LAPPEENRANTA UNIVERSITY OF TECHNOLOGY

Department of Information Technology

Master's thesis

WIRELESS e-BUSINESS APPLICATION – METHODS FOR FORECASTING THE DEMAND OF WIRELESS SERVICES AND TECHNOLOGIES

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ABSTRACT

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The study was a part of the research project, which considered the Wireless e-Business Applications and Services. The objectives of this study were to determine the role of forecasting in decision-making and planning processes, and to define the most useful and most frequently used technological forecasting methods. This study focused on assessing forecasting methods from the point of view of high technology companies and considered technological forecasting as long-term forecast.

The study is based on the analysis of the literature, which considers technological forecasting, long-range planning and innovation process. Using the source material, the study describes the use of technological forecasting as gaining information for the organizational planning process. It also defines and evaluates technological forecasting methods as follows: trend analysis, Delphi method, cross-impact analysis, morphological analysis, and scenario analysis.

The emphasis of the study was to point out the main characteristics, limitations, applications and costs of each forecasting method. By using suitable method useful information about the possible and desirable future scenarios could be provided to help organizational planning and decision-making.

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Tämä tutkimus oli osa sähköistä liiketoimintaa ja langattomia sovelluksia tutkivaa projektia ja tutkimuksen tavoitteena oli selvittää ennustamisen rooli päätöksenteko- ja suunnitteluprosessissa ja määrittää parhaiten soveltuvat ja useimmin käytetyt teknologian ennustusmenetelmät. Ennustusmenetelmiä tarkasteltiin erityisesti uuden teknologian ja pitkän aikavälin ennustamisen näkökulmasta.

Tutkimus perustui teknologista ennustamista, pitkän aikavälin suunnittelua ja innovaatioprosesseja käsittelevän kirjallisuuden analysointiin. Materiaalin perusteella kuvataan teknologian ennustamista informaation hankkimisvälineenä organisaatioiden suunnitteluprosessin apuna. Työssä arvioidaan myös seuraavat teknologisen ennustamisen menetelmät: trendianalyysi-, Delfoi-, cross-impact analyysi-, morfologinen analyysi- ja skenaario analyysimenetelmä.

Työ tuo esille jokaisen ennustusmenetelmä ominaispiirteet, rajoitukset ja sovellusmahdollisuudet. Käyttäen esiteltyjä menetelmiä, saadaan kerättyä hyödyllistä informaatiota tulevaisuuden näkymistä, joita sitten voidaan käyttää hyväksi organisaatioiden suunnitteluprosesseissa.

ACKNOWLEDGMENTS

I would like to thank professor Tuomo Kässi for instructing me in making this study, for constructive discussions and encouraging criticism.

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1. INTRODUCTION

"Technology changes. Economic laws do not. Today's business world is different in a myriad of ways from that of a century ago. But many managers are so focused on the trees of technological change that they fail to see the forest." (Shapiro, 1999, p. 2)

1.1. Telecom Business Research Center

Telecom Business Research Center (TBRC) is a unit of Lappeenranta University of Technology. It was established in summer 1999 as a junction of four departments: Business Administration, Industrial Engineering and Management, Information Technology, and Electronic Engineering and Electronics.

The projects of Telecom Business Research Center are focused on the Telecom and Information technology industry. The main aim is to connect university researchers and industry. In order to do this, research groups focus on specific managerial problems and challenges.

The staff of TBRC consists of university personnel. Nowadays, it is a virtual organization of about 50 active persons. There are also people from co-operating companies working with TBRC and enabling fast and effective connection with the partners.

Research teams are usually multidiscipline and consist of the researchers from different fields such as economics, information technology, telecommunications, logistics, etc. This approach combines the technological and commercial knowledge and enables the high-level multidiscipline results.

1.2. Research Project: New Business Models Arising from the Convergence of E-business and Mobility in the USA and Europe

The official name of the project is "New business models arising from the convergence of e-business and mobility in the USA and Europe". As a short name of the project is used "Wireless e-business".

1.2.1. Introduction of the project

The convergence of the IT and Telecom markets is creating completely new ways for companies to operate. The application of new technology in so-called old industries will make the Infocom sector to boom. The time window for utilizing an innovation into a new business has shrank and business-to-business e-commerce sales are developing and growing very fast.

The American way is to commercialize new business ideas fast based on existing building blocks, i.e. technology and services. Europeans move with technology standards, which easily slow down the development, but creates eventually larger standard platforms. On the other hand Europe has a major competitive advantage: the European wide GSM standard, its installation in all of the European countries and clear evolution path. The standard platform can be utilized between business partners and within the companies own operations as well as approaching the customers.

Mobility, widely understood, opens a completely new way for companies to apply e-business in their operations.

1.2.2. Scope of the project

The research program of the project concentrates primarily on business-to-business and intra-business segments and compares the markets in the USA and in Europe. The researched companies are large industry leaders and their suppliers.

The chosen industries are:

- ICT (Information and Communication Technology Industry)
- Paper
- Retail

1.2.3. Research targets of the project

- Create a competitive Wireless E-Business research team in Finland and link it thoroughly into research in the USA.
- Create comparative research results between the USA and Europe in application of Wireless E-Business.
- Build co-operation between universities in Finland and in the USA.
- Apply modeling technologies like AHP, real options etc. into fore sighting of the Wireless E-Business market development.
- To study the new business models arising from the usage of Wireless Applications.
- Define scenarios for the E-Business development paths in Europe and in the USA and create alternative future outcomes from that. To study and model the industry restructuring in selected industry sectors due to change from Service Operator industry perspective.

1.2.4. Business targets of the project

- Recognize the main benefits or opportunities for the companies in so-called old industries.
- Analyze and forecast the speed of the change, time-to-market and growth opportunities
- Analyze the risks or hindering factors, "stumbling stones", delaying or stopping the possible development.
- Define required enabling technologies and services models
- Analyze the opportunities for new types of business models and changes to exiting ones.
- Forecast or build scenarios of the new roles and industry structure.

1.2.5. Structure and phasing of the project

The project will be divided into sub-projects, which are divided into separate research projects coordinated within this program.

Firstly, the program concentrates on analyzing the present situation and strategic trends, which open new business opportunities and enable new business models. New application models are created by using the lead user method, and technical configurations and requirements are planned. New applications are analyzed with a "Return on investment" approach. The methods used are ROI, AHP and Real Options.

Second part of the program takes psychological and learning aspect in the application of the above forecasted technology and service diffusion and concentrates on taking a new aspect by finding the reasons slowing the applications of technology in organization.

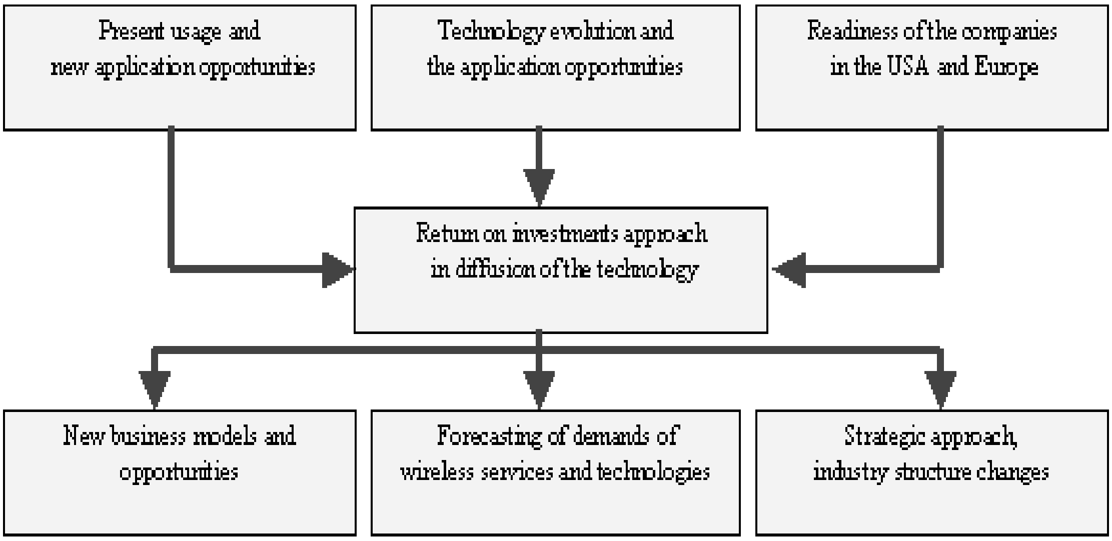

Figure 1. The research project (Petteri Laaksonen, 2001)

1.3. Objectives and restrictions of the study

The objectives of this study are to determine the role of forecasting in decision-making and planning processes, and to define the most useful and most frequently used technological forecasting methods. This study also collects initial information for further studies.

The business environment of high technology companies is unstable and fuzzy. High technology companies are continuously trying to find new development and business opportunities. This study focuses on assessing forecasting methods from the point of view of high technology companies and considers technological forecasting as long-term forecasting.

