$ is a preference order, taking the form of a binary relation between some of the elements of $\mathcal{A}$.

The algebra $\mathcal{E}$ will consist of what might be termed real-world events, together with any other hypothetical events, which it may be convenient to bring to mind as an aid to thought. The class $\mathcal{E}$ will simply be referred to as the algebra of events. It is denoted by $\mathcal{C}$, the set of all consequences that the decision-maker wishes to take into account, preferences among such consequences will later be assumed to be independent of the state of information concerning relevant events. The class $\mathcal{C}$ will simply be referred to as a set of consequences. The term action is used to refer to each potential act available as a choice in a decision situation. Within the wider frame of discourse, the preferred term option may include hypothetical scenarios. The class $\mathcal{A}$ of options, or potential actions, will simply be referred to as the action space.

Either beliefs are to be used directly in the choice of an action, or are to be reported in some selected form, with the possibility or intention of subsequently guiding the choice of a future action. Using early presented notation, the elements of a decision problem in the inference context are:
- $a \in A$, available "answers" to the inference problem
- $\omega \in \Omega$, unknown states of the world
- $u : A \times \Omega \rightarrow R$, a function attaching utilities to each of the consequences (a,ω) of a decision to summarise inference in the form of an "answer", a, and an ensuing state of the world, ω
- $p(\omega)$, the specification, in the form of a probability distribution, of current beliefs about the possible states of the world.

The optimal choice of answer to an inference problem is an $a \in A$, which maximises the expected utility,

$$\int_{\Omega} u(a, \omega)p(\omega)d\,\omega. \qquad (1)$$

Alternatively, if instead of working with $u(a,\omega)$, it is performed with a so-called loss function,

$$\int_{\Omega} (a, \omega)f(\omega) - u(a, \omega)\,, \qquad (2)$$

where f is an arbitrary, fixed function, the optimal choice of answer is an $a \in A$, which minimises the expected loss,

$$\int_{\Omega} l(a, \omega)p(\omega)d\,\omega\,. \qquad (3)$$

It is clear from the forms of the expected utilities or losses which have to be calculated in order to choose an optimal answer, that, if beliefs about unknown states of the world are to provide an appropriate basis for future decision-making, where, as yet, *A* and *u* (or *l*) may be unspecified, it is necessary to report the complete belief distribution *p(ω)*. However, in an immediate application to a particular decision problem, the optimal answer may turn out to involve only limited, specific features of the belief distribution, so that these are "summaries" of the full distribution suffice for decision-making purposes. (Bernardo and Smith 2003, 256.) Bayesian decision theory formulates rational behaviour as the maximization of subjective expected utility. The Bayesian approach of combining individual preferences and beliefs has turned out to be suitable in numerous contexts in artificial intelligence and statistics. Still, the Bayesian paradigm creates a few controversies because of the relativism that arises unavoidably from its subjectivity, and another reason may be certain practical difficulties concerning the building and handling of complex models.

The principles of expected utility assume that the subject can assign a probability distribution on the set of possible words. Commonly, two different interpretations of probability are distinguished; the classical, 'objective' one, and the Bayesian, 'subjective' one. In the classical interpretation, the probability of an event is taken to be limiting relative frequency of occurrences of the event under a suitable specified infinite random trial. Under this interpretation, probabilities are usually considered as 'objective', real entities of the world that are independent of the subject. This is in sharp contrast to the Bayesian subjective interpretation. Under the Bayesian interpretation, probabilities can be assigned to any meaningful statement about the world. The probability of a statement measures a subject's uncertainty, or degree of belief, about the truth of the statement.

The set of actions available to an individual in any given situation can be represented by a variable or a group of variables that are under the full control of the decision-making individual. Choosing an action amounts to selecting a set of decision variables in a Bayesian network and fixing their values unambiguously. Such a choice normally alters the probability distribution of another set of variables, judged to be consequences of the decision variables. If each configuration *c* of the consequence set ***C*** is assigned a utility measure *U(c)*, representing its degree of desirability, then the overall expected utility associated with action a is given by

$$U(a) = \sum_{c} U(c)P(c \mid a,e) \qquad (4)$$

where $P(c|a,e)$ is the probability distribution of the consequence configuration ***c***, conditioned upon selecting action *a* and observing evidence ***e***. (Pearl 1988, 290.)

Consequences of actions are normally not associated with numerical payoffs, but instead involve complex descriptions of a world situation. A rational method of choosing between two actions would be to evaluate the benefit (or value, or desirability) of each of the various consequences and weight the benefits with the probabilities that the consequences will occur. (Pearl 1988, 290–291.)

5.1.2 Modelling of decision-making using Bayesian method

The goal of statistical modelling is to find nontrivial cause and effect relationships and to predict the likely outcomes of observed situations. A statistical model is a mathematical description of information and uncertainty related to the target being studied, and it is used to change knowledge of the modelled target area into an inductive group of rules. The probability model consists of parameters and relationships between them. A probability distribution is connected to each probability model.

The first step of the modelling process is to identify those determining variables (covariants) of the target that have great explanatory power over predictive variables. In the second phase, the relationships between determining and predictive variables are described. In case of a model that already has parameters, the relation induced by dependence assumptions is presented as a directed network. The network presentation describes knowledge about the relationships between the parameters of the domain. If interpretation of causality is added to the network structure, we can speak of causal networks (Pearl 1988).

Whatever causal knowledge is necessary for building a model is assumed to be possessed by the decision maker, and is captured in the conditional probability distributions in the model. The decision maker is assumed to know that, for example, manipulating the barometer will not affect the weather. The problem is pushed away from the formalism to the interaction between the decision analyst and the decision maker and, effectively, since reference to causality seems to be unnecessary in decision models, decision theorists and decision analysts can afford to deny any connection between directionality of arcs and causality. (Druzdzel and Simon 1993.)

The ability to predict the effect of changes in structure is important for intelligent decision support systems that autonomously generate and evaluate various decision options. To be able to perform this task, they need a way to compute the effect of imposing values or probability distributions on some of the variables in a model. This can be done only if the model contains information about the causal relations among its variables. (Druzdzel and Simon 1993.)

Causal ordering is an asymmetric relation between variables, determined by collection of mechanisms embedded in a system. It is defined formally in the context of models of real-world systems, whose primitives are equations describing mechanisms acting in these systems. Causal ordering is qualitative in nature, in the sense that it does not require full algebraic specifications of equations in the model. Actually, knowledge of which variables in a model participate in which equations is sufficient.

Decision makers are usually encouraged to specify variables that are directly relevant probabilistically or causally to a variable and influence that variable directly. These variables neighbour one another in a graph and a directed arc is drawn between them. Often, the direction of this arc reflects the direction of causal influence, as perceived by the decision maker. Sometimes, the direction of the arc reflects simply the direction in which the elicitation of conditional probabilities was easier. Knowledge of causal asymmetries is necessary in predicting the effects of changes in the structure of the system and, because of the role of causality in human reasoning, is essential in human-computer interfaces to decision support systems. (Druzdzel and Simon 1993.)

Bayesian methods provide formalism for reasoning about partial beliefs under conditions of uncertainty. In this formalism, propositions are given numerical parameters signifying the degree of belief accorded them under some body of knowledge, and the parameters are combined and manipulated according to the rules of probability theory (Pearl 1988, 29–33).

In the Bayesian formalism, belief measures obey the three basic axioms of probability theory:

$$0 \leq P(A) \leq 1 \tag{5}$$

$$P\,(Sure\_proposition) = 1 \tag{6}$$

$$P(A \vee B) = P(A) + P(B) \text{ if A and B are mutually exclusive.} \tag{7}$$

The third axiom states that the belief assigned to any set of events is the sum of the beliefs assigned to its nonintersecting components. More generally, if B_i, i = 1, 2,…,n, is a set of exhaustive and mutually exclusive propositions (called a *variable*), then $P(A)$ can be computed from $P(A, B_i)$, i = 1, 2,…,n, using the sum

$$P(A) = \sum_i P(A, B_i). \tag{8}$$

Contrary to the traditional practise of defining conditional probabilities in terms of joint events,

$$P(A \mid B) = \frac{P(A,B)}{P(B)} \tag{9}$$

Bayesian philosophers see the conditional relationship as more basic than that of joint events, i.e., more compatible with the organisation of human knowledge.

As in equation 8, the probability of any event A can be computed by conditioning it on any set of exhaustive and mutually exclusive events B_i, i = 1, 2,…,n,

$$P(A) = \sum_i P(A \mid B_i)P\,B_i). \tag{10}$$

This decomposition provides the basis for hypothetical reasoning in the Bayesian formalism.

The basis of Bayesian techniques lies in the inversion formula (Pearl, 1988),

$$P(H \mid e) = \frac{P(e \mid H)P(H)}{P\,(e)}, \tag{11}$$

which states the belief is a hypothesis H upon obtaining evidence e can be computed by multiplying previous belief $P(H)$ by the likelihood $P(e|H)$ that e will materialise if H is true. $P(H|e)$ is called the *posterior* probability, and $P(H)$ is called the *prior* probability. The dominator $P(e)$ hardly enters into consideration, because it is merely a normalising constant $P(e) = P(e|H)P(H) + P(e|\neg H)P(\neg H)$, which can be computed by requiring that $P(H|e)$ and $P(\neg H|e)$ sum to unity.

In Bayesian reasoning, the inversion problem "What is model M's likelihood, when condition D has been observed?" is to be solved, when the direct problem "What are observed state D's likelihoods, if model would be M?" can be solved. The task is to solve posterior-probability distribution $P(M|D)$ when the credibility function $P(D|M)$ is known. To the posterior distribution, it is presented thus:

$$P(M \mid D) = \frac{P(M,D)}{P(D)} = \frac{P(M)P(D \mid M)}{P(D)} \propto P(M)P(D \mid M) \qquad (12)$$

The equation's term $P(D|M)$ is a likelihood term. The term $P(M)$ is a priori likelihood distribution. So that deduction can be applied, a priori likelihood distribution has to be defined for the models. The priori distribution places background knowledge into posterior distribution. When new situations D' are observed, the posterior distribution functions as the new priori distribution. This way, the degrees of beliefs about the state can be updated in a way that is mathematically conflict free. Because P(D) is one invariant constant in relation to the model, it is sufficient to examine the outcome $P(M)P(D|M)$, when comparing hypotheses or estimating the posterior distribution with sampling techniques.

Posterior-likelihood is calculated

$$P(M)P(D \mid M) = \int_{dom(\Theta_M)} f(M,\theta_u) f(D \mid M,\theta_u) d\theta_u \qquad (13)$$

applying with all model class M's unknown parameters θ_u.

The hierarchical model M is the qualitative and quantitative logical description of the combined probability distribution of the parameter vector. Its characteristic network defines the qualitative description that describes the dependencies between parameters, but does not address the strength of these dependencies. Local density functions $f_i(\theta_i \mid pa(\theta_i))$ provide the quantitative description of the model that defines the strengths of the dependencies of model M.

Definition. A hierarchical model is the triplet M = (F, Θ_M, G) , in which $\Theta_M = (\theta_1 \ldots \theta_M)$ is a random vector, hereinafter called a parameter vector. Component $\theta_1 = \Theta_{M\pi(i)}$ of the parameter vector Θ_M are called parameters. F = $\{f_1,\ldots,f_n\}$is a group of functions. $G = (V, E)$ is a directed network, in which $V = \{v_1,\ldots,v_m\}$ and $E \subset V \times V$. The network G is called the characteristic network of model M. The arguments of function $f_i \in F$ are variable $\chi_i \in dom(\theta_i)$ and those parameters $pa(\theta_i)$ of the parameter vector Θ_M that are θ_1's immediate parents in network G. The function f_i needs to be x_i's density function when parameters $pa(\theta_i)$ have been attached. Thus, every function f_i contains a group of probability functions $B_i = \bigcup_{y \in dom(pa\theta_i)} \{f_i(y,x_i) \mid x_i \in dom(\theta_i)\}$. Furthermore, $P(y \in A \mid pa(\theta_i)) = \int_A f_i(pa\theta_i), |,x_i) dx_i$ has to apply with every $1 \le i \le n$ and $A \subset dom(\theta_i)$.

In practice, characteristic network G is first formed from the model M, so that it describes the dependencies between the parameters of the target group and then defines the density functions for parameters that correspond to network nodes. Characteristic network G of model class M is called a Bayes network. If it is non-cyclic, to its node v_i is added the corresponding parameter θ_i's density function $f_i(\theta_i|pa(\theta_i))$, and its structure presents the conditional independency assumptions of the target to be modelled, and those only through d-separation (Pearl 1988).

Likelihood model's learning is comprised of the two phases; a conditional independence model and so qualitative description's (without cycle network), and quantitative description's (parameter and their density functions) learning. An arbitrary dependency model is not in the presentable network form (Pearl 1988).

5.2 Related work on Bayesian networks

5.2.1 Bayesian belief networks

A belief network consists of a qualitative part, encoding a domain's variables and the probabilistic influences among them in a directed graph, and a quantitative part, encoding probabilities over these variables. Probabilistic information is available in many different shapes. It ranges from numerical point and interval probabilities, through order of magnitude estimates and signs of influences and synergies, to purely qualitative statements concerning independence of variables. (Druzdzel and Van der Gaag 1995.)

Probabilistic networks are known to be an effective representation for decision-making and reasoning. Since probabilistic networks have precise, local semantics, human experts can often provide prior knowledge in the form of strong constraints on the initial structure of the network. Probability theory views the world as a set of random variables $X_1,\dots, X_n$, each of which has a domain of possible values. The key concept in probability theory is joint probability distribution, which specifies a probability for each possible combination of values for all random variables. Given this distribution, one can compute any desired posterior probability given any combination of evidence (Binder *et al* 1997).

Bayesian Belief Networks (BBNs) have become popular as means of representing uncertainty within various problem domains. The structure of a BBN readily permits the fusion of expert domain knowledge with an information stream, and the updating of beliefs as new information or evidence is obtained. A BBN has the topology of a directed acyclic graph (DAG). Each node represents a variable of interest in the domain that is being modelled. There are two types of variables permitted – random and deterministic. A deterministic variable is one that always returns the same output value for a fixed set of inputs. Although usually less common than random variables, deterministic variables often take the form of simple functions such as min, max or sum, or else act as logical operators. (McNaught 2003.)

The arcs in the DAG represent direct probabilistic dependencies between variables. They encode qualitative knowledge about a domain, most often elicited from domain experts.

The DAG portrays a particular factorisation of the joint probability distribution of all the variables in the system, making extensive use of conditional independence relations in order to make the computational burden feasible.

There are two main elements to be considered in the construction of BBN – the dependency structure as represented by a DAG, and the associated set of probability distributions. In some studies, both of these elements have been elicited from domain experts. In some others, both elements have been derived or learned from a data set, while yet another group makes use of experts to derive the structure, but also uses a data set to estimate probability distributions. This latter option is particularly appealing for a number of reasons. Firstly, experts appear to be comfortable with the task of structuring the dependence relations in a domain. They are usually less comfortable, however, with providing probability estimates. Furthermore, in some cases, a large number of probabilities may be required. This can put unreasonable time demands on experts, particularly in domains such as medicine. (McNaught 2003.)

There are many approaches to the automated construction of a BBN from data. An obvious problem is the potentially huge number of possible DAGs, which might be appropriate for even a moderate number of variables. If there is some prior knowledge concerning the likely structure of a domain, this provides useful constraints on the model space to be searched. In order to assess the fit of models to a data set, many scoring methods have been suggested, including the Bayesian Information Criterion (BIC) and the Minimum Description Length (MDL). These usually aim to avoid over-fitting by penalising model complexity. The leave-one-out method of cross-validation is a popular way of testing how well models fit new data.