1.4. Structure of the study

This study consists of eight sections. The first section introduces the research project and in section 2 considers forecasting as a part of the managerial action in an organization. The section points out how forecasting is related to the planning process through decision-making. The section 3 explains technological innovation process and the change of technology and how it creates the need for forecasts. Section 4 describes the most often used technological forecasting methods: trend extrapolation of a single phenomenon, Delphi method, and Cross-impact analysis, and scenario analysis. Section 5 evaluates the methods and describes the most common pit falls of forecasting the change of technology and the section 6 gives a short summary of each method. In section 7, the most important facts of the study are collected into the summary and finally, section 8 includes the conclusions of this study.

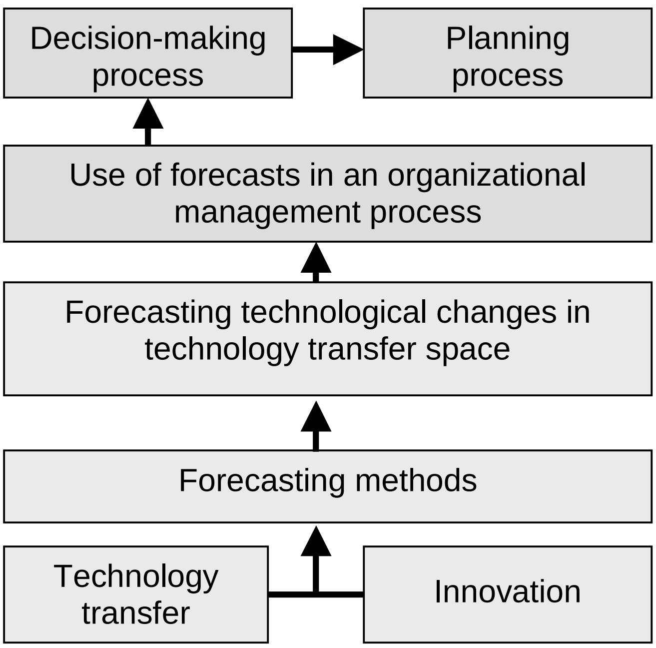

Figure 2. Framework of the study

2. PREDICTING THE FUTURE

The future has always been one of the main symbols through which human beings have ordered their present and have given reason to their past. While futures research in the academic purpose is a recent pursuit, conjecture, speculation, and exploration of future events have always been prime features of the human condition. Human survival itself is very largely predicated on the conscious capacity to organize present actions, which base on past experience and future goals. (Fowles, 1978, p. 5) As Godet reminds, the future can be explained not only by expanding the past to the future but also by the image of the future imprinted upon the present (Kuusi, 1999, p. 8).

The purpose of futures research is to discover or invent, examine and evaluate, and propose possible, probable and preferable future. At the most general level, the futurists are trying to contribute toward making the world a better place to live in. (Bell, Vol. 1., 1997, 73-75)

Futures research, after all, exists primarily to provide information with all the tools and techniques at disposal about the future for decision-making. Decision makers need forecasts of situations that will demand their attention and forecasts that project the outcomes – intended or unintended – of their planned actions. (Gordon, 1999, p. 63) Roy Amara (1991) pointed out the means that can be used include the following:

- making plans and choosing the paths of possibilities,
- exploring the selected paths and the likelihood of their occurring,
- describing the arguments for, and employing, particular paths.

“The central dilemma is that we cannot know the future, but we must act as if we did.” Hartikainen (1994, p. 8)

2.1. Forecasting the future in organizations

The vision about the future can be reached in many ways. It can be reached from experience, intuition, and rules of thumb of a decision-maker. The vision can be provided by using formal manners through long-range forecasts and trends, or creation of scenarios. When exploring the alternative futures, it is possible to make one’s decisions and choices more justified and to make it easier to take the ever-continuing change. (Hartikainen, 1994, pp. 3-4)

The role of forecasting systems in the management of an organization must be well understood and well defined. There are two major roles for forecasting in an organization. The first, most obvious, and frequently cited role is to reduce the range of uncertainty confronting management. The second one is the fact that forecasting can effectively broaden the range of options available to decision makers. (Makridakis, 1983, pp. 795-800) Decision makers need forecasts of situations that will demand their attention and forecasts that project the outcomes – intended or unintended – of their planned actions. In the present days, especially high technology organizations exist in a high velocity environment. The rate of change of technology is enormously high and under such environment organizations must continuously upgrade their technology and their planning (Gordon, 1999, pp. 63-64).

Porter et al. (1991, pp. 12-13) emphasize that the management of an organization is making decisions today that affect the organization’s future. Changes in technology might cause major changes in the organization’s core business. Therefore, all additional information is needed and planning tools must be developed to confront the uncertainty. They must generate the information that illuminates the possible future and gives flexibility to meet the future. "The greatest benefit of forecasting lies in its use as guidance for activities of organizations (Cetron, 1969, p. 5)."

2.1.1. Forecasting and decision-making

Predicting the future always includes uncertainties that will or will not happen in the future. Lipinski and Loveridge (1982) describe that the future opens as a wedge-shaped terrain of possibilities. The terrain is uneven; peaks and valleys of opportunity and threat dot the landscape. Forecasters must explore the future and convey the lay of the land to the decision makers. A balance must be struck between the probability and detail: the finer the detail of forecast, the lower the probability of that detail occurring or a future represented by expansive boundaries can be predicted with more certainty, but little useful detail can be given for decision-making. Forecasting provides the decision maker with an estimate of the kinds of futures possible and the specific actions that might lead to each of the alternatives. (Porter et al., pp. 49-51)

Thus decision-making, according to Martino (1993, pp. 251-252), is choosing the act from among the set of feasible course of actions. The action is a change in the present situation or an attempt to retain the present situation. For every action there is always more than one course of action available; otherwise there is no need for decision-making.

As mentioned above, the purpose of decision-making is to change things or at least make a choice not to change. Decision-making in an organization may change the objectives, its structure, the allocation of its resources, or the assignment of its personnel. These topics always arise when in an organization faced with technological changes and technological forecasting, there is a good opportunity to provide the decision maker with the information needed for choices among the possible changes. (Martino, 1993, pp. 251-253)

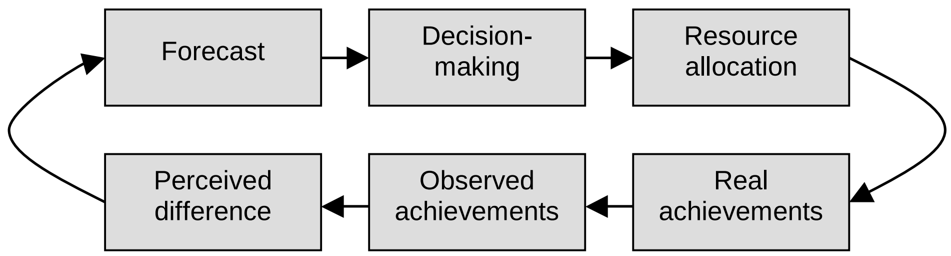

Figure 3. Decision feedback loop (Ayres, 1969, p.198)

As Gode (1987) says: "Thinking before action, anticipating possible problems, and undertaking present actions in the light of desired future." (Hartikainen, 1991, p. 15)

2.1.2. Forecasting and planning

Forecasting is often confused with planning. Forecasting relates with planning so that forecasting is concerned with determining what the future will look like, rather than what it should look like. The latter is the goal of planning. (Armstrong, 1985, p. 6)

Interaction between planning and forecasting can be 1) separated or 2) integrated. Separated forecasting attempts to apply "bounce" and direction at discrete planning steps. In the integrated approach, forecasting provides continuous stimulus and guidance to planning. It can be seen that forecasting is only auxiliary to planning and will ultimately mark a significant enrichment of the planning function. (Jantsch, 1967, pp.83-85)

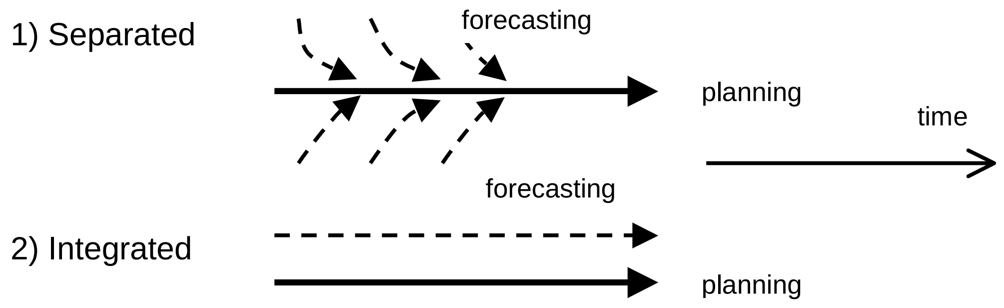

Figure 4. Difference between separated and fully integrated forecasting and planning functions graphically. (Jantsch, 1967, p. 84)

Nevertheless, the main focus of planning is on the future. The entire purpose of planning is to achieve a preferred future and it is an attempt to apply rationality to the task of shaping the future. Planning provides the link between a preferred future and a present action. (Martino, 1993, p. 247)

Effective organizational planning links daily tasks to organizational objectives. Organizational planning is formal and follows some reasonable model. Schmidtlein and Milton (1989) stated that a model of planning exhibits the following characteristics: (Porter et al., 1991, p. 31)

- Organizational goals exist and they can be determined.
- Alternative courses of action can be determined and evaluated in relation to organizational goals.
- Logic and analytic procedures can help decide courses of action.
- Implementation of decisions made through planning activities is feasible and even likely.

Technology planning is one subset of activities in organizational planning. It relates the progress of technological change to the organization's strategic plan. (Porter et al., 1991, p. 33-34) According to Jantsch (1969), technological planning includes three levels and at each of these levels technological forecasting can be used differently (Lanford, 1972, p.1):

- At policy planning level: technological forecasting clarifies scientific-technological elements determining the future boundary conditions for organizational development.
- At strategic level: technological forecasting recognizes and compares alternative technological opportunities.
- At operational level: technological forecasting sets the probabilistic assessment of future technology transfer.

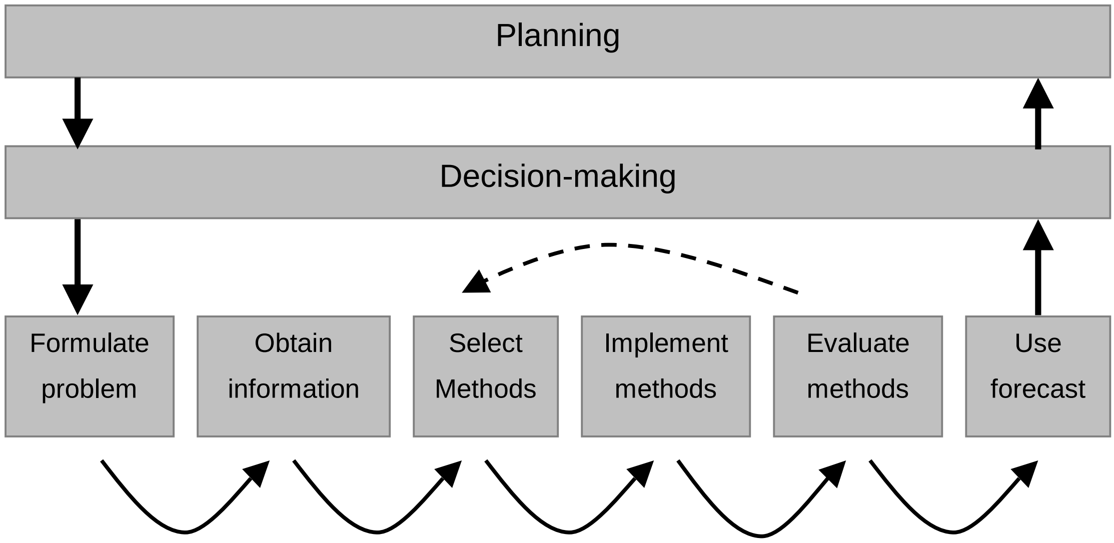

Figure 5. Stages of forecasting (Armstrong, 2001, p.). The place of forecast in the planning process.

3. TECHNOLOGICAL FORECASTING

3.1. Technology transfer space

Forecasting is the probabilistic assessment, on a relatively high confidence level, of future technology transfer and it provides information about the changes in technology transfer space. The process of technology transfer space can be represented within two-dimensional scheme of technological progress. In technology transfer space, two levels can be separated: development and impact levels. In these levels, eight steps from discovery to social impacts can be distinguished. (Jantsch, 1967, pp. 23-25)

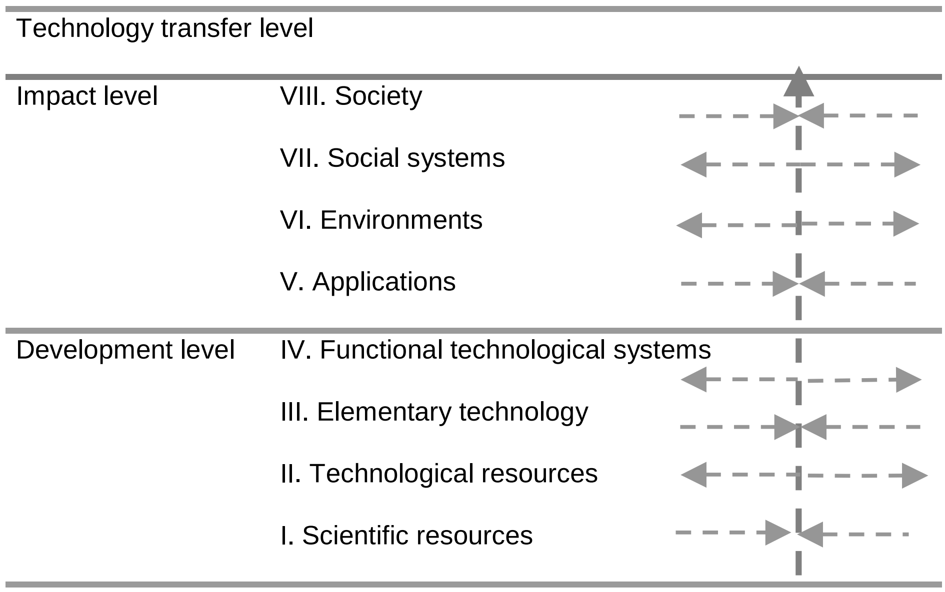

Figure 6. Levels and vertical and horizontal directions of technological progress in transfer space. (Jantsch, 1967, p. 24)

Technology transfer can be seen as taking place in a vertical as well as horizontal direction. Vertical transfer begins from fundamental science and continues to technology and further systems and their impacts on different levels. The extension of the vertical transfer by a considerable subsequent horizontal technology transfer (e.g. application and service engineering, diffusion of knowledge) marks *technological innovation*. Any change in the technology transfer space affected by technology transfer is referred to as *technological change*. Technological forecasting is concerned with every form and direction of transfer as well as with the rate of change within the entire transfer space. (Jantsch, 1967, p. 24-27)

3.2. Innovation

According to Porter et al., (1991, p. 58) technology forecasting means forecasting activities that focus on technological changes. Technological change is closely related with innovations: without innovations technical changes would not occur. The role of the forecast is to define the alternatives, options, and consequences. However, the effects of interest are new technologies and incremental and discontinuous changes in existing technologies.

An innovation is any idea, object, or practice that is perceived as new by members of social system. Diffusion of innovation causes changes in the structure of society and its function. The diffusion of new ideas leads to social changes because of the acceptance or abandonment of the idea. (Mahajan et al. 1985, p. 7-8) The intricate mechanism by which technological innovation is effected can be explained in terms of vertical and horizontal technology transfer. Innovation follows the vertical levels of transfer space from discovery to large-scale acceptance or as today more and more tends to follow horizontal direction in the technology transfer space. The factors that set the mechanism in motion are still less known. Several surveys clarify the basic conditions which favour technological innovation: (Jantsch, 1967, p. 64-76)

- goal-oriented and inspirational nature of the innovator

- availability of financial and other resources
- existence of an information base
- learning, a factor which seems to favour outsiders who learn about the field
- accidental factors, which are mostly marginal factors.

According to Kuusi (1999, p. 68), innovation process always includes the idea how the goal of the innovation can be achieved. This idea of innovation usually belongs to tacit or hidden knowledge and the problem is how to change this knowledge to the explicit form for argumentation. Anticipation of the innovation process is difficult and even impossible because every innovation process is a leap into the unknown. B. R. Martin (1995) sees the anticipation of the future courses as a tool for decision-making and considers it equal to innovation process (Hartikainen, 1994, p. 13).

3.2.1. Innovation cycles

Cycles of major technological innovations can be clearly defined from discovery to commercial distribution. According to Jantsch (1967, pp. 39-42), cycles of innovations depend basically on the area of technology. Every innovation has a time lag between the steps in technology transfer space. By using technological forecasting, these unnecessary pauses between the steps can be reduced almost to zero. Following time spans determine the time frame of technology transfer up to the application level:

- time span until discovery
- time span between discovery and invention
- time span between invention and commencement of full-scale development

- development time is also sensitive to reducing the time span by technological forecasting.

3.3. Technological forecasting

Forecasting a technology is an attempt to anticipate the character, intensity, and timing of changes in technology for the organizational goals. It can identify key uncertainties, potential breakthroughs, upcoming substitutions of one technology for another, likely cost reductions, and new applications. It provides information on changes over time in technical parameters and in the relative diffusion of technology. (Porter et al., 1980 p. 55)

Technological forecasting is concerned, as a whole, with technology transfer space in every form and direction of technology transfer. One of the important potentials of technological forecasting is the recognition of possibly preferable alternatives to attain the same end-point. As Porter (1980) listed above, there are several aims for technological forecasting and they often are individual. But the basic questions which technological forecasting attempts to answer include these four areas (Jantsch, 1967, pp. 27-28):

1. time span required for technology transfer between any two points in the transfer space,
2. effort involved in the effectuation of any technology transfer between any two points in the transfer space,
3. effect at the end-point of any technology transfer between any two points in the transfer space,
4. selection of a suitable starting point in the transfer space to effectuate technology transfer to a specific end-point on an equal or higher level.