It is not a surprise that applications for BBNs have been found for several domains. Examples of medical expert system include MUNIN for diagnosing neuro-muscular diseases (Andreassen *et al* 2001), HEPAR II for diagnosing liver disorders (Onisko *et al* 2000), and PATHFINDER, which is used in lymph node pathology (Heckerman *et al* 1992). The ability of BBNs to support the task of fault diagnosis makes them suitable for applications in the field of reliability and maintenance. An application for fault diagnosis in automotive electronic sub-systems has been implemented in hundreds of Fiat repair centres across Italy. TRACS is a system based on a BBN, which has been developed to assist the Ministry of Defence in the estimation of military vehicle reliability. British Telecom is employing BBNs to speed up and optimise their software testing procedures for new products (Rees *et al* 2001). (McNaught 2003.)

5.2.2 Influence diagrams

Influence diagrams help the decision maker and analyst visualize graphically how decisions, uncertain events, and results are interrelated. Influence diagrams offer a compact form and global look at the probabilistic structure of decision problems, the timing of available information, and the interdependence of decisions that can be taken and uncertain outcomes that may arise. Although they do not give detailed information on the outcomes of chance events or specific decision choices, they make three important contributions. (Marshall and Oliver 1995, 135.)

First, and probably the most important contribution is that influence diagrams provide a framework in which experts and decision makers can discuss problem structure and dependencies without invoking formal mathematical or statistical notation and analysis. The decision maker focuses on the problem and the possible implications of his or her decisions. The analyst is usually most comfortable in the world of mathematical modelling, giving advice on techniques that can be used to solve well-posed mathematical problems, or techniques of inference, prediction, and optimization. A second important contribution is in the reduction of large volumes of data to that portion essential and relevant to decision-making. It is more important than ever before to discard what is irrelevant and keep only what is relevant for decision-making. Last is the important contribution of algorithms and numerical techniques that can be used to reduce the complexity and size of influence diagrams. An influence diagram is able to provide sensitivity analyses and to reveal the importance of alternative model structures, forecasts, and policies to the decision maker. (Marshall and Oliver 1995, 135–136.)

Influence diagrams are directed acyclic graphs with three types of nodes – decisions nodes, chance nodes, and a value node. Decision nodes, shown as squares, represent choices available to the decision maker. Chance (uncertain event) nodes, shown as circles, represent random variables or uncertain quantities. The value (result) node, shown as a diamond, represents the objective or utility to be maximized (Figure 15). (Pearl 1988, 307.)

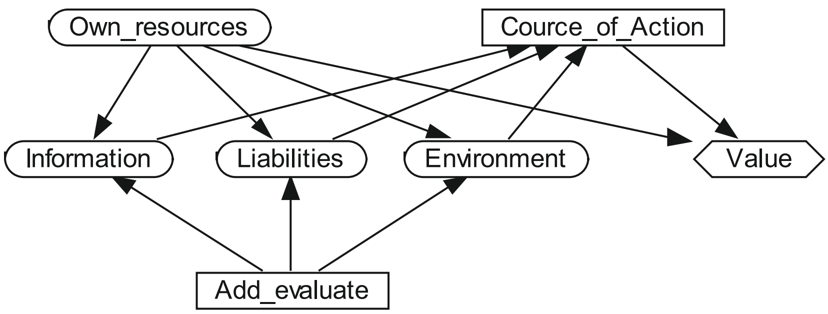

Figure 15. Example of an influence diagram for decision-making

The arcs in the graph have different meanings, based on their destinations. Arcs pointing to utility and chance nodes represent probabilistic or functional dependence, like the arcs in Bayesian networks. They do not necessarily imply causality or time precedence, although in practice they often do. Arcs into decision nodes imply time precedence and are informational, i.e., they show which variables will be known to the decision maker before the decision is made.

An influence diagram can be viewed as a special type of Bayesian network, in which the value of each decision variable is not determined probabilistically by its predecessors, but rather is imposed from the outside to meet some optimization objective. Where the domains of the variables in a Bayesian network are fixed, the domain of each decision variable in an influence diagram varies according to previous decisions. (Pearl 1988, 307.)

5.2.3 *Qualitative probabilistic networks*

Qualitative and infinitesimal probability schemes are consistent with the axioms of probability theory, but avoid the need for precise numerical probabilities. Using qualitative probabilities could substantially reduce the effort for knowledge engineering and improve the robustness of results. The axioms of decision theory assume only the ability to make qualitative judgments to order events by probability or outcomes of desirability. The quantification of probabilities and utilities can be based on purely qualitative judgments. (Henrion *et al* 1994.)

Influence arcs in a belief network represent the existence pf probabilistic dependence between variables. Thus, the directed graph itself represents purely qualitative relationships. Typically, these relationships are also quantified as probability distributions for each variable conditional on its predecessors (parents). A more specific, but still purely qualitative representation is the *qualitative probabilistic network* (QPN). This specifies the signs of probabilistic influences and synergies among variables, and provides the basis for qualitative inferences about the directions of effects on belief and decisions of evidence. (Henrion 1989.)

QPNs are in essence a qualitative abstraction of Bayesian belief networks and inference diagrams. A QPN requires specification of the graphical belief network, expressing dependence and independence relations. In addition, it requires specification of signs of influences and synergies among variables (Druzdzel and Henrion 1993).

Parson and Mamdani (1993) had presented an approach to reasoning about qualitative changes. Their motivation behind this work was to integrate different approaches to reasoning under uncertainty, in particular probability, possibility, and evidence theories. Their qualitative approach differs from that described above in that it is concerned with changes in possibility values and belief values as well as with probability values.

Parson and Mamdani (1993) had written that Wellman's QPN do not describe the qualitative behaviour of probabilistic network exactly. Some dependencies between variables are ignored in favour of simplicity, and synergy relations are sometimes introduced to represent them where it is considered to be important. In their own approach, the qualitative changes predicted are exactly those of the quantitative methods. Their qualitative method also provides a means of integrating uncertainty handling formalisms on a purely syntactic basis. All that needs to be done to find the qualitative relation between two values is to write down the analytical expression relating them and take the derivative of this expression with respect to one of the values. Parson (1995) has continued with the problem of over-abstraction in this case. More formally, he introduced a new kind of qualitative influence based on the absolute value of conditionals.

According Henrion *et al* (1994), another approach to qualitative probabilities is kappa-calculus. κ-calculus can be looked at in two ways: 1) as providing a scheme for non-monotonic reasoning whose semantics are firmly grounded in probability and decision theory; or 2) as providing a simplification of belief networks with numerical probabilities. From the second perspective, proponents of κ-calculus may claim further possible advantages over traditional numerical belief networks:

1. It may be easier to express beliefs by partitioning events into a small number of sets of relative plausibility, which are values, than by assigning each event a precise numerical probability.
2. Results from reasoning with κ-calculus are more robust, and therefore more trustworthy, since they are based on less specific inputs.
3. Reasoning with κ-calculus is easier to understand and explain.
4. Inference methods with κ-calculus can be computationally more efficient.

In order to be able to apply κ-calculus to probabilistic reasoning on a belief network with finite probabilities, it is required to provide a mapping from probabilities into κ-values. An approximation for finite values of ε was used. For finite ε, the κ-calculus partitions the real interval [0,1] into regions identified by integers, based on the smallest power of in the polynomial.

κ-calculus is a quite appealing alternative to numerical probabilities. It should be significantly easier to elicit from experts. Inference may be more efficient, and resulting inferences should be somewhat more robust changes in probabilities.

Parson (1995) has pointed out three basic differences between the presented systems. Firstly, even when fully refined, QPNs are mainly concerned with changes in probabilities rather than probabilities themselves, unlike κ-calculus. Secondly, QPNs do not require the use of infinitesimals in order to be consistent with probability theory, and so could be considered a more correct approach. Lastly, κ-calculus achieves order-of-magnitude reasoning by defining an absolute scale from which different values are taken, in contrast to a purely relative method.

Druzdzel and Henrion (1993) have written that belief propagation is more powerful than the graph reduction approach for two reasons: it uses product synergy, which is a qualitative property of probabilistic interactions, and it offers a reasoning scheme, whose operators do not lead to loss of qualitative information and whose final results do not depend on the order of their application.

5.2.4 Time-critical dynamic networks

Decision processes do not always manifest themselves so that a clear beginning and a clear end can be structured. More often, conditions change over time and a choice made earlier may no longer be appropriate or deemed useful. Furthermore, an alternative that was not viable at a particular time in the past may now appear more desirable, based on the new set of conditions present. The sequential decision structure is a series of basic risky decisions in successive time periods, with arrows used to indicate relationships between each temporal choice set (Marakas 1999, 122).

A decision made in one time period affects the degree of total measured success across all time periods, as well as the measured success in that same time period. In addition, decisions in the following time periods are affected to a degree by decisions made previously. Using a sequential structure model, the decision maker explicitly acknowledges the links between decisions with a common objective made over time. The opportunity to change course at some point in the future leaves open the possibility that a somewhat riskier strategy could be pursued in one time period and, if not successful, could be followed by a more conservative approach to mitigate the damage from the prior period. Also, this modelling structure allows the decision maker to see the future so that a decision to defer action until a period sometime in the future may also be made. (Marakas 1999, 123.)

Technically, assume that the network is defined using a vector of adjustable parameters λ. Each conditional probability table (CPT) entry w_{ijk} can be viewed as a function $w_{ijk}(\lambda)$. Assuming these functions are differentiable, it is obtained

$$\frac{\partial \ln P_w(D)}{\partial \lambda_p} = \sum_{i,j,k} \frac{\partial \ln P_w(D)}{\partial w_{ijk}} \times \frac{\partial w_{ijk}}{\partial \lambda_p} \qquad (14)$$

One of the most important applications of this equation is learning the behaviour of stochastic temporal processes. Such processes are typically represented using dynamic probabilistic networks (DPNs). A DPN is structured as a sequence of time slices, where the nodes at each slice encode the state at the corresponding time point (Figure 16). The CPTs for a DPN encode both a *state evolution model*, which describes the transition probabilities between states, and a *sensor model*, which describes the observations that can result from a given state. Typically, one assumes that the CPTs in each slice do not vary over time. The same parameters therefore are duplicated in every time slice in the network. (Binder *et al* 1997.)

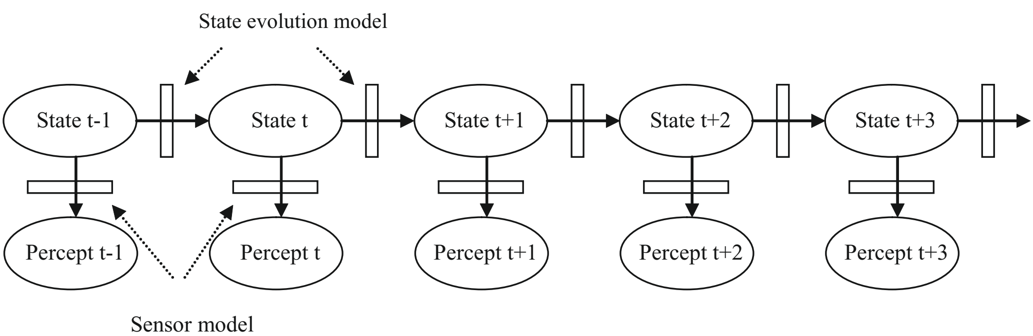

Figure 16. Generic structure of a dynamic probabilistic network

A formalism called *time-critical dynamic influence diagrams* (TDID) provides explicit support for modelling and solution of time-critical dynamic decision problems. TDID is designed to facilitate the modelling and solution of time-critical dynamic decision problems. It extends the standard influence diagram by including the concepts of temporal arcs and time sequences. It also incorporates the dynamic influence diagram as a representation for inference purposes. A TDID model has the *condensed* form and the *deployed* form. The condensed form is mainly used to represent or define the dynamic decision model and is the form used in the modelling process. The deployed form is used only for inference purposes and is constructed from the condensed form. Although, in principle, both forms can be converted to and form each other, they serve different purposes in the modelling and solution process. (Xiang and Poh 1999.)

To construct a knowledge-based model, the model construction process can be used, which is supported by a domain knowledge base. The steps for the model construction process are (Xiang and Poh 1999):

1. Given a time-critical dynamic decision problem, specify the problem requirements, such as its urgency and deadline.
2. Select a set of models that satisfies the requirements from the domain knowledge base.
3. Select the optimal model from the set of models based on model quality and computation cost.
4. Modify or customise the TDID according to user requirements if necessary.
5. The TDID is converted into the deployed form, a super value node is added and the optimal solution determined.

Horvits and Barry (1995) assessed time-dependent utility in terms of the dynamically changing probability that a mission would be terminated prematurely. They found that it was useful to use multi-attribute utility to understand the tradeoffs among dimensions of value in an outcome. The goal of management in time-critical situations is to maximize the expected utility of a manager's decisions. The expected utility of considering previously hidden information must be evaluated in the context of a complete decision-theoretic analysis, taking advantage of all of the available information.

5.3 Conclusions of presented methods

Bayesian Belief Networks (BBNs) have become popular as means of representing uncertainty within various problem domains. The structure of a BBN readily permits the fusion of expert domain knowledge with an information stream and the updating of beliefs as new information or evidence is obtained.

The problem in performing both probability propagation and abductive inference in an arbitrary belief network has been proven to be NP-hard by Cooper 1990. That is to say, there is no single algorithm that is efficient for all belief networks (Che *et al* 1993).

Influence diagrams play an important joint role in the interactive process of building and testing decision models and deriving solutions to decision problems. ID capture and illustrate the important influences and relationships of decisions with uncertainties. They help in understanding the probability structure of the problem without getting into details of specific alternatives and outcomes that can occur.

In QPN, belief propagation is more powerful than in the graph reduction approach for two reasons: it uses product synergy, which is a qualitative property of probabilistic interactions, and it offers a reasoning scheme, whose operators do not lead to loss of qualitative information and whose final results do not depend on the order of their application.

TDID is designed for time-critical dynamic decision problems. It extends the standard influence diagram by including the concepts of temporal arcs and time sequences. It also incorporates the dynamic influence diagram as a representation for inference purposes.

The goal of management in time-critical situations is to maximize the expected utility of a manager's decisions.

The main issues of comparison of presented methods are collected in Table 7. As a result of this examination, we can state that TDID can be used as a basic method of the support system for anticipatory decision-making.

Table 7. The comparison of presented methods

	BBN	ID (Marshall and Oliver 1995, 188)	QPN	TDID
Timing		Shows timing of all decisions and uncertain events.		Shows timing of all decisions and uncertain events.
Conditional Independence	Represent direct dependencies between variables	Shows dependence among uncertain events and decisions.	Signs of probabilistic influences and synergies	Shows dependence among uncertain events and decisions.
Size	Number of nodes grows linearly with the number of variables.	Number of nodes grows linearly with the number of variables.	Number of nodes grows linearly with the number of variables.	Number of nodes grows linearly with the number of variables.
Data	Identifies dependencies of variables without need for data.	Identifies dependencies of variables without need for data.	Identifies dependencies of variables without need for data.	Identifies dependencies of variables without need for data.
Variable Type	Both random and deterministic	Both continuous and discrete decisions and probabilities.	Signs of influences	Each node represents a set of time-indexed variables
Asymmetry		Scenarios with different event sequences not distinguished.		
Modelling Usefulness	Most useful in initial stages of modelling. Expert's interaction needed.	Most useful in initial stages of modelling. Captures interaction between decision maker and analyst.	Signs of probabilistic influences and synergies	In time-critical contexts
Bayes-rule	Indicated by arc reversal, but calculation not shown.	Indicated by arc reversal, but calculation not shown.	Indicated by arc reversal, but calculation not shown.	The concepts of temporal arcs and time sequences
Method	To assess the fit of models to a data set, many scoring methods suggested	Reduction by a set of reduction operations possible using advanced method	Based on local message passing, Mainly concerned with changes in probabilities	Reduction by a set of reduction operations possible using advanced method

Chapter 6

Method to Bayesian Decision Support Model

The previous chapter has provided method to probabilistic decision-making and to Bayesian modelling. This chapter will present a solution to the Bayesian decision support model. First, the model of the Decision Support System will be discussed. Second, a model of a Bayesian decision support system will be presented. Third, the principles of dynamic modelling and chaotic environment model will be introduced. Finally, applications of decision-making and risk management will be presented.

6.1 Structured Model of Decision Support System

Decision models can be classified in a number of ways. Models that do not explicitly acknowledge time are called static models, and those that do are referred to as dynamic models. Another widespread method of classification is by a technique's mathematical or logical focus.

An abstract decision model focuses on the mathematical precision with which various outcomes can be predicted. The decision maker is constantly faced with creating a balance between models that capture the complexity of the problem with models that are simple enough to analyze and solve. In keeping with the concept of functional decomposition, abstract models can be divided into four subsystems as follows (Marakas 1999, 124–127):

– a *deterministic model* is one in which no variable can take more than one value at any given time. In this model type, the same output values will always result from any given set of input variables (linear programming, optimization, convex programming, differential equations).
– in a *stochastic model*, at least one of the variables is uncertain and must be described by some probability function. These model types are often referred to as probabilistic models, because they explicitly incorporate uncertainty into their structure (game theory, queuing theory, time series analysis, path analysis).
– a *simulation* can be thought of as a technique for conducting one or more experiments that test various outcomes resulting from the combining of modelled subsystems into a dynamic environment. Simulation is intended to imitate reality rather than simply model it.
– a *domain-specific model* is for sciences that have evolved to the point where the need for highly specific types of decision-making techniques and contexts has emerged. In these cases, each discipline has developed its own set of abstract mathematical modelling techniques to serve its needs. Well-known domains, such as economics, operation research, sociology, ecology, medicine, and meteorology have each developed their own unique abstract modelling techniques.

The study of decision-making and problem solving has attracted much attention throughout most of last century. Most of the tools of modern operations research use the assumptions of subjective expected utility (SEU) theory. They assume that what is desired is to maximize the achievement of some goal, under specified constraints and assuming that all alternatives and consequences or their probability distributions are known. Especially if it is combined with incomplete information, SEU theory faces difficulties. The most ambitious attempt to answer questions of this kind was the theory of games. But the answers provided by the theory of games are sometimes puzzling and ambiguous. In many situations, no single course of action dominates all the others; instead, a whole set of possible solutions are all equally consistent with the postulates of rationality. In the probabilistic version of the theory, Bayes's rule prescribes how people should take into account new information and how they should respond to incomplete information. (Simon 1986.)

Over the past forty years, the complementary fields of cognitive psychology and artificial intelligence have produced a fairly well-developed theory of problem solving that lends itself well to computer simulation, both for purposes of testing its empirical validity and for augmenting human problem-solving capacities by the construction of expert systems. The growing importance of computational techniques in all of the sciences has attracted new attention to numerical analysis and to the topic of computational complexity. (Simon 1986.)

The Bayesian Decision Support System (BDSS) forms condition-action-effect rules perceiving an environment and acting in the environment. The formed rules specify what may change after the implementation of a decision in a given situation. The goals of the system are

- to evolve a complete, accurate, and compact set of rules representing an environmental model. *Complete* refers to the goal of representing all possible situation-decision-effect combinations in the model, *accurate* means that the model should always specify correct anticipations, in each situation-decision combination, *compact* refers to the aim of representing the model by the least number of rules possible in the environment.
- to apply anticipatory decision-making processes to simulate an appropriate behaviour.

BDSS interacts autonomously with an environment. In a behavioural act at a certain time t, it perceives a situation $s(t) \in \mathrm{I} = \{v_1, v_2, ..., v_m\}^L$ where m is the number of possible values of each environmental attribute, $v_1, \ldots, v_m$ are the different possible values of each attribute, and L is the string length. The decision-making system can act upon the environment with a decision $\mathrm{d(t)}\ \ \mathrm{D} = \{\delta_1, \delta_2, ..., \delta_n\}$ where n specifies the number of different possible decisions in the environment and $\delta_1, ..., \delta_n$ are different possible decisions.

An expert system consists of two parts; knowledge base and inference engine. The knowledge base contains the domain-specific knowledge of a problem encoded in some manner. The inference engine consists of one or more algorithms for processing the encoded knowledge of the knowledge base together with any further specific information at hand for a given application. Both parts are important for an expert system. Modern expert systems strive for the ideal of a clean separation of both components. (Cowell *et al* 2003.) This study concentrates on constructing an inference engine.

BDSS consists of the following components (Figure 17):

- the situation part (S) specifies the set of input states in which the decision-maker can be applied, *Environment Model*
- the decision part (D) proposes an available decision, *DS Model*
- the effect part (E) anticipates the effects that the decision-maker 'believes' to be caused by the specified decision, *Synthetic environment*

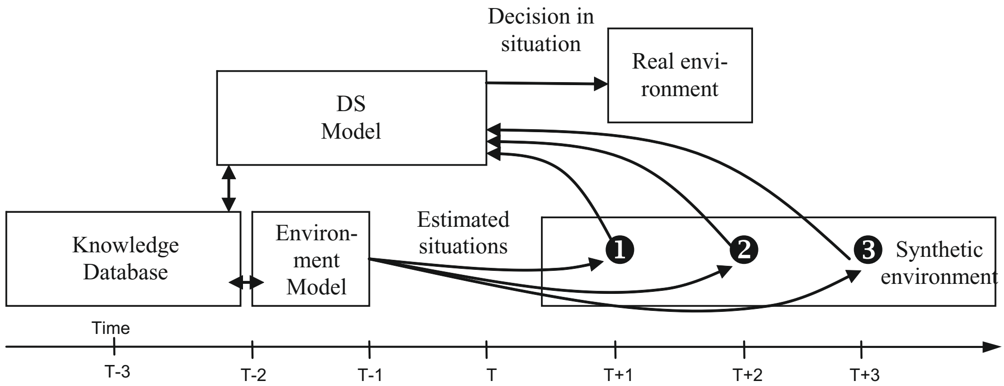

Figure 17. The structured model of the decision support system

6.1.1 Evaluation of decision alternatives

Almost all decision models are formulated and solved assuming the availability of perfect information. This is usually referred to as decision-making under certainty. The availability of partial or imperfect information about a problem leads to two categories of decision-making situations; *decisions under risk*, and *decisions under uncertainty* (Taha 1992, 411–412).

In most decision models, a problem resolves to select a best course(s) of action from a number (possibly infinite) of available options. The decision maker does not expect the environment to be a malevolent opponent. In decisions under uncertainty, competitive situations exist in which two or more opponents are working in conflict, in which each opponent tries to reign at the expense of the others. These situations are distinguished from customary decision-making under uncertainty by the fact that the decision maker is working against an intelligent opponent (Taha 1992, 412).

In developing the criteria for decisions under risk, it is assumed that probability distributions are known or can be secured. In this respect, these probabilities are referred to as *prior* probabilities. It is sometimes possible to perform an experiment on the system under study and, depending on the outcomes of the experiment, modify the prior probabilities to reflect the availability of new information about the system. The new probabilities are known as *posterior* probabilities. (Taha 1992, 420.)

By decision theory, the final rules to solve the problem of inference by four steps are simple. By including three more steps, the problem of decision can be solved. All of these seven steps can be presented as following *Algorithm 6.1* (Jaynes 2003, 417).

Algorithm 6.1 (the problem of decision solving)
Input
Output
Method
1 Enumerate the possible states of nature θ_j, discrete or continuous, as the case may be
2 Assign prior probabilities $p(\theta_j|I)$ which represent whatever prior information I decision-maker has about them
3 Assign sampling probabilities $p(E_i|\theta_j)$ which represent a decision-maker's prior knowledge about the mechanism of the measurement process yielding the possible data sets E_i
4 Digest any additional evidence $E = E_1E_2\ldots$ by application of Bayes' theorem, thus obtaining the posterior probabilities $p(\theta_j|EI)$
5 Enumerate the possible decisions D_i
6 Assign the loss function $L(D_i, \theta_j)$ that tells what a decision-maker wants to accomplish
7 Make the decision D_i which minimizes the expected loss over the posterior probabilities for θ_j

6.1.2 Risk management

The perspective of companies and different organizations is in accordance with their need for security, and it concentrates on threats directed at a company's main activities and the protection of continuity of operating. The key question of risk management is to find out what information and functions, which levels of requirement, and what parties need to be protected. Thus, the question is one of extensive classification of information. According to the risk management of insurance companies, risk is the product of the probability of an event and the cost of its effects. This can be applied to the definition of a threat, so that a threat is the product of the threat's realization and its effects. (Savisalo 2001, 130.)

A risk can be divided into the following factors:
- the likelihood of the realization of a threat (Savisalo 2001, 135)
  - P(penetration), i.e., the likelihood of penetration
  - 1-P(perception and interception), i.e., the intruder is not observed and intercepted
  - P(finding and identification), i.e., the intruder finds and identifies the target
  - P(affecting), i.e., the intruder achieves the desired effect
- consequences
  - interruption of operating (delay)
  - reduction of resources, refocusing (costs)
  - failing of critical points, irreparability (inefficiency)

Measuring or reliably assessing the absolute likelihood of threats does not seem fully possible. Assessment is made more difficult by the sometimes rapid change of individual threat factors from unlikely to very likely. This is because, typically, much more experience is needed in the beginning of the lifespan of the threat-causing effect mechanism and its application and use. Essential parts of a professional threat include inconspicuous activity, the small risk of exposure and getting caught, as well as extensive bluffs. The economic and functional effects of threats are somewhat easier to determine if it is possible to determine the threat's worst realizations. (Savisalo 2001, 141–142.)

Vulnerability and determined threats must be adjusted to each other. Where vulnerabilities are large and the threat of the opponent is apparent, its activity is likely to succeed. The assessment of risks is the phase of decision-making that determines the functional process, balances discovered vulnerabilities with threats, and finally decides whether countermeasures are needed for the remaining risks. (Halonen 2000, 45.)

A management event can be seen as a kind of process of occurrences, and it is a time-bound current that is examined by the observer or that "sends" a message to the observer. The phenomenon can be divided into two phases: 1) the communication phase and 2) the decision-making phase; however, it is difficult to completely separate these from each other (Nikander 2002, 114–115), as follows:

1) The communication phase can be divided into three parts:
   a) the detecting of the early warning;
   b) the interpretation of the early warning;
   c) the acceptance of the early warning. An important factor in the communication phase, in addition to the actual message (observation), is the observer. He determines how the observation will be interpreted, because the message only reaches others in the interpretation of the observer.
2) In the decision-making phase, the relevant questions are: what is the significance of the early warning for the project, and what responses should be adopted on the basis of that early warning in this project situation at hand and in the prevailing project environment?

The utilization of early warnings in decision-making has two procedures (Nikander 2002, 120); 1) early warnings and 2) problems or risks. In the *early warning* procedure, the main question to be answered is: a) what problem (risk) does the detected early warning refer to? In a *problem- or risk-oriented* perspective, the following questions should be answered: b) can early warnings implying the materialization of a particular risk be detected? and c) what kinds of responses (observation procedures) can be used to procure additional information of the threat of materialization of a particular problem (risk)? Two stages of assessing the future are included in early warning utilization. First, the severity, likelihood of materialization, and time available in which the potential problem (risk) should be analysed (assessed, anticipated) on the basis of the available information and the view (experience, beliefs) of the evaluator. This is equivalent to risk management that includes consideration of the information provided by early warnings. Second, the decision-maker should evaluate the impact of the planned responses to the action, and the reactions, and responses of the various environment parties and/or outsiders in the situation at hand. As mentioned earlier, the model presented here can be a tool for anticipating the future aspects of decision-making problems.

According to a model by Nikander (2002, 121–122), in an early warning oriented approach,

1. The first stage is detecting an early warning; this is always done by a person and the early warning is detected in the stream of events.
2. In the second stage, the observer accepts his observation (message) and begins to interpret it, i.e., either considers it an early warning or rejects it as insignificant. The greatest problem is probably deciding whether the information in question is really significant or merely an arbitrary "event".

3. In the third stage, the observer tries to determine the state of knowledge of the early warning, i.e., the significance to COA of the information it provides. The scale of assessment does not need to be absolute or valid in all cases, as long as it is definable in the situation in question.
4. In the fourth stage, the observer strives to identify the problem (risk) that has emerged, as well as its possible causes (risk factors, causes of risk). This assessment is influenced not only by all the information provided by the warning (categorizations), but also by the situation (internal trends), the circumstances of the environment (external trends) and the beliefs and assumptions of the interpreter. The possible utilization of various risk management methods (risk analysis, etc.) is relevant in this stage at the latest.
5. The time available in the fifth stage is explored along with recognizing risks. The question to be answered is: how much time is available for the responses required by the problem (risk)? In other words, how urgent is the situation? This, too, is strongly influenced by the situation (internal trends) and by the environment (external trends), as well as by the interpreter. Probably the greatest difficulty in stages 4 and 5 is to convince the decision-maker of the existence of a problem, its impact on the action, and the necessity of responses. This can be called a credibility problem; it emerged in the interviews conducted for this study and is equally apparent in studies on military intelligence, international security, and international risks.
6. Finally, in the sixth stage, it is necessary to endeavour to decide which responses the observed situation calls for.

A challenge for risk analysts or risk assessment practitioners is to develop more harmonised practices for conducting risk assessment in which issues related to establishing confidence in risk assessment results are systematically and generically addressed. This entails a conceptual framework for addressing determinants of confidence of the decision-makers with respect to risk assessment results. Since risk assessment is based on the principle of decomposition, many variables and model parameters relate to specific phenomena or events for which no empirical data is available. This motivates the use of expert judgement as a source of information in estimating unknown variables and parameters (Rosqvist 2003, 9–10).

In the case of Bayesian mechanistic probability aggregation, the decision-maker defines the likelihoods of the experts' judgements, and treats these judgements as data for updating his or her prior belief to posterior belief according to Bayes' rule. The data is typically given in the form of a finite number of percentiles or full probability distributions. (Rosqvist 2003, 25.) The decision-maker makes his decision based on risk assessment results and quality verification results. The basic decision options for the decision-maker are a) to accept the risk assessment results, or b) to request refinements in the risk assessment, based on the recommendations of the peer review group. (Rosqvist 2003, 39.)

Risk management is an important decision-making activity at all organization levels, strategic, operational and tactical, although the details vary according to the level. The level of the risk that prevails in any given situation is determined both by the severity of the consequences arising from the occurrence of the risk event and the likelihood of its occurrence.

Requirements for risk management tools are (Staker 1999), for example:
– the tool should contain modules for data collection, analysis and the output of results

- the risk analysis methodology should reflect the organisation's policy on using risk analysis tools and should be explicitly stated
- the output information must effectively support managers in assessing the relative merits of alternatives so as to result in reliable and cost-effective risk reduction measures
- the tool should maintain a history of the data collected during the data collection phase of the analysis
- the tool should readily accommodate changes that occur in the network and allow a revised risk assessment
- the tool should provide an automated means for generating a near optimal selection of countermeasures to achieve the required risk level

6.2 Bayesian Decision Support System modelling

The development of a probabilistic network model can be broadly split into three phases and presented as the following algorithm.

Algorithm 6.2 (the development of a probabilistic network model)
Input
Output a probabilistic network model
Method
1 **Define** the model
2 specify relevant variables
3 specify structural dependence between variables
4 assign component probabilities to the model
5 **Construct** the inference engine
6 moralise the graphical model
7 triangulate the moral graph
8 find the cliques of the moral graph
9 make a junction tree from the cliques
10 **Use** the inference engine for individual case analysis
11 initialize potentials on the junction tree
12 perform local propagation taking account of evidence
13 find node marginal distributions

Discrete multistage decision problems under uncertainty involve random variables, decision variables, and a loss or utility function. A decision variable has a number of states called decisions or choices; making a decision is modelled by selecting one choice from the range of possible choices of the decision variable. Decisions are taken in a specified order, and each has consequences either by its contribution to an overall loss or utility, or by revealing the state of one or more random variables, or both. For example, a decision might be to choose to perform one from among a set of possible tests, as a result of which certain results or diagnoses become possible. The objective is to find, for each decision variable, the optimal choice to make given what is known at the time the decision is to be taken. The optimal criterion by which decisions are judged is that of maximizing overall expected utility or of minimizing overall expected loss. (Cowell *et al* 2003, 155.)