Especially, in the high technology environment where the rate of change of technology is great and the life cycles of products continue to shrink, an organization can only survive if it continuously upgrades its technology through systematic forecasts. (Mishra et al., 2002, p. 1-2)

3.4. Technological forecasting situations

According to Makridakis (1989, p. 319), there are three forecasting situations in which technological forecasting methods can be used:

- The first forecasting situation is *when* a given new process or product will become widely adopted. For example, a company may be concerned about the timing for the adoption of a new product or process.
- The second one is predicting *what new* developments and discoveries will be made in a specific area. For example, a corporation would like to know or anticipate new processes and technologies that will be developed in their business over the next 15 years to help them in planning plant expansion programs, long-range market development, and long-range R&D investments.
- The third one concerns *the type of changes* and eventual patterns or relationships. This type of changes might happen when an area or environment is undergoing or is about to undergo a major change (such as the international competitive environment).

3.5. Classification of technological forecasting methods

Forecasting methods can be divided into qualitative and quantitative methods. Qualitative methods are based on the information that the history of the past development is known and the forecasts can be done with that historical information. The latter, quantitative methods can be used when historical information is not available or does not exist. Qualitative methods can be used for the following two types of forecasts (Waissi, 1979, p. 8):

1. forecasts about the implementation of a particular technology (spin-offs, breakthroughs),
2. forecasts about the technology, which is still unknown, or development of the technology.

It can be seen that the qualitative forecasting methods basically base on human and intuitive assessments (Waissi, 1979, p. 10).

Jantsch (1967, pp. 31) explains the technological forecasting exploratory and normative methods, and intuitive methods using the technological transfer space. The first two are opposed to each other in the technology transfer space. Exploratory forecasting starts with knowledge and assessments about the past and seeks to forecast the future. Forecasts consist of the present information about the current situation and the trends. With this information, the aim is to predict the future events and when they will occur (Waissi, 1979, p. 9). Normative forecasting begins with an objective (goal) and works backward to the present in an effort to determine the optimum approach to achieve the objective (Ayres, 1969, p. 33). The identification of the goals may provide the key to the course of technological innovation (Porter et al. 1980, p. 112).

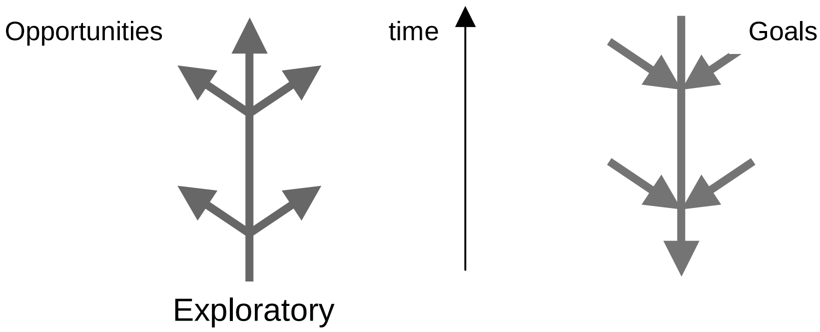

Figure 7. Direction of technological transfer (Jantsch, 1967, p. 30)

Qualitative methods	
Explorative	**Normative**
Trend extrapolation	Relevance tree
Analogy, Cross-impact	Scenario
Delphi method	
Morphological method	

Figure 8. Classification of the forecasting methods (Waissi, 1979, p. 10)

The third type of technological forecasting techniques, intuitive methods, in technology transfer space represents a view from outside of the transfer space. This view from outside of the space helps to identify the starting points for normative techniques. (Jantsch, 1967, p. 113-115) Intuitive thinking as a means of achieving exploratory technological forecasts seems to guide to the wrong directions. Using systematic thinking as an informed judgment will be superior to intuitive methods where the effects of causal relationships are projected into the future (Jantsch, 1967, p. 133-134).

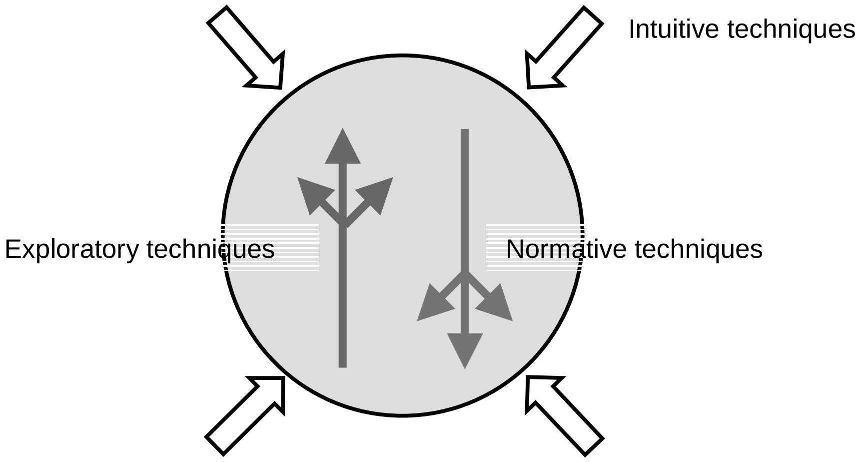

Figure 9. Transform directions of techniques in transfer space (Jantsch, 1967, p. 113)

Despite the fact that there are more than 100 distinguishable versions of techniques, elements of techniques and formal attitudes, a particular feature of past developments in forecasting techniques is the attempt to adapt them to processing of probabilistic input information, with probability distributions constituting the output, and to systematic evaluation of alternatives. (Jantsch, 1967, p. 18-20)

3.6. Background for selection of forecasting methods

The quality of forecasts greatly depends on the proper selection of appropriate techniques. According to Armstrong (2001, p. 366), there are six basic ways of selecting forecast methods: Convenience, Market popularity, Structured judgment, Statistical criteria, Relative track records, and Guidelines from prior research. “Selecting the appropriate forecasting method for technological forecasting the most preferable way is to match the technological forecasting method to the technology is to compare them under consideration the given set of characteristics” (Mishra et al., 2002, p. 1). However, according to Jantsch (1967, p. 109), the selection of a specific method in technological forecasting emphasizes the aspect of users' experience: the use of methods enhances recognition of the relevant factors, their relationships with the problem in question, and their inter-relationships.

It is a fact that differences between good forecasting and the use of techniques cannot be made. Their most important contributions to practical forecasting can be summarized in the following three observations: (Jantsch, 1967, pp. 18-19)

1. They elucidate the role of individual input factors, compel a comprehensive consideration of such factors, and assure some homogeneity of results.
2. They tend to reduce prejudice and bias.
3. They permit the evaluation of complicated patterns in input information and facilitate the systematic evaluation of alternatives.

The next sections present several forecasting methods which are capable to provide information for the organizational planning and decision-making by answering the questions like technological breakthroughs, nature of technological innovation, development time, diffusion and spin-offs of technology.

4. TECHNOLOGICAL FORECASTING METHODS

4.1. Extrapolation of time series

Exploratory forecasting methods are utilized to project future developments on the basis of past history. They are really extrapolative in nature. They start with a set of events that have taken place up to the time of forecast, an attempt to identify the patterns present in that history, and project these patterns into the future. They assume that whatever has caused the patterns of the past, will continue to operate to produce similar patterns in the future. When this assumption is valid, purely extrapolative methods can be highly useful and simple to use. (Fowles, 1978, p. 373) It is, of course, not like that in the real world, but trends show the long-term growth and evolution of a particular technology and help to define the future possibilities by projecting past trend to the future.

“Extrapolative methods are reliable, objective, inexpensive, quick, and easily automated. As a result, they are widely used, especially for inventory and production forecasts, for operational planning for up to two years ahead, and for long-term forecasts in some situations, such as population and technological forecasting.” (Armstrong, 2001, p.217)

4.2. Trend extrapolation

Trend extrapolation aims at defining the time dependent function of the variable that depicts the development of the variable in time. The trend function can be used in forecasting future development on three levels of requirements that are different in terms of information (Mäenpää, 1977, p. 10):

1. Trend functions are used to give a clearer view on the direction of the previous development of the phenomenon. We can see how fast the increase or the decrease has been and whether the change has been steady, escalating or slow, as well as determine how significantly external disturbances have driven the phenomenon off course.
2. By following the trend function further in time, we can consider what the development would be like, if the trend did not change. We could

perhaps conclude what types of changes in the direction of the development are probable or inevitable.

3. We believe that the nature of the development will stay the same, and by extrapolating the trend function, we aim to forecast the future development.

Using trends especially for long-term technological forecasting, it is possible to forecast beyond the upper limit of the current technology. Projecting the trend into the future makes it possible to forecast a successor technology without an assumption on what that new technology will be. But the trend will not invent the technology. (Martino, 1993, pp. 80-81) Even under appropriate conditions, trend extrapolations should be used in combination with complementary technology forecasting methods, e.g. intuitive methods (Porter et al., 1991, p. 169).

4.3. Trend analysis

The analysis of trends is based on extrapolation of a given data collection. The first step in the trend analysis process is selecting or developing appropriate measures of technology for use in forecasting (Martino, 1993, p. 93). When the needed data is available, the upper limit for the particular phenomenon must be determined, and at the end of the process follows the model identification and mathematical and graphical projection of the model (Porter et al., 1991, pp. 169-170).

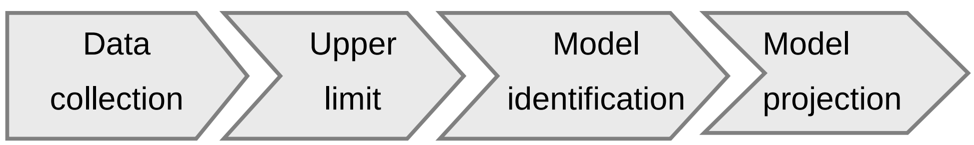

Figure 10. Phases of trend analysis

4.3.1. Data collection

“Basic strategy of extrapolation is to find data that are representative of the event to be forecast (Armstrong, 1985, p. 153)”. Three most important criteria can be listed to apply in selecting an appropriate variable. First, the variable chosen must measure the level of functionality of technology. It is necessary to understand the technology and its application for choosing the appropriate variable. Secondly, the variable that is chosen must describe both the new technology and any older technology it replaces. Thirdly, you must have data from which to compute historical values of the variables. (Porter et al., 1991, 140-141)

The data, collected measures of a technology, describe the function the technology performs. There is also need for distinguishing the technical parameter from the functional parameter. The former measures utility to the user and the latter can be manipulated by designators. From the point of view of research and planning, it is useful to use technical parameters, whereas functional parameters are more suitable for marketing planning. (Jantsch, 1967, p. 143)

4.3.2. Identify the model

Trend and growth curves are used to forecast the performance of individual technical approaches to solving a problem. They are used to forecast how and when a technical approach will reach its upper limit and frequently the curves are used to forecast the rate in which a new technology will be substituted for an older technology in a given application. S-shaped (sigmoid) curves depict the movement of the innovation process of a particular technology in the technology transfer space either in vertical direction or horizontal direction. At the first stage, an invention has been made and the progress of development is slow because of many difficulties. Then the commercial potential is recognized and diffusion is growing fast until the upper limit is reached and the penetration is slowing down. It is often important to forecast the timing of these changes in the growth rate, and frequently one is interested in forecasting the rate at which a new technology will be substituted for an older technology in a given application. (Martino, 1983, pp. 59-61)

The Pearl curve (logistic curve)

Ralph Pearl's work on the analogy of the population increase to the growth of biological organisms (cell division) has been cited by writers on the field of population forecasting, economic forecasting, and by Lenz in technological forecasting. D. J. DeSolla Price includes technological forecasting in the larger framework of all growth phenomena in science. The great attraction, which this analogy has, is explained by the fact that it yields symmetrical S-curve naturally, without further assumptions (Jantsch, 1967, p. 150). The growth equations can be used to estimate the degree of maturity of a technology in order to approximate the probable rate of growth and time leveling off. (Lanford, 1972, pp.78-80)

Pearl's curve:

$$y = \frac{L}{1 + ae^{-bt}} \qquad (1)$$

where

L is upper limit for growth of the variable *y*

a and *b* are the coefficients obtained by fitting the curve to the data

t is time

One of the advantages of Pearl's curve is that the shape and the location can be controlled independently. Changes in the coefficient a affect the location only and the coefficient *b* affect the shape only. This makes the curve useful in other mathematical applications, e.g. diffusion of innovation. (Martino, 1983, p. 61)

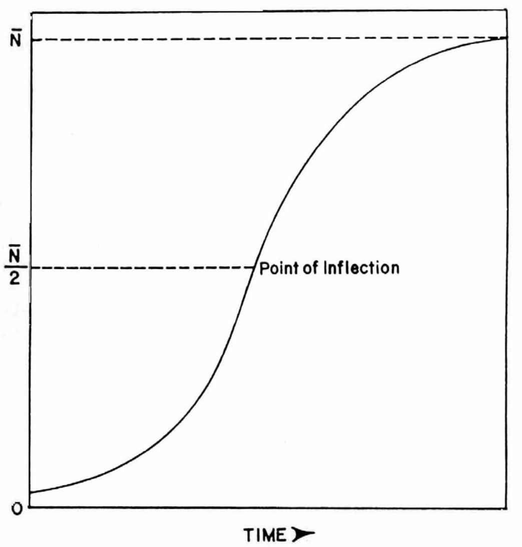

Figure 11. Pearl Curve (Mahaja et al., p. 19)

John C. Fisher and Pry have developed the Pearl's formula further, and using this modified formula, substitution forecasts of each technology can be made. The substitution proceeds at a rate determining by the formula (Lanford, 1972, pp.73):

Fisher-Pry curve $$f = 1/2[1 + \tanh \alpha(t - t_0)]$$ (2)

where f is the fraction of applications in which the new technology has been substituted for the old

t_0 the time for 50 % substitution

a is the shape coefficient for the curve

t is time

The Fisher-Pry forecast starts with the finding that a new technology is starting to displace an older technology. A measurement term which best defines the fraction of total usage of each technology must be selected. The time-series data is used to establish the initial takeover rate and to predict the year in which takeover will reach 50 % on the basis of the formula. The inflection point is always half the upper limit. The forecast formula produces the S-curve in forecasting the rate of takeover. (Lanford, 1972, pp.73)

The Gomperz curve

Analogy to economic growth is also called as a Gomperz's law. *The Gomperz's model* is most appropriate in cases in which equipment replacement is driven by equipment deterioration. It is a suitable model when a new technology offers no clear-cut advantages over an old. (Porter et al., 1999, pp. 185-186)

Gomperz curve:

$$y = Le^{-be^{-kt}} \quad (3)$$

where y is the variable representing performance

L is upper limit

b and k are coefficients to be obtained from fitting the curve to a set of data

t is time

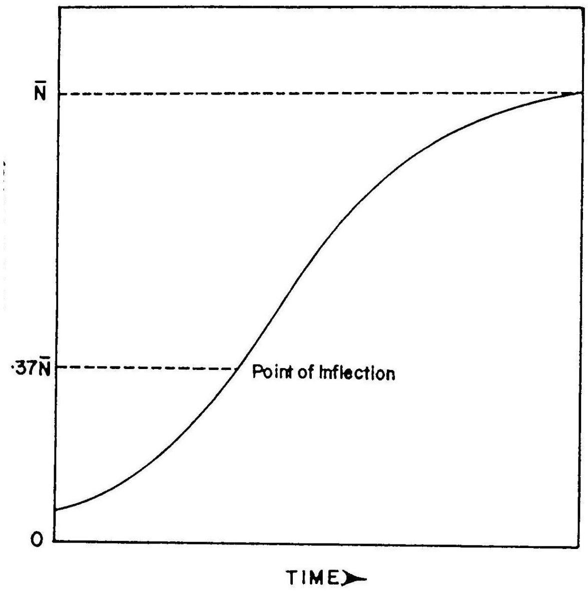

Figure 12. Gomperz Curve (Mahajan et al., p. 20)

Forecasting by the curves involves fitting a curve to a set of data on technological performance, then extrapolating the curve beyond the range of data. “This procedure includes three assumptions:

1. The upper limit to the curve is known.
2. The chosen curve to be fitted to the past data is the correct curve.
3. The past data gives the coefficients of the chosen curve formula correctly.” (Martino, 1983, p. 60.)

4.3.3. Fitting the model to the data

At first, it is recommended that the data is graphed (plotted) when fitting data into the shape of a curve, because individual data points might be problematic. Points that are far from others may result from special circumstances, mistaken measurement, transcription errors, and so on. After graphical examinations of data, the parameter estimation of the model using Least Squares in nonlinear regression can be made (Porter et al., 1999, pp. 138-174) or the formula can be transformed into a straight line, and the best straight line is then fitted into the transformed data (Martino, 1983, pp. 61-62). When extrapolating a trend, it is important to take the confidence interval into account. However, the confidence interval only describes the uncertainty of the trend caused by the error term. (Mäenpää, 1977, p. 10-12)

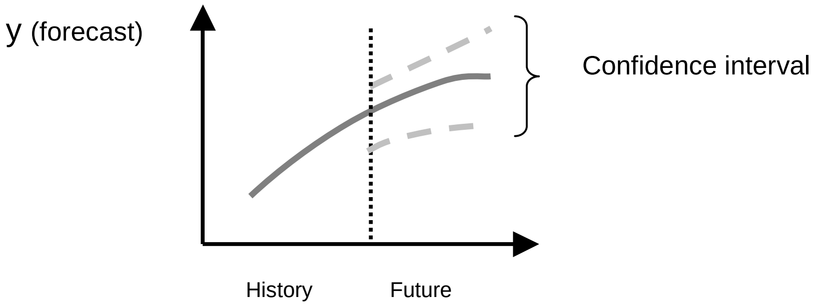

Figure 13. Confidence interval (ci) (Mäenpää, 1977, p. 11) see appendix 2.

Porter et al. (1999, p. 174) also remind that after fitting the appropriate shape of a curve into a model, it is also very suitable to perform a sensitive analysis. It can be done either by a quantitative or qualitative way. Quantitative analysis includes calculation of confidence intervals for future values to be expected. Qualitative analysis uses opinions of selected experts to avoid outside influences like unexpected events, incorrect measurements and so on.