A case is called complete if every random variable has a state or value assigned to it. A database is complete if all cases in the database are complete. For an incomplete case, one or more of the random variables does not have a value associated with it, the data are missing, or unobserved, or censored. Some variables may never be observed, their values always missing from the database. Such variables are called hidden or latent variables. In other cases, values of variables may be sometimes observed, sometimes missing. (Cowell *et al* 2003, 200.)

Decision makers have preliminary or prior probability estimates for the states of nature that are the best probability values available. However, to make the best possible decision, the decision maker may want to seek additional information about the states of nature. This new information can be used to revise or update the prior probabilities so that the final decision is based on more accurate probability estimates for the states of nature. Since the manager's provided initial subjective probability estimates were estimates developed prior to the collection of any sample information, they are referred to as the prior probabilities for state of nature. The research will provide new information that can be combined with the prior probabilities through a Bayesian procedure to obtain updated or revised probability estimates for the states of nature. These revised probabilities are called posterior probabilities. In many cases, the experiment conducted to obtain the additional information will consist of taking a statistical sample, so the new information also is often referred to as sample information. (Anderson *et al* 1997, 589–590.)

Based on the process of anticipatory decision-making and the requirements of the decision support system, the four-layers process necessary to produce a Bayesian network model will be generated. One part of model is the environment which consist of the network structure, and which represents the chances of the environment with nodes (E1,…, E4). Every node includes a function of change and the result of function, which represents the state of the node. The model itself consists of layers of censoring, planning, evaluation and decision, and finally execution, and every layer consists of specific types of nodes (C, P, D, V) as follows:

- *The censoring layer* defines all processes, measures, and formats of observing the environment. An input to this layer is measured observations. The censoring layer includes the nodes (C1,…, C3), which observes the environment nodes. The results of these nodes are a distribution of the environment state (a prior).
- *The planning layer* includes a process to make relations between observed measures. The planning layer includes the nodes (P1,…, P5). The result of this layer gives the planned alternatives to decision-making.
- *The evaluation and decision layer* includes a process that provides alternatives to the decision maker in order to make his or her choices. The evaluation and decision layer includes the nodes (D1, D2). The results of these nodes are a selected course of action to execution.
- *The executing layer* includes a process that calculates the final value and the risk of decision, suggesting a final course of action with consequence estimation. The executing layer includes the nodes (V1, V2), which show (example) the final values and the risks of decision.

Figure 18 illustrates an example for a combination of models, layers of these models, and the structure of a Bayesian decision network.

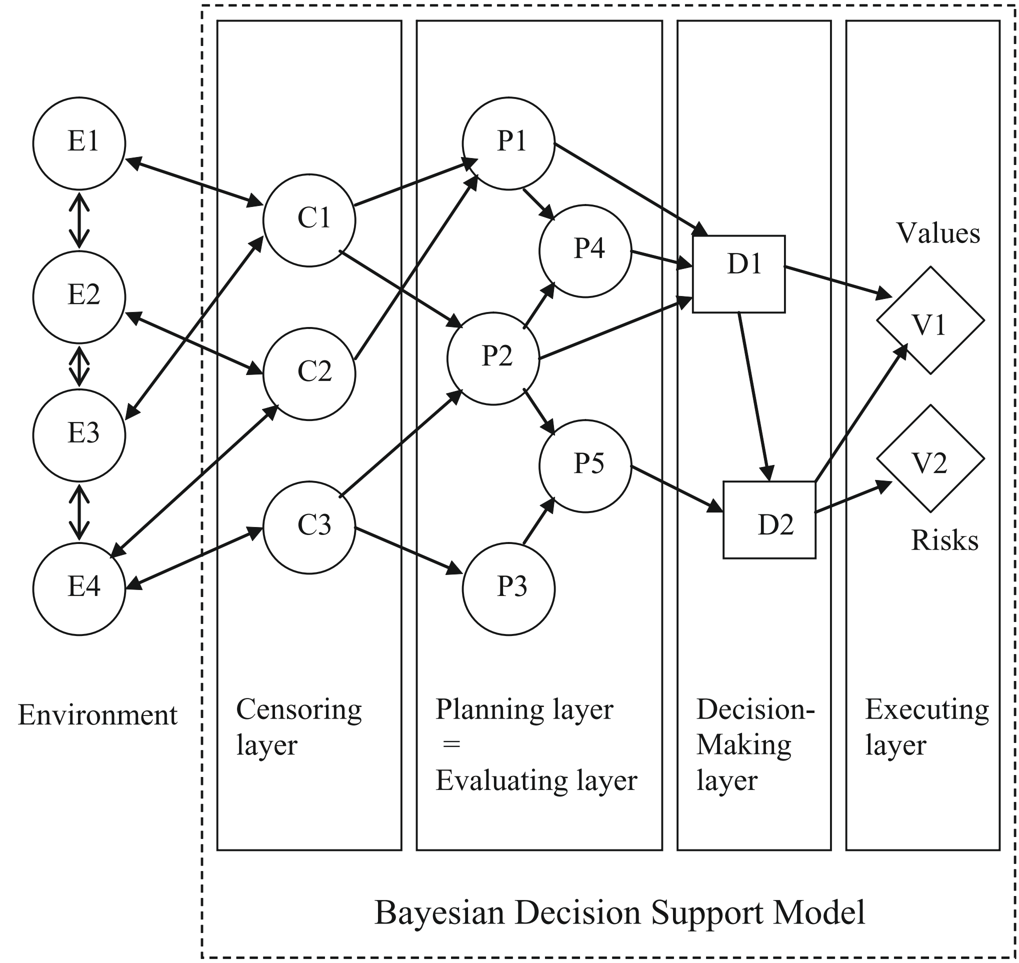

Figure 18. Example of the layers and nodes of the Bayesian Decision Support Model

Based on the latter principles of the above model, the next algorithm is defined, and it produces a Bayesian network for decision-making support.

Algorithm 6.3 (The algorithm for Bayesian Decision Support Network)
Input Censoring nodes
Output a Bayesian decision network model
Method
1 **Select** the censoring nodes ($C_1,\ldots,C_n$) from the censoring layer, (n=1,...,i).
2 **Define** the decision alternatives and create a decision node(s).
3 **Define** the values to decision alternatives and create value/utility node(s).
4 **Plan** relations as follows:
5 **Define** a relation from each of the censoring nodes to decision nodes.
6 **Define** planning nodes ($P_1,\ldots,P_m$) if needed, (m=1,...,i).
7 **If** planning node **then** define relation from censoring node **and** to decision node.
8 **If** planning node number > 1 **then** define relation between planning nodes.
9 **Accept** all defined relations in network.
10 **Define** priori-distributions to the network nodes.
11 **Evaluate** network.
12 **Accept** to use.

A support to anticipatory decision-making associated examples can be realized based on methods of classifying and defined by Algorithm 6.4. In decision-making and risk management, a decision-maker has to select alternatives (attributes of decision node). In the existing situation, the environment information from scanning censors will be determined. These decision nodes and the censor nodes will be formed with expert or other available information. A result of the decision network is a recommendation of the best COA, and information concerning the possible consequences of that decision.

Algorithm 6.4 (the problem of decision solving)
Input situation s, list of possible decisions d, time step t , anticipated time steps
Output decision suggestion
Method

1 while (t ≤ time steps)
2 s ← s(t)
3 do
4 d ← *selecting a decision* [d(t)]
5 r ← *doing* risk analysis in the situation s using selected method of risk management
6 s ← *implementing* d upon the situation s(t) using selected method of implementing a decision
7 t ← t+1

Subalgorithm 6.4.1 (selecting a decision)
Input list of possible decisions
Output most preferred decision
Method

1 Enumerate the possible states of nature θ_j, discrete or continuous, as the case may be
2 Assign prior probabilities $p(\theta_j|I)$ which represent whatever prior information I decision-maker has about them
3 Assign sampling probabilities $p(E_i|\theta_j)$ which represent decision-maker's prior knowledge about the mechanism of the measurement process yielding the possible data sets E_i
4 Digest any additional evidence $E = E_1E_2\ldots$ by application of Bayes' theorem, thus obtaining the posterior probabilities $p(\theta_j|EI)$
5 Enumerate the possible decisions D_i
6 Assign the loss function $L(D_i, \theta_j)$ that tells what decision-maker wants to accomplish
7 Make that decision D_i which minimizes the expected loss over the posterior probabilities for θ_j

6.3 Dynamic Environment Modelling

6.3.1 Dynamic environment

Much of the research on human decision-making involves discrete judgments in static environments under certain conditions. Judgments under such circumstances may not provide a sufficient basis for developing either descriptive or normative models of decision-making in dynamic, naturalistic environments. The more novel and complex the environment, the greater the need to test different options and evaluate their effects, in order to discover how one can best exercise influence over the system. Effective decision-making in complex and dynamic environments requires a generative capability in which various cognitive skills are applied to ferret out information, interpret and integrate feedback, test and revise knowledge, and implement selected options. Leaders have to live with the consequences of errors in judgment and faulty decisions. (Bandura 1998, 451.)

An organization's environment is constantly changing. The conceptual constructions of rational models have often been based on the simple assumption that this change can be predicted, at least statistically, or by examining the likelihood of certain events. This is not the case, however. The environment can be analyzed in at least three different ways. In Salmela's study (1996, 16), these three types are differentiated as follows:

– *the turbulent environment*, in which the amount of change is high, and the predictability of change is low (can be seen also as chaotic)
– *the dynamic environment*, in which there is a lot of change, but change is at least to some extent predictable from past experience
– *the stable environment*, in which change is small, and when change takes place, it can be predicted from past experience

Table 8. The types of environments and their effects on management process (Salmela 1996, 72–73)

	Stable/Dynamic	Turbulent/Chaotic
Analysis of external environment	Identify key strategic assumptions	Identify external trends, formulate alternative visions of the future
Analysis of organisation environment	Base on existing action strategy	Analyse alternative strategic responses to environmental changes
Interaction between phases	Periodic meetings	Continuous, iterative, intermittent
Action schedule	Predefined steps and deadlines	Sensitive changes in action environment
Timing of decisions	According to the schedule	All the time and at any time
Emphasis in planning	Plan formulation	Plan formulation and implementation

A chain of process, in which an event *a* produces an event *b*, and which produces an event *c* etc., is a typical model for linear and deterministic explanations. Change is not conformed to earlier limits, but it changes the environment, forming new combinations from dynamic and static areas. The speed of change can lead to an unorganized situation and finally to chaos. In addition to periodic behaviour forms, deterministic systems may produce several other forms as well. Inlets of order may appear in the midst of confusion. A complex system can create turbulence and order simultaneously. (Gleick 1990, 64.)

According to Aula (2000, 12), the viewpoints of chaos theory are included in the management methods of a present-day leader. The theory makes possible new ideas concerning everyday leadership and gives the preconditions for the finding of new paths of leadership in the unstable network of the operational environment. The chaos point of view of an organization and its leadership help an organization to be always prepared. In a scientific sense, chaos means random or chaotic behaviour that nevertheless is controlled by ultimate invisible order. Thus, chaos is something that looks incidental but is not. Chaos theory can be seen as a set of concepts and methods that can be used to study and interpret non-linear problems that contain random elements. The networking of the world and flows of information guarantee that even a small fraction of information can accumulate in an instant irrespective of time and space.

If activity is controlled by chaotic non-linear properties, its current situation cannot be returned to the past with the finite level. Development is chaotic and conclusions about the past or the future cannot be made from events occurring right now. The development of the process is always interrupted by a factor that is considered a disturbance, and this means that earlier explanations and the understanding about the state of affairs are no longer valid. A chaotic phenomenon is unpredictable, and exact information cannot be obtained about its progress or the forthcoming end state. However, the course of chaos is not random. It develops within the limits of a chaotic track, i.e., a so-called strange attractor, specific to each type of system. The relationship between any two parts, factors or conditions of the chaotic system cannot be predicted over the long term, meaning that relationships change non-linearly over time. (Aula 1999, 24.)

Chaos sets principle borders to our ability to predict the future. Because we cannot accurately measure the initial condition of any physical system, our predictions become faulty before long. If we are measuring a chaotic system, our predictions become very faulty very quickly. Something seemingly insignificant in the determination of the initial condition of a dynamic system leads the chaotic system quickly to an unpredictable state (Heinämaa and Tuomi 1989, 230–231). Chaos research has revealed three properties (Hietarinta 1994, 4): even a small change in the initial condition can cause a completely different final condition, even a simple equation can cause extremely complex behaviour, and chaos observed in dynamic systems is not completely arbitrary; some order can be observed.

The ups and downs of management activities create interesting questions concerning a competitive situation between a decision-maker and his/her environment. It can be questioned that:

– What are the indices that form a phase of the cycle? Observing, planning, decision-making, and implementation are valuable indicators for management behaviour.
– What are the appropriate numbers of phases in a cycle? The transition from one phase to the next is given by the turning point's trough and peak. A cycle consists of a lower turning point, an upswing, an upper turning point, and a downswing.
– Do all cycles follow the same underlying rules, or has there been a drift of the rules?

The aim is to obtain from the environment observation data rules that state in which phase the cycle is in. This task is less clearly defined than the task of anticipating management activities, because management cycles themselves are basically a theoretical model to explain the variation in environment data.

It can be assumed that the relevant information lies in the value of the indicator alone. The interval segmentation can easily be found by discretizing the attribute values and joining consecutive time points with identical discretization. The goal is to find a discretization of the indicators, which already contains as much information about the cycle phase as possible. This directly leads to the use of information gain as the discretization criterion. (Morik and Rüping 2002.)

The dynamics of dissipative systems is simple. Each movement weakens over time and strives towards a state of final rest. These resting states characteristic of the system are called equilibrium states. If the system is not in an equilibrium state at the initial moment, or if its speed is not zero, movement begins. Movement resists friction, and from its effect kinetic energy is constantly reduced. However, it reduces gradually; speed is constantly reduced, and the system approaches a border condition that turns out to be equilibrium. When energy has come to zero, movement ceases at equilibrium. The state of equilibrium can be either stable or unstable. (Ekeland 2001, 96.)

A dynamical system is a system that evolves in time. In mathematical terms, a dynamical system is given by a set *M*: the set of all possible states in which the system can be. There are different classes of dynamical systems. In *discrete* dynamical systems (maps), the time steps discrete values $x_n = f\ (x_{n-1})$, $n = 1, 2, 3,\ldots$ The law of evolution is given by the iteration of a map $f\colon M \rightarrow M$. In *continuous* dynamical systems (flows), the law of evolution is given by differential equation. (de Simone 2002.)

This research is concentrated on discrete dynamical systems. The dynamical system is autonomous, so its law of evolution is independent of time, and deterministic, so its future evolution is determined uniquely by its present state (the initial condition). There is no "randomness" in the law of evolution. Turbulence is a different phenomenon than chaotic behaviours. Turbulence is an effect of the very high dimensionality of the problem (de Simone 2002).

The research of chaos development in the description of the system and explanation of its behaviour adds requirements to the traditional system and contingents models still to expanded and subject to further inspection. The traditional system and its contingent perspective do not have models incorporated into, for example, the next system's basic properties (Aula 1999, 114–115, based on Contractor 1994):

– *mutual causality*, whereby traditionally changes are explained using one-way causal relations expositive models, does not, however, lend the ability to model backwards events, which characterize circulars and agglomerate dependency relations
– *dependency from time*, all dynamic systems are time dependent, which means that their later condition depends on an earlier condition, either from the previous or even before the previous condition, and expectations of an upcoming condition also affect the human system.
– *irrecoverable time*, time progresses in only one direction and, according to thermodynamics' second main rule, all real systems are irrecoverable. Time irrecoverableness, such as time dependency, is a non-linear system's property
– *non-continuity*, with which sudden qualitative changes happening in an organization process's development can be characterized, is qualitative non-continuous change happening in one factor, caused by continuous change in another factor.

Such environmental factors, which can affect both objective function and constraints, are referred to as uncontrollable inputs to the model. Inputs that are controlled or determined by the decision maker are referred to as controllable input to the model. The specific controllable and uncontrollable inputs of a model depend on the particular problem or decision-making situation. Uncontrollable inputs can either be known exactly or be uncertain and subject to variation. If all uncontrollable inputs to a model are known and cannot vary, the model is referred to as a deterministic model. If any of the uncontrollable inputs are uncertain and subject to variation, the model is referred to as a stochastic or probabilistic model (Anderson *et al* 1997, 7–8).

All uncontrollable inputs or data must be specified before a model can be analysed, and a decision or solution for the problem recommended. Many inexperienced quantitative analysts assume that once a problem has been solved and a general model developed, the problem is essentially solved. These individuals tend to believe that data preparation is a trivial step in the process and can be easily handled by clerical staff. Actually, this assumption could not be further from the truth, especially with large-scale models that have numerous data input values. A fairly large database is needed to support a mathematical model, and information systems specialists also become involved in the data preparation step. Once the model development step and data preparation steps have been completed, it can be proceed to the model solution step. In this step, the analyst will attempt to identify the values of the decision variables that provide the best output for the model: the optimal solution.

6.3.2 Model of Dynamic Environment

The observed time series generated by the real world seldom appears to be stationary, but instead exhibits more complicated behaviour. Today, many time series are so dominated by cyclic fluctuations that the attempt to extract an underlying signal, such as a long-term trend from a short run of data, is frustrated (Jaynes 2003, 534).

The almost universal de-trending procedure in economics is to suppose the data to be

$$y(t) = x(t) + e(t), \tag{15}$$

composed additively of the component of interest $x(t)$, a linear trend Bt, and a random error or noise $e(t)$.

The direct application of probability theory as logic leads to the calculation of the probability of whatever is unknown and of interest, conditional on whatever is known. This mean that it does not seek to remove the trend or seasonal component from data that is fundamentally impossible, because there is no way to know the true trend or seasonal term (Jaynes 2003, 536).

It is assumed that the N data are not necessarily uniformly spaced in time, but are taken at times in some set $\{t{:}t_1,\ldots,t_N\}$, that the noise probability distribution, although Gaussian, is not necessarily stationary or white (uncorrelated), and that the prior probabilities for parameters are not necessarily independent. Now the model is

$$y_{t_i} = T(t_i) + F(t_i) + e(t_i),\ 1 \le i \le N, \tag{16}$$

in which it may write $y_i \equiv y(t_i)$, etc., with data $D = (y_1,\ldots,y_N)$, where $T(t)$ is the trend function, not necessarily linear, $F(t)$ is the periodic seasonal function, and $e(t)$ is the irregular component (Jaynes 2003, 545).

Next will be presented an example of modelling a chaotic environment by mathematical statements. The dissipative model that depicts a change in the environment describes the system as dynamic, open, complex, and unstable. The model sees the system as being in a state of interaction with the environment and the uncertainty factors caused by the environment. The time sequences that describe a change in the environment can be formed with the formula

$$x_{n+1} = ex_n - ex^2_n \quad (17)$$

where x is the state of the environment at n moment, e describes the change in the environmental factors in time, and n the steps in time (Lines 200, 147). By using various figures as e's value, dynamic time sequences can be produced (see Figures 25 and 26).

6.3.3 Implementation of action environment

The implementation of the action environment rests upon development of eight different information sets that enable environment by providing planners with an understanding of systems (Saunders-Newton and Frank 2002). The information sets are:

1. Technical, containing the physical characteristics of organisational tools and describing the physical features and limitations of systems.
2. Geographic, relating objects, such as sensors, people, and other actors, to positions within physical space, making it is a body of knowledge about the distribution of assets and objects within the physical world.
3. Infrastructure, combining technical and geographic information into a basic understanding of how objects and actors within the system relate to one another based on their technical capabilities. Infrastructure information is value-neutral, in that it does not capture preferred ways of making connections within the system, only describing what connections exist or are possible.
4. Organisational, overlaying manmade organisations on the infrastructure data set. It addresses how human beings have formalised their relationship into hierarchies and networks for the purpose of achieving group objectives and carrying out operations. It is value-neutral in that it captures explicitly defined organisational structures but does not account for organisational routines or innovations based on context or pressures.
5. Socio-political, capturing the broader range of social and political objectives of agents, organisations, institutions, and actors in the system. It describes the social and political conditions from which organisations develop and serve.
6. Psychological, explaining the influence of emotion, identity, moral, and other nonmaterial factors in decision-making and conduct.
7. Context, parsing the previous data sets. It forms the body of theories and perspectives that allow analysts and decision-makers to select appropriate technical, geographic, infrastructural, organisational, socio-political, and psychological models to evaluate situations.
8. Dynamics, allowing analysts and decision-makers to understand how systems change across time and between structures and states in response to external stimuli. Dynamics is a set of theories, hypotheses, and assumptions that relates bodies of knowledge to one another and explains causal relationships between action and outcome.

The combination of these information sets is necessary for environmental modelling. The use of a single set of information biases options and restricts the ability of decision-makers to engage an adversary. As the sets of information expand, engagement options increase, and previously attractive courses of action become unattractive as more information becomes available. A deeper, more meaningful planning, decision-making, and implementation can also be developed.

In another approach, Nikander (2002, 92) presents possibilities for using the eight areas of interest which were considered essential in the decision-making process concerning risk management: Personnel, Management, Co-operation, Control, Working, Communication, Environment, and Documents. Concerning communication, managers' used media can be classified by richness: face-to-face, interactive media (phone, electronic media), personal static media (memos, letters, reports), and impersonal static media (e.g., flyers, bulletins) (Zeller 2006, 4). The highest levels of interactivity of these are personal communication with physical presence or interactive media (Zeller 2006, 26).

By using these areas and reclassifying them, and by following the conclusions of Chapters 3 and 4 in this study, the four areas of interest found which were considered essential in the decision-making process concerning decision analysis are:
1. Information, which refers to documents and working results.
2. Resources, which means personnel, (equipment, infrastructure, and materials).
3. Communicative action, which refers to communication as face-to-face or mediated actions, sending and receiving of information of management, co-operation and control.
4. Environment.

All these items could be classified for an environment model type. Used model possibilities are presented in Table 9. This approach produces a model of action environment, gives flexibilities to the modeller and includes more details in the model.

Table 9. An example of domains of action environment with subareas, model types, and models

Domain	Subarea	Model type	Model possibilities
Information			equation (16) or (17)
	Documents	Dynamic	
	Working results	Dynamic	
Resources			equation (16) or (17)
	Personnel	Dynamic or Turbulent	
	Equipment	Stable	
	Infrastructure	Stable or Dynamic	
	Materials	Stable or Dynamic	
Communicative action			equation (16) or (17)
	Sending	Dynamic or Turbulent	
	Receiving	Dynamic or Turbulent	
Environment		Dynamic or Turbulent	equation (16) or (17)

6.4 Solved problems

The models of this research are implemented by using an application named Netica™. Netica is a versatile, user-friendly program through which a user can find patterns in data, create diagrams encoding knowledge or representing decision problems, use these to answer queries and find optimal decisions, and create probabilistic expert systems. It is suitable for applications in the areas of diagnosis, prediction, decision analysis, sensor fusion, expert system building, reliability analysis, probabilistic modelling, and certain kinds of statistical analysis and data mining (Netica).

Netica is a comprehensive tool for working with Bayesian belief networks and influence diagrams. It can built, learn, modify, transform, and store networks, as well as answer queries or find optimal solutions using its powerful inference engine. Netica uses the fastest known algorithm for deriving exact general probabilities in a compiled belief network, in which a message is passed to a join tree or junction tree of cliques. The algorithms used are described by Spiegelhalter and Neapolitan. In this process, Netica first compiles the belief networks into a join tree. The join tree is implemented as a large set of data structures connected with the original belief network, but invisible to user. The user enters findings for one or more nodes of the original belief network, and when the user wants to know the resultant beliefs for some of the other nodes, belief updating is performed by a message-passing algorithm operating on an underlying join tree. It determines the resultant beliefs for each of the nodes of the belief network, which it displays as a bar graph, or needle meter, at each node.

6.4.1 Application of Decision-Making

The goal of dynamic decision-making is to select an optimal course of action that satisfies some objectives in a time-dependent information warfare environment. The decisions may be made in different stages and each stage may vary in duration. A decision made in one time period affects the degree of total measured success across all time periods as well as the measured success in that same time period. In addition, the decisions in the following time periods are affected to a degree by the decisions made earlier. Using a sequential structure model, the decision-maker explicitly acknowledges the links between decisions with a common objective made over time. The opportunity to change course at some point in the future leaves open the possibility that a somewhat riskier strategy could be pursued in one time period and, if not successful, could be followed by a more conservative approach to mitigate the damage from the earlier period. Also, this modelling structure allows the decision-maker to see the future so that a decision to defer action until a later period sometime in the future may also be made (Marakas 1999, 123).

One of the most important applications of equation is in learning the behaviour of stochastic temporal processes. Such processes are typically represented by using dynamic probabilistic networks (DPNs). A DPN is structured as a sequence of time slices, in which the nodes at each slice encode the state at the corresponding time point. The conditional probability tables (CPTs) for a DPN encode both a state evolution model, which describes the transition probabilities between states, and a sensor model, which describes the observations that can result from a given state. Typically, one assumes that the CPTs in each slice do not vary over time. Therefore, the same parameter is duplicated in every time slice in the network. (Binder *et al* 1997.)

The task of this application is to support the process which will affect continuous anticipatory decision-making. The main purpose is to collect items which cover the most important areas of the decision-making environment. The network includes all these parts which are necessary for effective decision-making (see Figure 19).

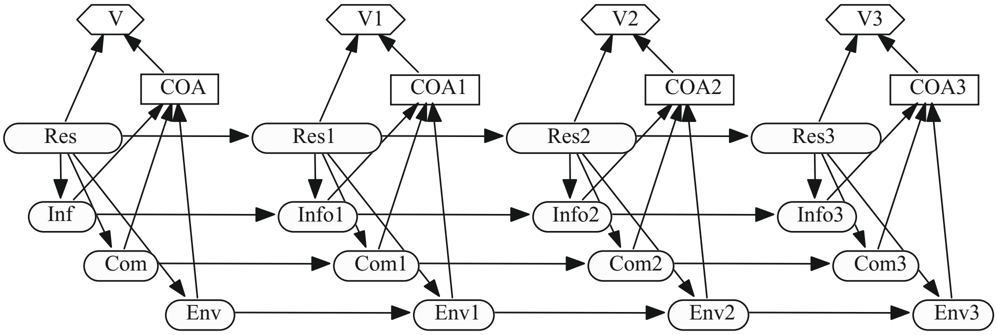

Figure 19. The rough network for anticipatory decision-making. Resources (Res), an information (Info), a communication act (Com) and an environment (Env) are chance nodes, a course of action (COA) is decision node and a value (V) is value node. The time expansion is illustrated with numbers 1…3.

6.4.2 Application of Risk Management

What is the likelihood that an important combination of assets in decision-making is affected by some risk? There are a number of motivations for selecting a methodology based on use the of Bayesian nets. One of these is their firm foundation in probability theory. The fact that the technique is based on probability theory ensures that it is compatible with the use of statistically gathered information. Another reason is the existence of a substantial body of theory concerning efficient computation using Bayesian nets. An important advantage is that they provide a user-friendly graphical notation for expressing complex probabilistic relations.

The model that has been developed has adopted the form of a tree, with the asset risk classes node being its root, and the asset attributes forming its leaves. The conditional probability tables that are attached to the random variables in the model may be estimated from collected statistical information where this is available. When such information is not available, the tables can be constructed on the basis of opinion.

A task of this application is evaluating those consequences that will have an effect on continuous anticipatory decision-making. Table 10 shows the scaled values (0…100) of relations between a cause and its consequences. These values are used as prior values in node "risk" of network. Figure 20 shows a rough network for anticipatory decision-making with risk analysis, which illustrates the elements of the network and a time expansion.

Table 10. Risks of management and their consequences

Cause or risk	Delay	Over costs	Inefficiency
Resources	22	18	60
Information	52	14	34
Communication	66	8	26
Environment	47	9	44

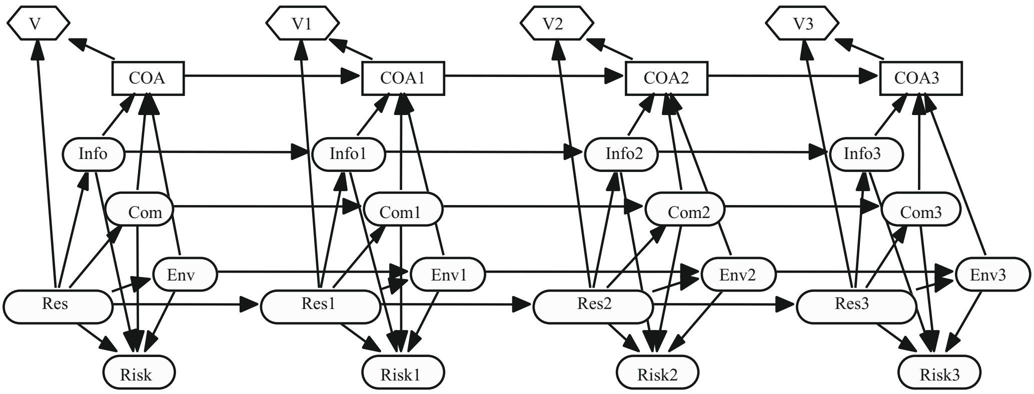

Figure 20: The rough network for anticipatory decision-making with risk nodes. Resources (Res), an information (Info), a communication act (Com), an environment (Env) and a risk (Risk) are chance nodes, a course of action (COA) is decision node and a value (V) is value node. The time expansion is illustrated with numbers 1…3.

Chapter 7

Validation of models and results of research

In this chapter, the validation process and results of research are discussed. Results are validated by methods of simulation and statistics.

7.1 Data and Test Model

In the simulation, the central problem is not constructing a suitable model. The problem is the inputs. To simulate an economy or a battle, it is not so much a question of initial conditions, although chaos theory shows that these alone create a confusion of results, except within a narrow range of values that converge on a stable outcome. The central problem is to anticipate the changes of external forces acting on the modelled economy or battle in which the changes themselves will be affected by the evolving situation (Hughes 1997, 3). It is difficult to find real-life data sets in which all of the variables are always observed, and it is also difficult to find a way to predict the future evolution of a time series, as may be seen in (Aguilar *et al* 1998) and (Small and Tse 2002). This was not the main aim of this research.

Another important question is: how long until the decision will be made? The analyst must respond before a deadline. A sound rule for any study is that a third of the time will be spent in defining the problem and understanding how to tackle it, a third in modelling and analysis, and a third in figuring out what has been learned (Hughes 1997, 25).

Simulation modelling is not without disadvantages. An optimal solution is not guaranteed by a simulation model. The model will only inform the decision maker of the probabilistic outcome and allow for a comparison of modelled scenarios. The results obtained from a simulation model are distinctly context specific and are not generalisable to other problem domains. Simulation is an attractive and entertaining method to managers. That it could yield equal or even better and more accurate results is often overlooked. When its limitations are understood and acknowledged, simulation is a powerful abstract analytical modelling technique that can provide positive results when properly applied. (Marakas 1999, 126.)

In this study, a test procedure is defined as a process (Figure 21). Using a simulation environment model, parameters for a BDSS Model are produced into two classes. Firstly, using full data, it models parameter values for a BDSS Model as a certain world. Secondly, using different levels of missing data, it models parameter values as an uncertain world. Using a BDSS Model, results are calculated and then these results are analyzed. These results illustrate values of correct decisions. Results are presented as success percentages.