4.4. Delphi method

4.4.1. Expert opinion

The Delphi method bases on expert opinions and can therefore be used for forecasting operations especially when these three elementary conditions exist (Martino, 1993, p. 15):

1. Historical data is not available or does not exist. This normally involves new technology.

2. The impact of external factors is more important than the factors governing the development of the technology. These external factors may include decisions of sponsors and opponents of the technology, and changes in public opinions. Expert opinion about the effects of these external factors may be the only possible source of a forecast.
3. Ethical or moral considerations are dominating the technological considerations that are governing the development of technology. These issues are inherently subjective, and expert opinion is the only possible source of a forecast.

Armstrong (1985, p. 91-92) argues that expertise beyond a minimal level in the subject that is being forecast is of little value when forecasting change. He also points out that the accuracy of forecast falls down after expertise attains a certain level. He explains that when performing forecasts, the errors can be organized into two sections: bias, which means preconceived notions about the world and into anchoring opinions to the tendency like conservatism.

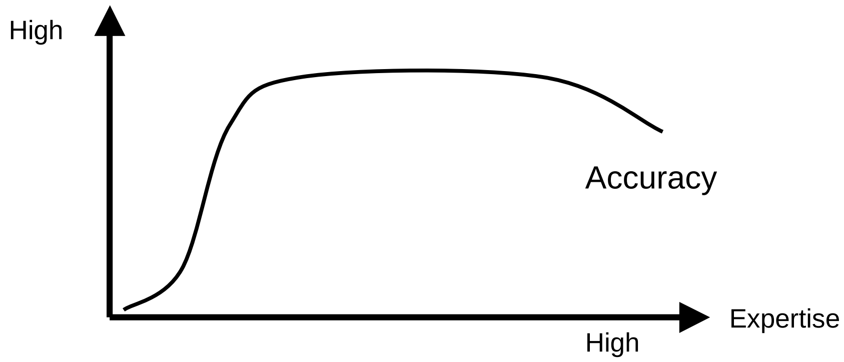

Figure 14. Relationship between expertise and accuracy in forecasting change (Armstrong, 1985, p. 92)

But how can the expertise on the future be defined? According to Kuusi (1999, p. 36) expertise can be divided into four types, which get different weights in different futures-oriented activities:

1. “The expertise on the future invariant behavior or invariant criteria of sameness of learning or not-learning beings.
2. The expertise on the capacity limits of learning beings.
3. The expertise on the interests of learning beings.
4. The expertise on the capability limits of learning beings.”

4.4.2. Use of the Delphi method

The Delphi-method has been developed to enhance the forecasting procedure and good results, but it has also been used in many other application areas. Linstone and Turoff (1975, p. 59) have listed several areas in which Delphi method is useful:

- Gathering current and historical data not accurately known or available
- Examining the significance of historical events
- Evaluating possible budget allocations
- Planning university campus and curriculum development
- Putting together the structure of a model
- Delineating the pros and cons associated with potential policy options
- Developing causal relationships in complex economic and social phenomena
- Distinguishing and clarifying real and perceived human motivations
- Exposing priorities of personal values and social goals

When considering the Delphi method as a communication process, it proves particularly useful in the following circumstances (Fowles, 1978, p. 275):

- When the problem does not need to lend itself to precise analytical techniques but can benefit from subjective judgment on collective basis.
- When the interacting individuals have difficulties to meet each other face-to-face, e.g. because of time or cost constraints. Furthermore, a conventional conference tends to be dominated by particularly strong personalities or by quantity of persons (bandwagon effect).

4.5. Delphi technique

Linstone and Turoff (1977, p. 3) present the following definition of Delphi technique: "*Delphi may be characterized as a method for structuring a group communication process so that the process is effective on allowing a group of individuals, as a whole, to deal with a complex problem."*

Linstone and Turoff (1975) divide the group communication process of the complex problems mentioned above into the following logical phases: The first phase is characterized by exploration of the subject under discussion. The second phase involves the process of reaching an understanding of the issue from the group point of view. The third phase is to examine the disagreements when dealing with the issue. Finally follows the evaluation of the gathered information. (Kuusi, 1999, p. 71)

4.5.1. Committee work and Delphi method

The basic idea of the Delphi technique is to obtain a group forecast while keeping the group dynamics to a minimum. The physical distance between the members of the forecasting group is the main point: because of that the process can be executed in the egalitarian environment. (Kuusi, 1999, p. 72)

“Metcalfe sees the Delphi process as another way for group working for the committees of the experts (Kuusi, 1999, p. 72)”. The major advantage of the committee is that the sum of the information is shared to all participants of the group. Adding members to a group does not destroy information. Even if one member knows more than the rest together, the other members do not reduce the total information available to the group. If the group contains only people who are experts in the subject, the total information is probably many times that possessed by any single member. Another advantage is that the number of the factors that can be considered by a group is at least as great as the number that can be considered by a single member. (Martino, 1993, p. 16) Metcalfe mentioned also that one common feature of the expert committees is the communication between the members.

Above, the advantages of committee working have been discussed. But there are also disadvantages concerning group working in the committees, which are often associated with the psychological characteristics: (Linstone and Turoff, 1975, p. 86)

- *The dominating personality, or outspoken individual who takes over the committee process.*
- *The unwillingness of individuals to take a position on issues before all the facts are in or before it is known which way the majority is headed.*
- *The difficulty of publicity contradicting individuals in higher positions.*
- *The unwillingness to abandon a position once it is publicity taken.*
- *The fear of bringing up an uncertain idea that might turn out to be idiotic and result in a loss of face*.

Delphi is intended to gain the advantages of groups while overcoming their disadvantages. Delphi was developed as a means of extracting opinion from a group of experts. (Martino, 1993, pp. 16-17) Delphi is considered the most prominent of the consensus methodologies. "The consensus could be achieved by the iterations and feedback process (Kuusi, 1999, p. 72)".

	Conference telephone call	***Committee meeting***	***Seminar***	***Conventional Delphi***	***Real-Time Delphi***
Effective Group size	Small	Small to medium	Small to large	Small to large	Small to large
Interaction by individuals	Coincident with group	Coincident with group	Coincident with group	Random	Random
Length of interaction	Short	Medium long	Long	Short to medium	short
Number of interactions	Multiple	Equality to chairman delays (flexible)	Single	Multiple, necessary time delays between	Multiple, as required by individual
Normal mode range	Equality, as chairman control	Equality, as chairman control	Presentation (direct)	Equality to monitor control (structured)	Equality to monitor or group control and no monitor
Principal costs	Communications Time-urgent considerations	Travel, individuals time Forced delays	Travel, individuals time, fees	Monitor time, clerical, secretarial Forced delays	Communications, computer usage Time-urgent considered
Other characteristics	Equal flow of info, can maximize psychological effects		Efficient flow of info to and from all	Equal flow of info to and from all Can minimize psychological effects Can minimize time demand of respondents	

Table 1. Comparison of the properties of normal group communication modes and the Delphi conventional and real-times modes. (Linstone and Turoff, 1975, pp. 8-9)

4.5.2. Basic characteristics of the Delphi

As already mentioned, the original idea of the Delphi method was to make well-argued judgments. It should be noted that the most expert working groups or committees have the same target. Also a major point is that the Delphi method is not the best method at finding accurate judgment concerning future events but it helps to find valid and relevant arguments for the judgment. (Kuusi, 1999, p. 85)

The Delphi process today exists in two distinct forms. These most common and frequently used forms are (Linstone and Turoff, 1975, p. 5-7):

1. Paper-and-pencil version that is called “Delphi Exercise”. The first phase is to design a questionnaire in a small monitor group and after the design, to send the questionnaire to a larger respondent group. When the questionnaire is returned, the monitoring group summarizes the results and develops new questionnaires for the respondents. This form of Delphi is a combination of a polling procedure and a conference procedure. This form of Delphi can be called “Conventional Delphi”.
2. A newer form, called “Delphi Conference”, replaces the monitor group by using software applications that carry out the results of the group results. This process aims at eliminating the delay between the rounds of Delphi, which sometimes might be quite important for the accuracy of the results, and it turns the process into a real-time communication system. This form of Delphi requires that the monitoring team define the characteristics of the communications system as a function of the group responses.

4.5.3. Anonymity of the Delphi procedure

Anonymity is also one of the basic elements of the Delphi method. The group members can state their opinions about the future anonymously. Interaction takes place in a completely anonymous manner through the use of a questionnaire. This anonymity has several beneficial effects. Group members cannot influence other members by the means of their reputation or higher professional position, and anonymity also eliminates the problem of reluctance to change a publicly stated opinion for a fear of losing face. (Kuusi, 2001a)

It is important to emphasize that anonymity lasts only during the argumentation. If respondents know with whom they are arguing, they are more motivated. After the process, there is no reasonable cause to hide the proposer the idea or opinion because it is always good for the proposer if he receives recognition for the good ideas. (Kuusi, 2001a)

4.5.4. Iteration of the Delphi process

The Delphi process includes several inquiry rounds. During these rounds, panel members (experts) have the opportunity to change their earlier opinions. Traditional Delphi methods emphasized statistical results like medians of expert opinions. If the opinion deviated from the average (consensus) opinions, the expert had to explain the opinion. It was recommended that the average opinions (consensus) be followed. Recent Delphi applications prefer to use only one iteration round and if needed, additional interviews, seminars and so on can be used. (Kuusi, 2001b, p. 20)

4.5.5. Feedback of the Delphi process

Members of the respondent group cannot present their opinions and ideas without explaining the reasons for the particular response to the questionnaire. They must provide arguments and stand up for their own ideas and opinions. (Kuusi, 2001a) The group interaction is performed by responses to questionnaires, and the monitoring group extracts from the questionnaires only the relevant information to the issue and presents this to the respondents. The individual members are informed only of the current state of the collective opinion of the group. Both the majority and the minority can have their views presented to the group, but not in such a way as to overwhelm the opposition. This relevant information basically includes statistical facts like median and deviation information. Using this information and iterative feedback process, the Delphi method aims to achieve the consensus among the group members concerning the issues of the exercise. (Martino, 1993, pp. 17-18)

4.5.6. Failures with the Delphi

Basically, the Delphi method seems like a very simple concept that is quite easy to employ. But many individuals have encountered problems because of inadequate consideration the problems involved in carrying out such exercise. Linstone and Turoff (1973, pp. 6-7) describes some of the common failures:

- "Imposing monitor views and preconceptions of a problem upon the respondent group by over specifying the structure of the Delphi and not allowing for the contribution of other perspectives related to the problem.
- Assuming that Delphi can be a surrogate for all other human communications in a given situation.