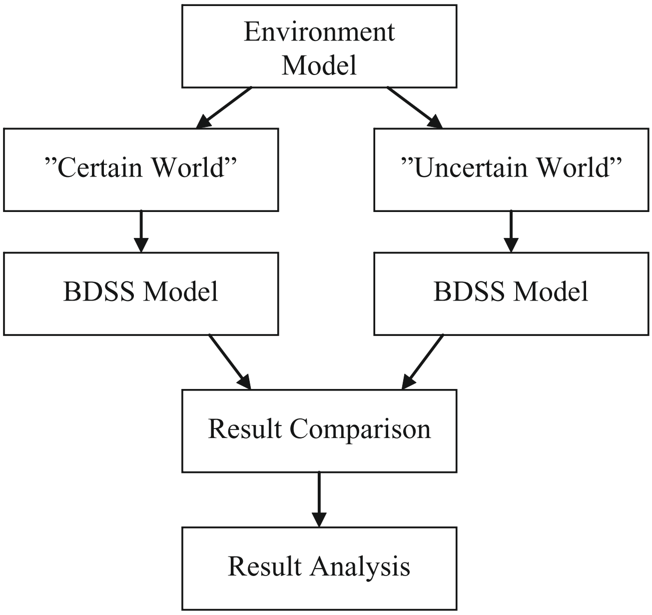

Figure 21. Test procedure

Two decision-making situations are presented to validate the construction that was formed on the basis of the decision-making process. It models two cases of a decision-making environment based on the speed of change. In Case 1, the environment's speed of change is slow, and in Case 2, the speed is faster. The idea is first to test the functionality of that construction, and then adjust the model to better fit the problem area. Finally, the model is validated more comprehensively by testing it with a decision-making model presented in a latter section. Those two different cases act as examples of the broad spectrum of possibilities that is required for decision-making both temporally and content-wise. The cases are considered from the decision-maker's viewpoint.

Through experiments on a number of data sets, answers are sought to questions about the usefulness of the Bayesian network for anticipatory decision-making support. For testing purposes, synthetic data sets are produced as time-series of values (0, 1). The time series are trended using a single sinusoid model (Jaynes 2003, 536). The used data sets represent a dynamic model of the decision environment's elements. Time sequences are the input queues received by the network. They represent changes in the parameter values received by the network, such as changes in resources, availability of information, the communication situation, and changes in the environmental status. The values describe moments of change, not the content of change.

The sample sizes were fixed at 50 time steps, and a slower model of environment (Case 1) was defined with cycle parameters in which the value of a parameter means the cycle's full length at time steps. The value for change parameter for resources is 20 time steps, for information 10 steps, for communication 8 steps, and for environment 16 steps.[1] Furthermore, a faster model (Case 2) was defined with the following values of parameters: resources 10 time steps,

[1] For example: resource change needs twice the amount of time that information change requires. Information is collected at twice the rate of environment change.

information 3 steps, communication 5 steps, and environment 7 steps. Accordingly, these parameters input values were generated to a Bayes network. Figures 22 and 23 illustrate this procedure more clearly as an example in Case 1.

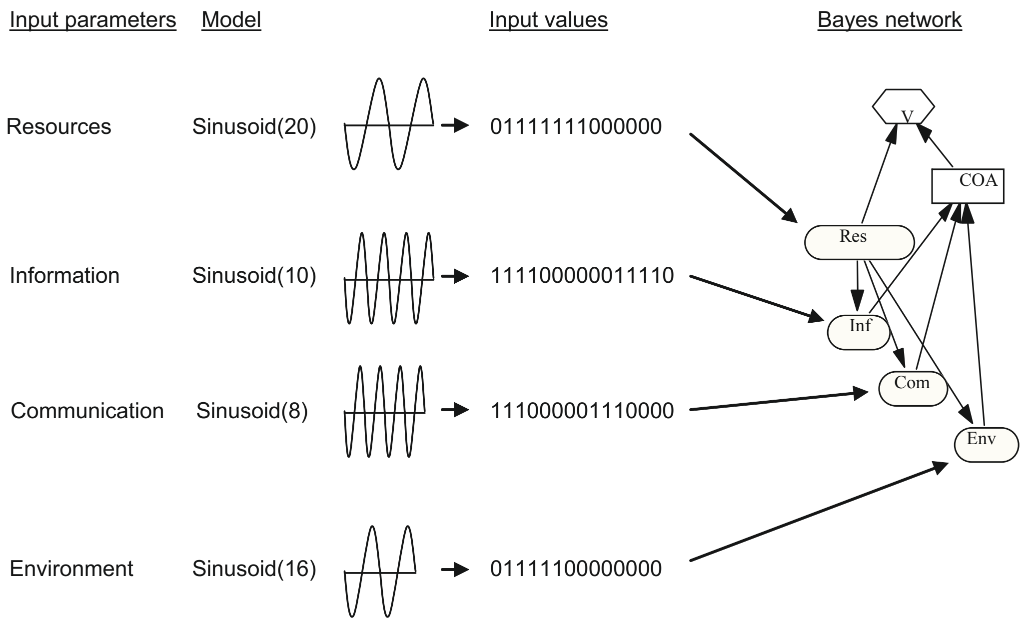

Figure 22. Basis for input values generation

Figure 24 shows a graphical representation of the time sequences, which have been formed according to the aforementioned rules. Changes in resources, information, communication, and the environment follow the changes presented in the figure between values 0 and 1. The time sequences in the figure form the reference that will be used in the future when comparing time sequences based on uncertainty and chaotic models and the results based on these time sequences.

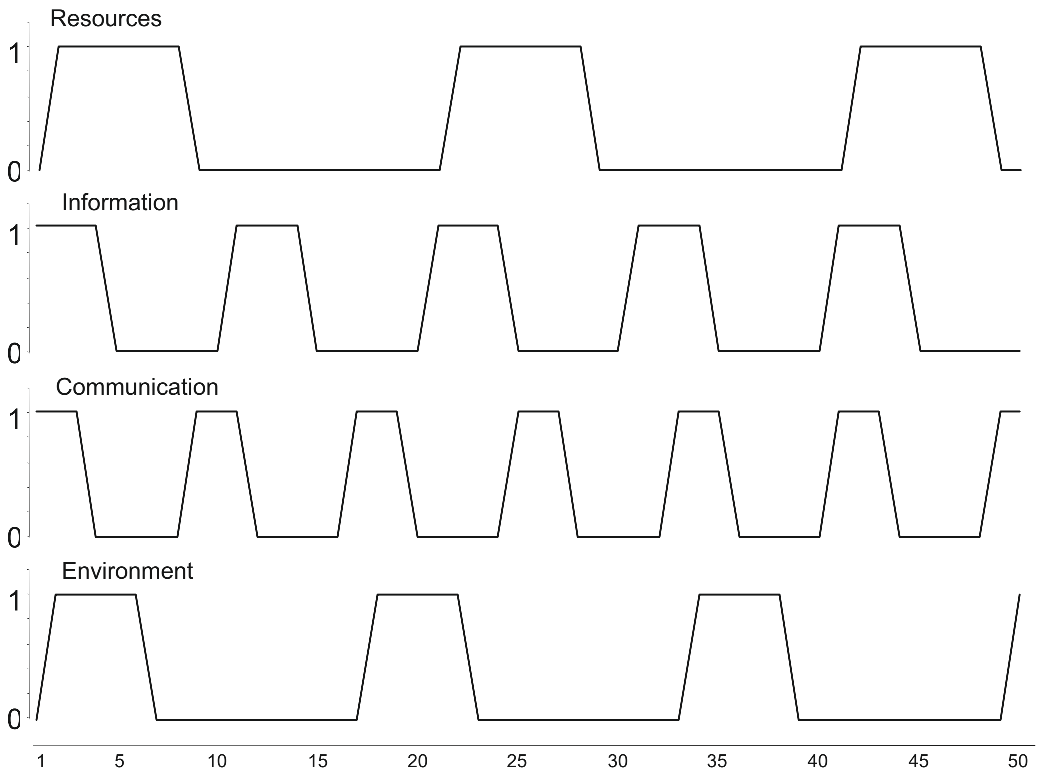

Figure 23. Result of input values generation in case of certain world at time steps 1…50

The uncertainty of the decision environment is modelled with missing data. Used levels are 10%, 20%, 30%, 40% and 50%. Figure 24 shows result of uncertainty 30%. Unifying equations (19) and (20) produced more dynamical environments. Using equation (19) to produce basic curve and after that, when value was 0, using equation (20) made more complex environment data sets. Figures 25 and 26 illustrate results.

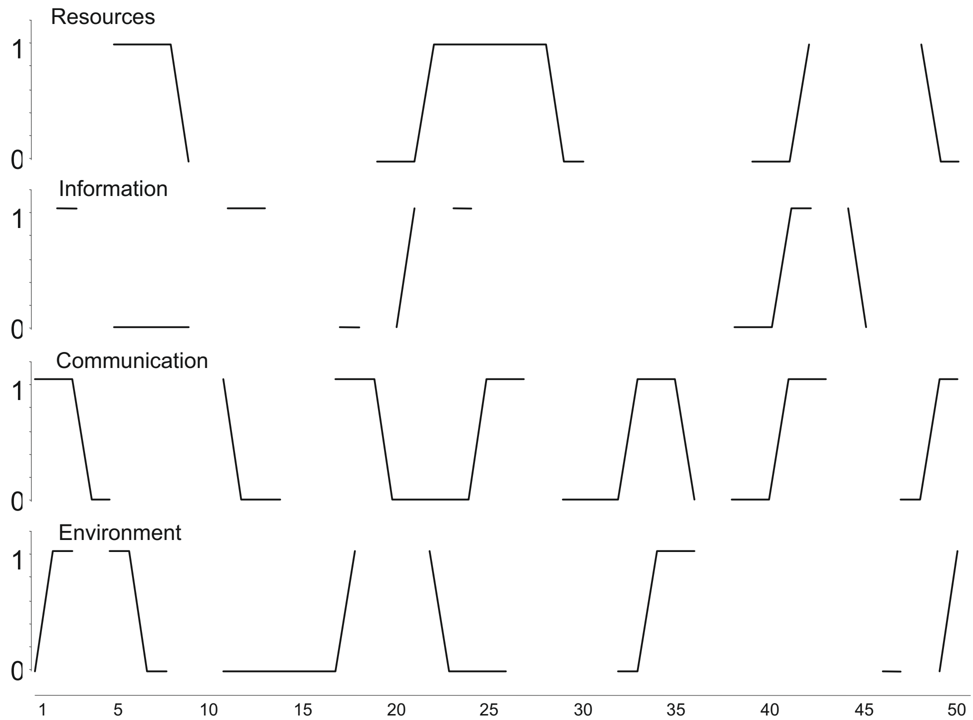

Figure 24. Result of input values generation in case of uncertainty 30% at time steps 1…50

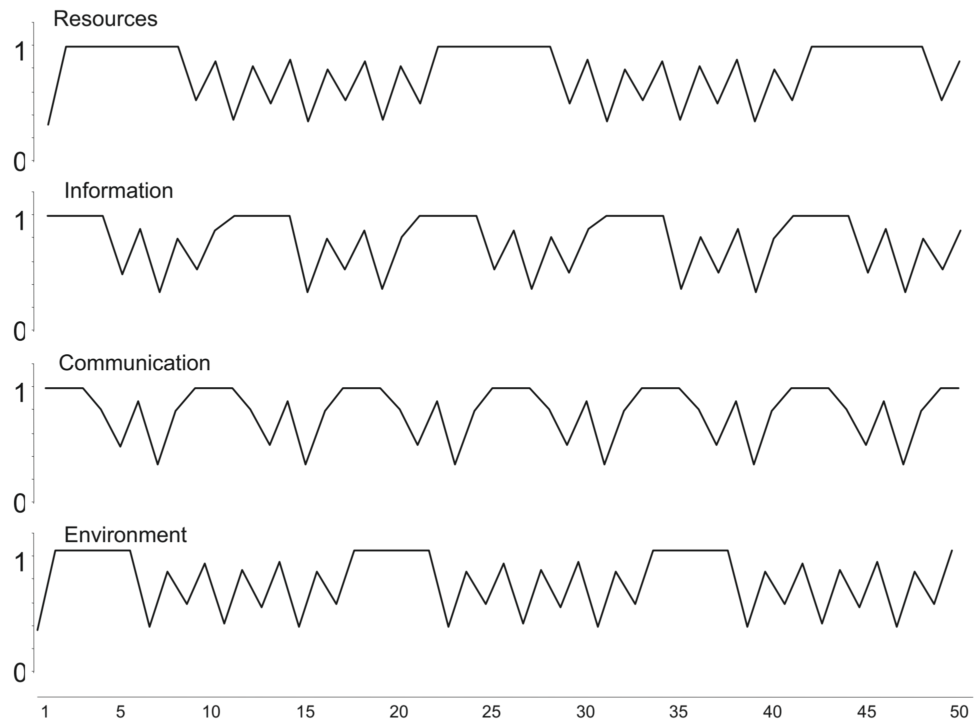

Figure 25. Result of input values generation in case of equation (20) with e = 3,55 at time steps 1…50

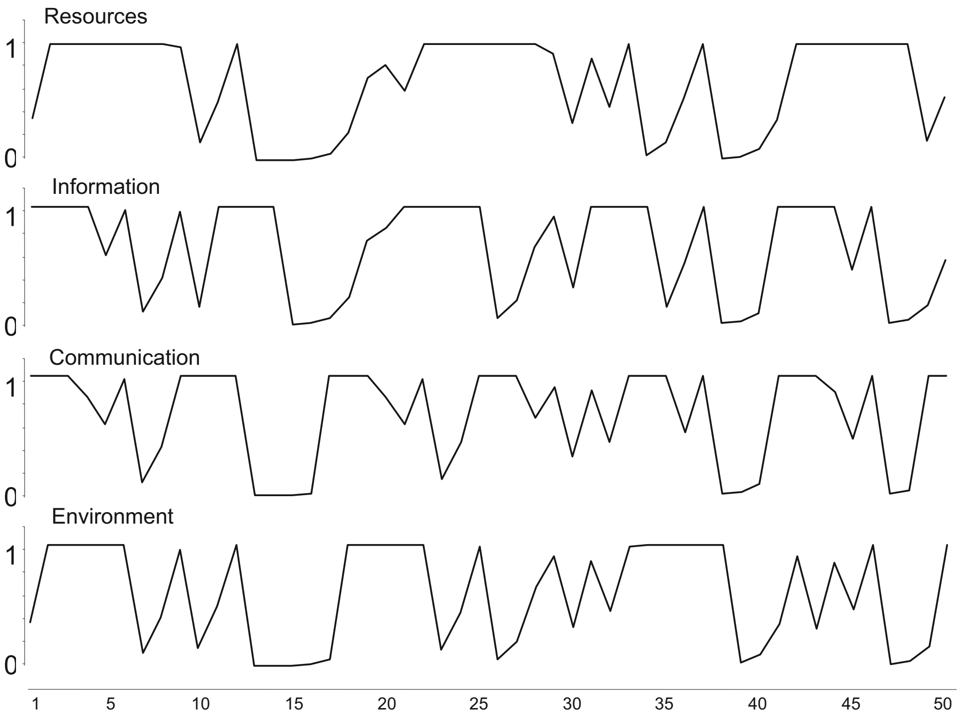

Figure 26. Result of input values generation in case of equation (20) with $e = 4$ at time steps 1…50

All decisions are made as human-in-loop and rational, which means that the author made all decisions step by step and the highest value of alternatives was selected. The number of decisions is 400 for certain decisions as reference world, and 6600 decisions for testing decisions accuracy in a dynamic action environment. Every uncertainty level is tested with three different data sets. Amount of decisions are as follows:

– certain decision as reference world: 2 (fast and slow models) x 4 (decision and 3 anticipated decisions) x 50 times = 400 decisions
– uncertain decisions: 3 sets x 2 (fast and slow) x 5 (missing data levels 10%/20%/30%/40%/50%) x 4 (decision and 3 anticipated decisions) x 50 times = 6000 decisions
– uncertain decisions: 3 sets using unified model with equations (19) and (20), and in (20) using values e = [3,15; 3,55; 4] x 4 (decision and 3 anticipated decisions) x 50 times = 600 decisions

7.2 Experiments in application of decision-making

In the this chapter, two decision-making cases are presented to validate - each as its part – the construction that was conducted on the basis of the decision-making process in chapter 4 and completed in chapter 6. The models describe the impacts of dynamic functions related to proactive decision-making on communication, information, resources, and the environment. As regards communication, dissipativity or integrativity are present in the model's dynamic.

The idea is first to test the functionality of that construction, and after that adjust the model to better fit the problem area. Finally, the model is validated more comprehensively by testing it with decision-making models presented in chapter 6.4.1. Those two different cases act as examples of the broad spectrum of possibilities that is required for decision-making both temporally and in content. Cases are considered from the decision maker's viewpoint.

During the tests, on a few occasions, the values for courses of action were so close to each other that a human made selection could differ from the rational one in a real situation. The result shows that uncertainty has an effect on anticipation. However, 10% of missing data accounts only for a deduction of 8,2% (slower change environment) or 2,2% (faster change environment) in success, and 50% of missing data has an effect of only 24,4% or 17,6%. More detailed values are presented in Table 11.

Based on the results of empirical tests and using regression analysis (Taha 1992, 402), equations to succession values are defined. The succession value (y) of anticipated decision based on missing data levels (x) may be determined in the slow environment (Case 1) using the equation

$$\hat{y} = -0.449x + 96.444, \tag{18}$$

and in the fast environment (Case 2) using the equation

$$\hat{y} = -0.358x + 100.56. \tag{19}$$

The correlation coefficient values, $r_{slow} = 0.942$ and $r_{fast} = 0.922$, indicate that the regression lines provide a good fit for the observed data. A reasonable fit normally occurs in the range $0.75 \leq |r| \leq 1$. In summary, success rates of correct anticipated decisions are higher than certain data levels.

Table 11. The results (%) of empirical tests at different levels of missing data (Kuokkanen 2006b). Anticipated decisions are compared to the actual decisions (at time T) at times T+1, T+2, and T+3. The anticipated decision's success-% is based on slow (Case 1) and fast changes (Case 2) in the environment.

		Slowly change environment				Quickly change environment			
Missing data		**T+1**	**T+2**	**T+3**	**Mean**	**T+1**	**T+2**	**T+3**	**Mean**
- 10 %	Min	88	90	86		96	96	96	
	Mean	94,00	92,67	88,67	91,78	97,33	98,67	97,33	97,78
	Max	100	96	94		98	100	98	
	Deviation	6,00	3,06	4,62	4,56	1,15	2,31	1,15	1,54
- 20 %	Min	84	88	80		94	88	90	
	Mean	89,33	88,67	86,00	88,00	95,33	92,00	92,67	93,33
	Max	92	90	92		98	96	96	
	Deviation	4,62	1,15	6,00	3,92	2,31	4,00	3,06	3,12
- 30 %	Min	82	82	80		82	88	84	
	Mean	83,33	84,67	84,00	84,00	87,33	89,33	85,33	87,33
	Max	86	88	86		94	92	86	
	Deviation	2,31	3,06	3,46	2,94	6,11	2,31	1,15	3,19
- 40 %	Min	74	72	66		84	86	84	
	Mean	78,67	77,33	70,67	75,56	88,67	89,33	86,67	88,22
	Max	82	86	74		92	94	92	
	Deviation	4,16	7,57	4,16	5,30	4,16	4,16	4,62	4,31
- 50 %	Min	66	70	72		82	80	78	
	Mean	72,67	78,00	76,00	75,56	84,00	82,00	81,33	82,44
	Max	76	84	80		86	84	84	
	Deviation	5,77	7,21	4,00	5,66	2,00	2,00	3,06	2,35

The succession value (y) of anticipated decision based on time step (x) and missing data level (z) may be determined in the slow environment (Case 1) using the equation

$$\hat{y} = (-0.063z - 3.163)x + (100 - \frac{z}{2.360}), \qquad (20)$$

and in the fast environment (Case 2) using the equation

$$\hat{y} = -0.932x + (100 - \frac{z}{3.950}). \qquad (21)$$

The correlation coefficient values between models at same missing data levels, $r_{-10\%} = 0.278$, $r_{-20\%} = 0.497$, $r_{-30\%} = 0.500$, $r_{-40\%} = 0.922$ and $r_{-50\%} = 0.812$, indicate that the all regression lines do not provide a good fit for results based on slow and fast environments. The consequence is that the models have to adapt to situation.

Continuing the test using data that produced unifying equations 16 and 17, the environment behaves dynamically and partly chaotically. The result is presented in Table 12.

Table 12. The results (%) of empirical tests based on data of equations 16 and 17. Anticipated decisions are compared to the actual decisions (at time T) at times T+1, T+2, and T+3. The anticipated decision's success-% is based on complex environment.

Value *e*	**T+1**	**T+2**	**T+3**	**Mean**
3,15	70	68	66	68,0
3,55	68	64	64	65,3
4	78	78	80	78,7

The latter results are almost acceptable, but by looking at results more clearly as desired correct decisions, it will be seen that a too chaotic environment influenced the decreasing success rate of decisions dramatically. At the area where environment data behaves dynamically, the decisions failed and followed curves of environment data. The anticipated decisions are not liable, and they are not useful for decision support. The result and problematic areas (marked as bold and cursive) are illustrated in Table 13.

The results of the presented Bayesian application determined that success rates of correct anticipated decisions are higher than certain data levels at uncertain environment, but not at rapidly changing environment. Correlation between uncertainty and success rate is strong. Models have to be adapted to each situation based on changing dynamics in the environment. Accuracies of the applications can be estimated on the basis of missing data levels with good fit or based on missing data levels and time steps. With these equations, the accuracy of Bayesian applications in other environments can be estimated.

Table 13. The results of empirical tests based on test data (Case 1) and dynamic model of equations 16 and 17. Anticipated decisions at time T+1 are compared to the actual decisions (left column).

Correct decisions	Missing data levels					Values to *e*		
	10 %	20 %	30 %	40 %	50 %	3,15	3,55	4,00
T	T	T	T	T	T	T	T	T
T	T	T	T	T	T	T	T	T
T	T	T	T	T	T	T	T	T
T	T	T	T	T	D	T	T	T
T	T	T	D	D	T	T	T	T
T	T	T	T	T	T	T	T	T
T	T	T	T	T	D	T	T	T
D	D	D	D	T	D	***T***	***D***	***T***
D	D	D	D	D	D	***D***	***T***	***D***
D	D	D	D	T	D	***T***	***D***	***D***
D	D	D	D	D	D	***D***	***T***	***T***
D	D	D	D	D	D	***T***	***D***	***D***
D	D	D	D	D	T	***D***	***T***	***D***
D	D	D	D	D	D	***T***	***D***	***D***
D	D	D	D	D	D	***D***	***T***	***D***
D	D	D	D	D	D	***T***	***D***	***D***
D	D	D	T	D	T	***D***	***T***	***D***
D	D	D	T	D	D	***T***	***D***	***T***
D	D	D	D	D	D	***D***	***D***	***T***
D	D	D	D	T	D	***T***	***D***	***D***
D	D	T	T	T	D	***T***	***T***	***T***
T	T	T	T	T	D	T	T	T
T	T	T	T	T	T	T	T	T
T	T	D	T	T	D	T	T	T
T	T	T	T	T	T	T	T	T
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T	T	T	T	D	D	T	T	T
T	T	D	D	D	D	T	D	T
D	D	D	D	D	D	***D***	***T***	***D***
D	D	D	D	D	D	***T***	***D***	***T***
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D	D	D	D	D	D	***T***	***D***	***D***
D	D	D	T	T	D	***T***	***T***	***T***
T	T	T	T	T	T	T	T	T
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T	T	T	T	T	T	T	T	T
T	T	T	T	T	T	T	T	T
T	T	T	D	T	D	T	T	T
T	T	T	T	T	D	T	T	T
T	D	D	D	D	D	T	D	D
D	D	D	D	D	D	D	T	D
D	D	D	T	D	T	T	D	T
Succ	47	46	41	40	38	35	34	39
Succ%	94	92	82	80	76	70	68	78
Succ D-area (total is 29)						14	15	19
Succ% D-area						48,3	51,7	65,5

7.3 Experiments in application of decision-making with risk analysis

As in the previous chapter, two decision-making cases are also now presented to validate the construction that was conducted on the basis of the decision-making process, but with risk analysis. The model is validated more comprehensively by testing it with decision-making models with risk analysis presented in chapter 6.4.2. Those two different cases act as examples of the broad spectrum of possibilities that is required for decision-making, both temporally and in content.

Through experiments on a number of data sets, answers are sought to questions about the usefulness of the Bayesian network for risk analysis as a part of anticipatory decision-making support. Two cases for a decision-making environment based on the speed of change are modelled. In Case 1, the environment's speed of change is slow, and in Case 2, the speed is faster. For testing purposes, synthetic data sets are produced to generate a real world situation. Used data sets represent a dynamic model of elements of the decision-maker's environment.

Two decision-making cases with risk analysis are presented to validate the construction that was conducted on the basis of the decision-making process. The idea is first to test the functionality of that construction, and then adjust the model to better fit the problem area. Finally, the model is validated more comprehensively by testing it with decision-making models, with risk analysis presented in a latter section. Those two different cases (Case 1 and 2) act as examples of the broad spectrum of possibilities that is required for decision-making both temporally and content-wise. Cases are considered from the decision-maker's viewpoint. Results of tests are presented in Table 14.

The results are based on a small time series, so their reliability must be approached critically. The results show that uncertainty has a clear effect on anticipation. However, 10% of missing data accounts for a deduction of 10,0% in success, and 50% of missing data has an effect of only 23,8 % in the slowly changing environment, and same values are 6,7% and 27,8% in the rapidly changing environment.

Table 14. The results (%) of empirical tests at different levels of missing data (Kuokkanen 2006b). Anticipated risks are compared to the actual risks (at time T) at times T+1, T+2, and T+3. Anticipated risk's succession-% based on slowly (Case 1) and quickly (Case 2) changing environments.

		Slowly changing environment				Quickly changing environment			
Missing data		**T+1**	**T+2**	**T+3**	**Mean**	**T+1**	**T+2**	**T+3**	**Mean**
- 10 %	Min	80	82	82		92	92	86	
	Mean	88,67	88,67	92,67	90,00	95,33	94,67	90,00	93,33
	Max	94	94	100		98	96	86	
	Deviation	7,57	6,11	9,45	7,71	3,06	2,31	4,00	3,12
- 20 %	Min	88	84	80		80	84	84	
	Mean	90,00	86,67	88,00	88,22	83,33	90,00	87,33	86,89
	Max	92	90	94		86	96	90	
	Deviation	2,00	3,06	7,21	4,09	3,06	6,00	3,06	4,04
- 30 %	Min	78	80	78		74	78	74	
	Mean	83,33	84,67	82,00	83,33	77,33	78,67	78,67	78,22
	Max	86	90	88		82	80	82	
	Deviation	4,62	5,03	5,29	4,98	4,16	1,15	4,16	3,16
- 40 %	Min	76	70	74		74	68	72	
	Mean	78,67	76,00	77,33	77,33	76,67	75,33	76,67	76,22
	Max	82	84	80		80	80	80	
	Deviation	3,06	7,21	3,06	4,44	3,06	6,43	4,16	4,55
- 50 %	Min	70	78	74		74	66	70	
	Mean	74,67	78,67	75,33	76,22	76,00	68,67	72,00	72,22
	Max	82	80	78		78	72	76	
	Deviation	6,43	1,15	2,31	3,30	2,00	3,06	3,46	2,84

Based on the results of empirical tests and using regression analysis (Taha 1992, 402) as a system evaluation, equations for succession values are defined. The succession value (*y*) of an anticipated risk based on missing data levels (*x*) may thus be determined in the slow environment (Case 1) from the equation

$$\hat{y} = -0.384x + 94.555\,, \qquad (22)$$

and in the fast environment (Case 2) from the equation

$$\hat{y} = -0.529x + 97.243. \qquad (23)$$

The correlation coefficient values, r_{slow}= 0.957 and r_{fast}= 0.952, indicate that the regression lines provide a good fit for the observed data. A reasonable fit normally occurs in the range $0.75 \leq |r| \leq 1$. In short, success rates of correct anticipated risks are higher than certain data levels.

The succession value (*y*) of an anticipated risk based on time step (*x*) and missing data level (*z*) may be determined in the slow environment (Case 1) from the equation

$$\hat{y} = (-0.030z - 0.690)x + (100 - \frac{z}{1.728}), \tag{24}$$

and in the fast environment (Case 2) from the equation

$$\hat{y} = -0.359x + (100 - \frac{z}{2.747}). \tag{25}$$

The correlation coefficient values between models at same missing data levels, $r_{-10\%}$= -0.994, $r_{-20\%}$= -1, $r_{-30\%}$= 0.002, $r_{-40\%}$= 0.865 and $r_{-50\%}$= -0.912, indicate that all regression lines do not provide a good fit for results based on the slow and fast environments. The consequence is that the models have to adjust depending on the situation.

In summary, the presented results show that the Bayesian network is useful for anticipatory risk analysis purposes. However, it seems to depend on the completeness of the information on the environment.

7.4 Results of research

The following lessons have been learned as a result of using Bayesian applications for decision-making support. An important part is the engineering judgment regarding how the design and test data are produced. It is easy to use a sinusoid to model a dynamic action environment, but a more complex model is needed to test this application more thoroughly. A testing program should be designed to ascertain that the application will meet specification.

The practical contribution includes the Bayesian Decision Support Model, which is based on Bayesian influence diagrams. The used approach of Bayesian influence diagrams as a meta-model combines different sources of uncertain information with a decision-making model. The practical benefit of the Bayesian influence diagram model is that it can be used interactively between the decision-maker and a sub-unit.

The networks used had been formed by using the processes presented in research. There were no problems in the operation of the networks and the creation of data. The Netica software functioned without any glitches.

In supporting decision-making, the rate of success in both cases was clearly higher than the missing data level, i.e., about half of the value. In risk analysis, a missing data level of 10% indicates a corresponding decrease in the success rate, but as the level decreases, the success rate settles at nearly the same level as when supporting decision-making, or at about half of the value. It should be noted that the accuracy of anticipation decreases slightly as the steps in time increase, but that is not as significant a factor as the missing data level.

Based on the above, it can be stated that the Bayesian Network supports anticipatory decision-making in environments that are not too dynamic or chaotic, both as regards actual decision-making and related risk analysis. In too dynamic an environment, the predictability of decision-making is not sufficiently reliable. In communication, this shows that a dissipative phase cannot be changed/turned to into an integrative phase.

In summary, the presented results show that the Bayesian network is useful for anticipatory decision-making, and its success rate can be estimated. Empirical evaluations show that theoretical arguments are confirmed by significant improvements. One great advantage is that a Bayesian network gives possibilities for use as an if-then-question analysis, and in use as free selection in generation of environment states. The disadvantages are that the completeness of information affects the accuracy of anticipated decisions and models have to be adjusted to each situation. However, this additional complexity does not reject the usefulness of presented processes and methods. There is no doubt that these methods are useful for anticipatory management and decision-making.

This conclusion stresses the significance of communication in practical management in dynamic as well as chaotic situations. In a dynamic situation, the dissipativity of communication must be reduced with integrative procedures even during a time of uncertainty.

Finally, it should be pointed out that the improvements observed in these results can only be attributed to the idea of using anticipatory decision-making support. This idea is certainly not limited to anticipatory decision-making, and should generalize well to other environments and situations.

Chapter 8

Conclusions

This study was motivated by my belief that there is a benefit to integrating knowledge of managerial communication and anticipatory decision-making with the application of Bayesian decision-making support.

Factors that influence managers' decision-making are management principles, available resources, environment, and communication. Following the principles of the transformative management model supports an organisation's proactive behaviour, the factors that impact decision-making change over time. Therefore, a decision-maker constantly has to make new decisions. In a changing environment, it is essential to make an organisation implement decisions in the desired way by means of communication. A system should be used to provide support to decision-makers and increase the effectiveness of decision-making effort. When the factors that influence decision-making are modelled in line with managerial principles, available resources, environment, and communication, the overall model supports the chosen decision-making model.