- Poor techniques of summarizing and presenting the group response and ensuring common interpretations of the evaluation scales utilized in the exercise.
- Ignoring and not exploring disagreements, so that discourage dissenters drop out and an artificial consensus is generated.
- Underestimating the demanding nature of Delphi and the fact that the respondents should be recognized as consultants and properly compensated for their time if the Delphi is not an integral part of their job functions."

This is not all. It can be shown that there is another class of criticism directed at Delphi. These are some virtual problems that do not affect the utility of the technique. The first virtual problem is the selection of a good group. Another problem is that a particular Delphi design for a particular application is taken as representative of all Delphis, whereupon this design does not work for another application. A third virtual problem is the honesty of the monitor team. Finally, misunderstanding may arise from differences in language and logic when group members are from different cultural backgrounds. (Linstone and Turoff, 1973, pp. 6-8)

4.6. The Delphi procedure

The figure shows the progress of the Delphi procedure and it will be explained more detailed in following sections.

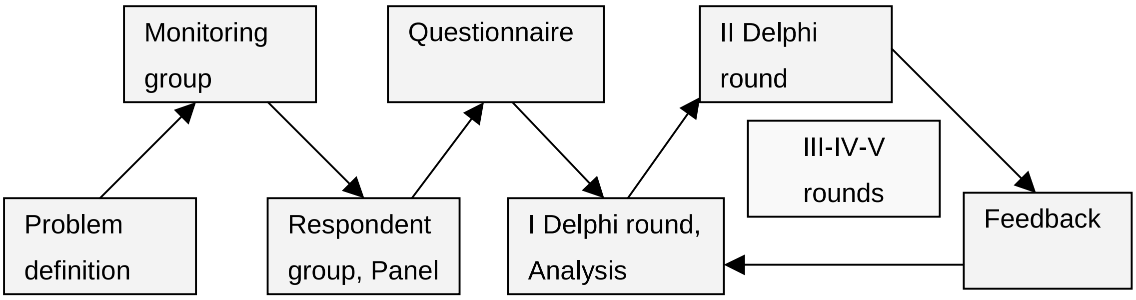

Figure 15. The Delphi process (Kuusi, 2001a)

4.6.1. Research problem

The first step in Delphi process as in every analysis is the definition of the research problem. The success of the inquiry depends greatly on the definition of the topic and the problem. Suitable topics for Delphi are so called hot spots, because they are not yet clear-cut problems. The development process of the topic might be still unaccomplished. In recent Delphi processes concerning technological development, relevant questionnaires are taken into account. For creating the questionnaire, different processes can be used. In the recent years, expert interviews, brainstorming, and small preliminary panels have been used. Suitable topics for the inquiries are technological turning points, spins offs, and the timing of implementation. Generally topics which are incubating and unstructured are very useful and interesting for the inquiry. (Kuusi, 2001a)

4.6.2. Construction of the panel

Creating panels is the second task of the Delphi process. Normally, it useful to create a panel which consists of three kinds of panelists: *stakeholders*, those who are directly affected; *experts*, those who have an applicable specialty or relevant experience; and *facilitators*, those who have skills in clarifying, organizing, synthesizing, stimulating and so on capabilities. The proportion of a panel from each category should be tailored for each application. (Linstone and Turoff, 1975, p. 68)

When assessing the capabilities of panelists, the following list can be used: (Kuusi, 2001a)

- expertise, professional skill, intelligence of the panelist,
- the ability to assess the future changes,
- imagination, creativity
- the ability to see a pattern, when nobody else yet can see it,
- finally, the assessments of each other.

4.6.3. Questionnaire of the Delphi

When panelists are dealing with the Delphi process for the first time as an expert, it is recommended that their willingness and possibility to participate in the Delphi process is confirmed. Panelists should be interested in the questionnaire, and it should bring out the expertise of the panelists. The motivation of the panelists also requires a lot of attention, because the process can go on for a long time. (Martino, 1983, p. 25)

The number of topics should be set in from two to four per round and 25 questions should be considered a practical upper limit. Long questions may cause problems and misunderstandings. Questions should be quite short and fairly simple, requiring only a single number in response, but too short questions cause diverging interpretation. On the questionnaire, there should also be ample room for comments and arguments. Another source of inaccuracy is the quality of the idea. If the idea is reasonable and profitable, its occurrence can be estimated into too close future. This can be avoided by careful design of questions and clarifying the point of view of the questionnaire. The time frame of the forecasts can be affected by the weighting of the panelist's opinions. E.g., crises, far away from this day, 20 years or more, are less important than crisis within two moths. This can be avoided using scenarios about the future environment, for which the forecast is reaching. (Kuusi, 2001a)

The questionnaire should concentrate on the forecasting task: the purpose is not to be wrestling with a complicated or confusing questionnaire.

4.6.4. Enquiry rounds and analysis

The first round

Interrogating a group of experts with a series of questionnaires carries out a Delphi sequence. Each questionnaire is a round. "The questionnaires not only ask questions, but also collect information to the group members about the degree of the group consensus and the arguments presented by the group members for and against various positions". (Martino, 1993, p. 19) It is recommendable to make a limited questionnaire. There are three main reasons to use quite a limited questionnaire: (Kuusi 2001b, p. 43)

1. By a limited questionnaire very useful and concrete results for decision-making can be attained.
2. By a limited questionnaire the first round can be performed with a few very qualified experts.
3. The third quite often-upcoming reason is insufficient resources.

The first questionnaire is completely unstructured and the panelists are asked to forecast events or trends. The topics base on scientific and political statements. The panelists give their yes/no/don't know answers and when necessary, explain them. When questionnaires are returned to the monitoring group, the answers are consolidated and similar items will be combined and less important dropped. This list of events becomes the questionnaire for the second round. (Martino, 1993, p. 19)

The second and third rounds and analysis

The panelists receive the consolidated list of events with the additional information and they are asked to estimate the time of occurrence for each event like date and so on. The monitoring group collects the forecasts and arguments of the panelists and generates the statistical summary: median date and the upper and lower quartile date for each even. In the next rounds, the questionnaires will be collected and analyzed and the most interested results are collected. The summary of the results of the rounds will be sent to the panelists. (Martino, 1993, p. 20)

The final round and analysis

The final results of the Delphi sequence are forecasts, measures of panel disagreements, and summaries of critical issues related to each event. The comments on each event provide a summary of those factors that the panelists believe are important and that may affect the forecast. The Delphi method reaches for the consensus, but it is also an intention to display disagreements and to search to causes of disagreements. One of the advantages of Delphi is that the statistical response includes the views of outliers as well as centrists. It has been found that the span from present date to median forecast date is a useful measure of panel disagreement. (Martino, 1993, p. 21)

This four-round structure describes the original format of Delphi. There have been numerous variations of this format.

4.6.5. The procedure of the Policy Delphi

The Policy Delphi is an application of the Delphi technique that seeks to identify the main features of the possible scenarios of the future (Kuusi, 2001b, p. 23). It deals largely with statements, arguments, comments, and discussions. To establish some means of evaluating the ideas expressed by the respondent group, rating scales must be established for such items as relative importance, desirability, confidence, and feasibility of various policies and issues. The Policy Delphi panel does not generate a decision for the decision maker. The group presents all the opinions and supporting evidence for the decision maker’s consideration. The Policy Delphi evaluates and aggregates different points of view about the issue. It should be able to serve any combination of the following objectives: (Linstone and Turoff, 1975, pp. 84-87)

- To ensure that all possible options are under consideration.
- To estimate the impact and consequences of any particular opinion.
- To examine and estimate the acceptability of a particular option.

In the Policy Delphi process, six communication phases can be identified (Linstone and Turoff, 1975, pp. 87-89):

1. Formulation of the issue
2. Exposing the options
3. Determining initial positions on the issue
4. Exploring and obtaining the reasons for disagreement
5. Evaluating the underlying reasons
6. Reevaluating the options. It is based upon the views of the underlying evidence and the assessment of its relevance to each position taken.