The purposes of this thesis were to show that it is possible to construct and successfully implement a Bayesian decision support model that utilises decision-oriented and constructive approaches. In this study, the behaviour of the surrounding environment was seen as dynamic, and a decision anticipated the future. As a result of this examination, we can state that TDID can be used as a method of the support system for proactive decision-making in a dynamic environment.

The field of management science and operation research has provided the theoretical framework in decision analysis that is necessary to design useful and relevant normative approaches to choice making, especially those that are concerned with systems analysis and model-based management. Background information from the areas of organizational behaviour and behavioural and cognitive science are needed for the design of effective systems for dialog generation and management.

Before providing answers to main research questions, the following propositions can be sorted out based on the previous chapters' conclusions:
[P1] An organisation uses *information to make sense of changes and developments* in its external environment; it searches for and evaluates information in order to make important decisions. The knowing organisation is effective because it continually evolves with its changing environment, refreshes its knowledge assets, and practises vigilant information processing in its decision-making.
[P2] Transformational leaders formulate a vision, develop commitment to it among internal and external operators, implement strategies to accomplish the vision, and embed new values and assumptions in the culture and structure of an organization. The fragmented nature of managerial activity reflects the fact that many interactions are initiated by others, and much of a *manager's behaviour has to be more proactive* than reactive in nature.
[P3] Inspected methods of *leadership and management are based on vision* and conception,

or based on implementation and action, in order to be effective. New ideas expand transformational leadership principals, updating and giving new meaning to traditional processes, especially to observing and planning.

[P4] By anticipating the changes occurring in the environment, an organization aspires to adjust to them in advance. In unstable conditions, the behaviour of various factors of both the environment and the organization is unpredictable. As an organization prepares to develop, it must *recognize the organization's* internal *changes*, and the environment's dynamic and non-continuous changes.

[P5] The ability to quickly *combine available information and use it* to form the correct situation picture and gain the necessary understanding to make a decision are basic requirements for success in one's own operations. The correct timing of decision-making in the management process makes it possible to reach significant operational advantages and benefit in terms of the environment. The correct timing of decision-making is always gauged in relation to events in the surrounding environment and estimates of how they will develop.

[P6] The *proactive communication* of decision-making has an important role in a situation of change. As an organisation changes, a proactive decision provides a basis for change and makes it easier to see the reasons behind the change. The decision-maker must ensure that everyone is informed about a decision and is ready to implement it. The implementing party needs feedback from the decision-maker to learn whether the implementation supports the decision. In communication, dialogue is used to ensure that objectives are met.

[P7] From the decision-maker's point of view, the environment's *communication can be either dissipative or integrative*, or possibly both. The decision-maker is not necessarily in active interaction with the environment. In these cases, some of the information coming in from the environment is interpreted by the decision-maker and may thus be unconfirmed. The information is unclear or may lack contributory factors and their values, meaning that options and decisions are prepared in a state of uncertainty.

[P8] There is a clear role for a *double function in anticipatory decision-making*. Integrative communication is emphasised in a decision's implementation, whereas dissipative communication refers to an environment's communication to an organisation and enables the creation of disorder, or it could be the product of failed implementation.

[P9] *Anticipatory management responds to the changes*, weakening predictability of events and shortened planning of the current operational environment. Thinking is focused on the creation of potential solution alternatives and purposeful selection between them.

[P10] Anticipatory management includes the processes of problem-solving. With management measures, an organization takes advantage of the operating sequence of structured problem-solving while *increasing its knowledge and know-how at individual and organization levels*. Knowledge and know-how that are in accordance with a decision are actively used during implementation. Knowledge and know-how acquired through rejected alternatives remain in individuals' and an organization's information structures of decision-making, in order to have a later influence either as active or tacit information.

[P11] The use of a Decision Support System is a provision of support to decision makers in terms of *increasing the effectiveness of the decision-making effort*. This involves the formulation of alternatives, analysis of their impacts, and interpretation and selection of appropriate options for implementation.

"How to prepare for anticipatory decision-making and how to support it?"
One of the greatest challenges facing the intelligent organization is to understand how the external environment is changing, what changes mean, and how the organization can best respond to the conditions. The Intelligent organization scans changing conditions continually.

The parallel management process enables all sub-process to operate simultaneously with situational follow-up. A changing situation can cause separate or simultaneous changes and measures in preparation, decision-making and execution. Especially important is vision and finding weak signals related to anticipation, whereby anticipation of change is possible. Trying actively to anticipate operating in an environment makes it possible to seize the initiative and create requirements for a successful decision. Increased speed of operating increases the importance of anticipatory management and information needs.

Decision-making ends the selection of alternatives. Qualitative and quantitative methods can be used in the selection process. Decision-making always includes uncertainty, because the decision-maker is not always clear about the consequences of different alternatives. It is possible to use a tool or algorithm that evaluates future risks. This procedure includes an analysis of values and risks. This analysis suggests whether or not to move ahead with an action and accept its risk. This kind of tool or algorithm solves a problem and suggests a next move. This procedure accepts the value and risk analysis.

Based on written conclusions, there are requirements for a model of decision-making. It must be known what kinds of phases will follow the current situation of the environment, the next stable or chaotic phases of the current situation, and the chaotic areas in the environment. The decision-maker has to know that the next possible situation could follow the current position in the environment. A prediction of a state of the next phase or a point of bifurcation has to be made. It has to be possible to observe the near environment to search for stable or chaotic locations. Adversities increase uncertainty, because the decision maker does not always achieve the desired goals. Results of action do not meet established targets, partly based on timetable or effects of action. One conclusion is that time itself is different in separate situations and at distinct levels of organization.

Anticipatory decision-making can be described using the following terms: information and knowledge of environments, decision-making with decision support, action, and effect. If the relevant decision support systems are based on good knowledge of the environment and of means of action and effect, then the resulting decision creates the possibility for swift implementation. By adding the decision-making function to a non-hierarchical network between organisation levels, it is possible to implement the decision on the level that is most suited to the situation. This way, more efficient, graduated actions at the right moment are made possible with good knowledge of the environment, including an improved decision capability. This requires the sharing of information, high quality situational awareness, and self-synchronization during the decision-making process.

"How to support anticipatory decision-making with managerial communication in management processes?"
The correct timing of decision-making in the management process makes it possible to

reach significant operational advantages and benefit in terms of the environment. The proactive communication of decision-making has an important role in a situation of change. As an organisation changes, a proactive decision provides a basis for change and makes it easier to see the reasons behind a change. The decision-maker must ensure that everyone is informed about a decision and ready to implement it. In the communication between the implementing party and the decision-maker, dialogue is used to ensure that objectives are met.

In anticipatory decision-making, integrative communication is emphasised in a decision's implementation, whereas dissipative communication refers to the environment's communication to an organisation and enables the creation of disorder, or it could be the product of failed implementation (see Figure 27). In a dynamic situation, particular attention must be paid to the contents of a communication's integrative message. The environment's uncertainty and the dissipative interpretations that support it must be taken into consideration in the message's content.

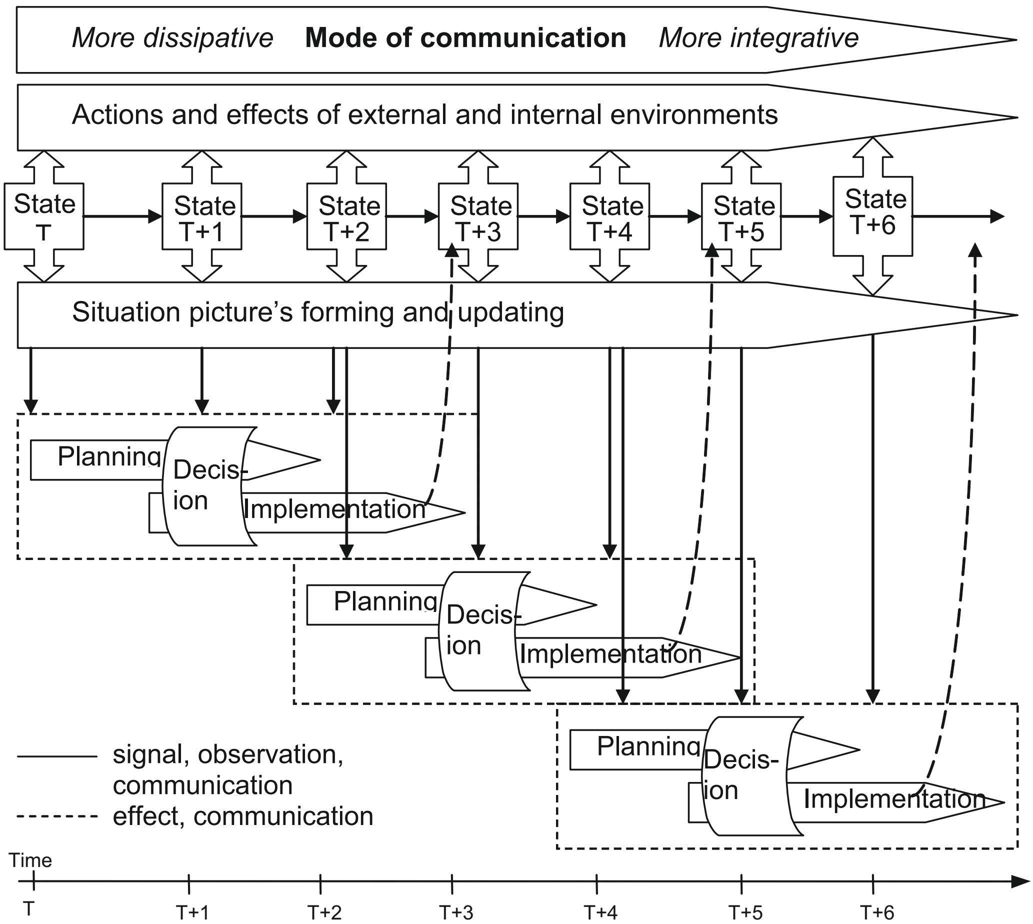

Figure 27. Communicative and anticipatory management process. The dotted lines from the planning-decision-implementation complex to state T+x illustrate the effect of implementation on the environment and communication act, while the solid lines from the situation picture to the planning-decision-implementation complex illustrate observations of the environment in conjunction with the decision-making process and communication act.

"What issues and processes are closely connected to an anticipatory decision-making support system?"

Computer science provides users with the database design and programming support tools that are needed in a decision support system. The field of management science and operation research has provided the theoretical framework in decision analysis that is necessary to design useful and relevant normative approaches to choice making, especially those that are concerned with systems analysis and model-based management. Background information from the areas of organizational behaviour and behavioural and cognitive science are needed for the design of effective systems for dialog generation and management.

Networked operations are a central means of managing complexity and change. Controlling it is becoming increasingly important to both organisations and individuals. Methods of managing complexity and change include a constant and intelligent process, modelling and simulation, as well as forecasting based on them, and control of the entire process.

Constructivism generalises issues, and therefore, its models are simpler than the actual object being modelled. This has an impact on the combination of models and the creation and use of larger constructs. Correspondingly, understanding the concept of time is also central to creating and using models. The principles presented in this research should be taken into account when building new management-related systems. Anticipatory management involves models (constructs) at least for management (expertise, decision-making, including risks, and implementation), the operating environment, and time.

"How will Bayesian method give support to an anticipatory decision-making, when based on inaccurate information?"

Bayesian belief networks build and test decision models and derive solutions to decision problems. BBN capture and illustrate the important influences and relationships of decisions with uncertainties. They aid in understanding the probability structure of a problem without getting into details of specific alternatives and outcomes that can occur.

The presented results show that the Bayesian network is useful for anticipatory decision-making, and its success rate can be estimated. Empirical evaluations show that theoretical arguments are confirmed by significant improvements. The disadvantages are that the completeness of information affects the accuracy of anticipated decisions and models have to be adjusted to each situation. However, this additional complexity does not reject the usefulness of presented processes and methods. There is no doubt that these methods are useful for anticipatory management and decision-making.

Discussion from contributions and recommendations about the model supporting anticipatory decision-making and communication

This research work has been built from the elements of several scientific fields (communication, management, and computer science). A challenge has been to fit these areas together with sufficient depth. The constructive research method provides a good possibility to examine these elements and their interdependencies. The model's functionality has been proven, but at the same time, we can take a critical view of its general applicability, which will perhaps be studied in further research or productisation.

The contribution of this thesis can be divided into theoretical and practical classes. The theoretical contribution includes the definitions and model of anticipatory decision-making. The main theoretical contribution of this study has been to develop a process for anticipatory decision-making that includes management with communication, problem-solving, and the improvement of knowledge. This study also contributes to decision-making support by providing an academic description of anticipatory decision-making that is grounded on firm theoretical discussion by demonstrating the idea of anticipatory decision-making for the parallel version. The theoretical contribution includes the definitions and model of Anticipatory Decision-making.

The practical contribution includes the Bayesian Decision Support Model, which is based on Bayesian influenced diagrams. The main contributions of this research are two developed processes, one for anticipatory decision-making, and the other for producing the model of a Bayesian network for anticipatory decision-making.

The anticipatory decision-making model should be tested in different kinds of organizations. Some of its elements need to be clarified. There will be many interesting theoretical and practical areas of research. Also, the Bayesian Decision-Making Support tool needs some improvements. A test analysis should be made, including the collection of a sufficient amount of comparative material.

Proactive communication based on uncertain information and the procedures aiming to ensure its success should be researched, both as regards planning an organisation’s operations and implementing them. Managers and management have an important role in building this kind of talent in an organisation.

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APPENDIX

Definitions

The appendix summarizes the most essential definitions. Definitions are listed in alphabetical order. The most of these definitions are based on The New International Webster's Comprehensive Dictionary (1996).

Anticipation. The prediction of future situations or events with respect to current knowledge and perceptions (Butz 2002, 161).

Anticipatory. Pertaining to, showing, or embodying anticipation. Anticipation is the act of anticipating; especially, a foreseeing or foretaste expectation.

Belief network consists of a qualitative part, encoding a domain's variables and the probabilistic influences among them in directed graph, and a quantitative part, encoding probabilities over these variables. Probabilistic information is available in many different shapes. (Druzdzel and Van der Gaag 1995.)

A decision is the act of deciding or making up one's mind.

Decision-making is the process by which decisions are made, especially important decisions affecting others and made by virtue of one's office or position.

An environment is one's surroundings or external circumstances collectively.

Environmental Model. The internal representation of an environment in some form. An environmental model specifies what changes after the execution of an action in a situation. The model is complete, accurate, and compact if the model specifies the correct effect for each possible situation-action tuple and furthermore realizes the specification with the smallest representation possible. (Butz 2002, 162.)

An influence diagram can be viewed as a special type of Bayesian network, where the value of each decision variable is not determined probabilistically by its predecessors, but rather is imposed from the outside to meet some optimization objective. (Pearl 1988, 307.)

Influence diagram nodes. Influence diagrams are directed acyclic graphs with three types of nodes. *Decision nodes*, shown as squares, represent choices available to the decision maker. *Chance nodes*, shown as circles, represent random variables or uncertain quantities. *A Value node*, shown as a diamond, represents the objective or utility to be maximized. (Pearl 1988, 307.)

Knowledge is a result or product of knowing; information or understanding acquired through experience; practical ability or skill.

Managerial communication can be understood as sharing of the messages, ideas or attitudes within an organisation between or among managers and associates. The aim is to share the meanings in order to achieve a desired outcome (Vihakara 2006, 19).

An organisation is the act of organising, or the state of being organised. A number of individuals systematically united for some end or work.

A process is a course or method of operations in the production of something.

Qualitative analysis is the process of finding how many and what elements or ingredients are presented in a substance or compound.

Quantitative analysis is the process of finding amount or percentage of each element or ingredient present, as in a compound.

Support is the act to give approval or assistance to; uphold; advocate; aid.

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