In many cases of the Policy Delphi, a three- or four-round limit can be maintained by utilizing the following phases: 1) the monitoring team using time that is required to carefully preformulating the obvious issues; 2) providing the list with an initial range of options but allowing for the respondents to add the lists; 3) asking for positions on an item and underlying assumptions in the first round. (Linstone and Turoff, 1975, p. 88)

4.6.6. Criticism of the Delphi method

During the seventies, the Delphi method went through a deep crisis, which was based on the analysis of Harold Sackman (1975). This criticism by Sackman practically ended the use of the method. From the end of the eighties, the use of the method increased again. In their analysis, Millett and Honton (1991) emphasized the view that the conventionally desired consensus of the experts is the weakness of the Delphi method. As a matter of fact, Linstone and Turoff (1975) introduced an application of the Delphi (Policy Delphi) that concentrates on producing alternative opinions and on the ambiguity of the issues. Sackman also pointed out that the statistical mean value of the expert opinions was misleading. Today most of the Delphi surveys concentrate on aggregating different scenarios about the future development instead of the dates of events or technical inventions. Recent versions of the Delphi method can be said to be more like scenario method than forecasting method. In some Delphi processes, experts are assessing various possible futures and in some other Delphi processes they are generating information, data, and starting points for scenarios. (Kuusi, 2001a)

4.7. Cross-Impact analysis

The basic limitation of many forecasting methods is that they only produce very limited forecasts. Events and trends are projected one by one, without explicit reference to their possible influence on each other. But almost every event and development is in some way connected with other events and developments.

The general notion of the Cross-Impact model was first suggested and developed by O. Helmer, T. Gordon, and S. Entzer in the Institute for the Future (IFF) in 1966, and the first experiments with the method were made by Gordon and Hayward in 1968 (Mäenpää, 1977, p. 53). The reason was that the Delphi method has one very common problem: to get at the underlying relationships among possible future events. The existence of interrelationships is the reason for complexity of many biological and social systems and for the counterintuitive nature of their behavior. Most individuals simply cannot follow the impact of one change through the system. The Cross-impact approach was developed to eliminate this problem and to examine the effect of interactions among elements of a whole system. (Linstone and Turoff, 1975, p. 325) “This technique is used to analyze the numerous chains of impact that can occur and to determine the overall effect of these chains on the probability that each event will occur by specific time.”

(Fowles, 1978, p. 301) In the technology forecasting arena Cross-Impact analysis, because of its flexibility and easiness of applying, is widely used and has various applications in many areas, including natural resource depletion, strategy and tactics for warfare, institutional change, organizational goals, communication capability, and computer capabilities (Porter et al., 1991, p. 223).

4.7.1. Basics of the Cross-Impact analysis

The basic concept of the model is that the occurrence of an event will affect the likelihood that other events will occur. There are three types of relationships that were defined to specify the linkages between two events: (Fowles, 1978, p. 302)

- *Unrelated*: The occurrence of one event does not affect the probability of the next one.
- *Enhancing*: The occurrence of one event increases the probability of the next one either by enabling it to occur or by provoking its occurrence.
- *Inhibiting*: The occurrence of the first event decreases the probability of the next one either by rendering it infeasible or impractical or by blocking or preventing its occurrence.

These relationships between the events can be of different strengths. The linkages among the events can be summarized into the cross-impact matrix with the different weightings. When this basic model deals with the future, it involves uncertainty, and therefore, it can be counted as a stochastic (~a contingent model) rather than a deterministic model. (Porter et al., 1991, p. 223)

4.7.2. The traditional Cross-Impact Analysis

Performing the Cross-Impact analysis can be divided in seven major steps for evaluating future conditions: (Fowles, 1978, p. 305)

1. Define the events to be included in the analysis.
2. Estimate the initial probability of each event.
3. Estimate the conditional (or impacted) probabilities for each event pair.
4. Perform a calibration run of the cross-impact matrix.
5. Define the policies, actions, or sensitivity tests to be run with the matrix.
6. Perform the cross-impact calculations for the policies, actions, for sensitivity tests.
7. Evaluate the results.

The first step is to define the events to be included in the study. Because the number of interactions to be considered increases rapidly (it is equal to n^2-n) as the number of events increases, limits should be set for the number of events. Most of the cases include 10 to 40 events. (Fowles, 1978, pp. 305-306)

The next steps are to estimate 1) the initial (marginal) probabilities of the events and 2) the conditional probability matrix. These probabilities are subjective and can be estimated through the process of individual experts, group working, or Delphi questionnaires. (Porter et al., p. 225) When the initial probabilities have been estimated with the reference to the other event probabilities, it is recommendable to consider the bounds on the conditional probabilities (Fowles, 1978, p. 307).

The statistically acceptable range of conditional probability can be done using the initial probabilities. This consistency calculation bases on several statistical notifications: (Porter et al., 1991, p. 225)

$P(i)$ = probability that event *i* will occur (the initial probability of *i*)

$P(I|j)$ = probability that event *i* will occur given that event *j* has occurred (the conditional probability of *I* and *j*)

$P(\bar{j})$ = probability that event *i* does not occur

$P(i|\bar{j})$ = probability that event *i* will occur given that event *j* does not occur

By using the laws of conditional probability and the probability of compound events, according to Sage (1977), the limits exist to the range of acceptable conditional probabilities. “If the occurrence of event *j* increases the probability that *i* will occur, then equation (1) holds and if decreases, then the equation (2) as follows”: (Porter et al., 1991, p. 225)

$$P(i) < P(i|j) < [P(i) / P(j)] \quad (1)$$

$$1 + \{[P(i) - 1] / P(j)\} < P(i|j) < P(i) \quad (2)$$

When the cross-impact analysis is completed, using a computer program should be calibrated the matrix by selecting randomly an event for testing and comparing its probability with a random number to decide occurrence or nonoccurrence, and calculating the impacts on all of the other events. These impacts are calculated by using odds ratios. Initial and conditional probability of the events are converted to odds with following relationship: (Fowles, 1978, p. 308)

$$odds = \frac{probability}{1 - probability} \quad (3)$$

Once the odds ratios have been determined, the calculations of the calibration of matrix proceed as follows:

1. An event is selected at random from the event set.
2. A random number (0-1) is selected and if it is bigger than the probability, the event occurs and vice versa.
3. If the event occurs, the odds of the other events are adjusted as follows

   New odds of event *i* = (Initial odds of event) x

   (Occurrence odd ratio of event *j* on event *i*) (4)
4. Steps from 1 to 3 are repeated until all the events have been tested.
5. Steps from 1 to 4 are repeated as many times as necessary.
6. The frequency of occurrence of each event for all computer runs of the C-I. matrix determines the new or calibration probability of the event.

Results of the calibration probabilities will normally be within a few percentage points of initial probabilities. If the results differ from the initial values more than a few percentage points, the matrix should be tested for these higher-order effects using a different string of random numbers. (Fowles, 1978, p. 312)

Sensitivity testing is the next step in the process. It consists of selecting a particular judgment (an initial or conditional probability estimate) about which uncertainty exists. The judgment is changed and the matrix is run again. If the calibration results differ greatly from the original probability estimations, the initial values of the matrix should be estimated again. (Fowles, 1978, p. 312)

The final step, the policy testing, is usually performed by changing probabilities or adding a new event into the matrix. After this change is done, the new run of the matrix is made and compared with the calibration run. Now the changes can be identified and the cross-impact matrix become a model of event interactions that is used to depict the impacts caused by policy actions. (Fowles, 1978, p. 313)

An example (Fowles, 1978, p. 310-311):

Using the equation (3) the impact of event *n* on event *m* is calculated as the ratio of the odds of event *m* given event *n* to the initial odds of event *m*. Thus, the initial probability matrix becomes the odds matrix (table 1).

The occurrence of event 2 causes the likelihood of event 1 to go from odds of 0,33 to 1,50 and all other probabilities are also converted to odds.

$$\text{Odds}_{\text{event1,2}} = 0{,}6 / (1\text{-}0{,}6) = 1{,}50$$

The odds ratio expressing the occurrence impact of event 2 on event 1 is, therefore, 1,50 / 0,33 = 4,5 (table 3)

		The probability of this event becomes:						The odds of this event becomes:		
If the event occurs	Initial probability	1 p(n│1)	2 p(n│2)	3 p(n│3)		If the event occurs	Initial Odds	1 p(n│1)	2 p(n│2)	3 p(n│3)
Event 1	0,25		0,50	0,85		Event 1	0,33		1,00	5,67
Event 2	0,40	0,60		0,60		Event 2	0,67	1,50		1,50
Event 3	0,75	0,15	0,50			Event 3	3,00	0,18	1,00	

Table 2. Probability matrix and odds matrix (Fowles, 1978, p. 310)

		The odds of this event are multiplied:		
If the event occurs	Initial odds	1	2	3
Event 1	0,33		1,50	1,90
Event 2	0,67	4,50		0,50
Event 3	3,00	0,55	0,50	

Table 3. Occurrence odds ratios (Fowles, 1978, p. 311)

4.7.3. Alternative Cross-Impact techniques

The traditional cross-impact analysis may be altered depending on the requirements of a particular analysis. An example of this is the sequencing of events. Sequencing involves certain events as precursor events that should always occur or be tested for occurrence after all the other events. In this way, a rationale order can be imposed on each of the Monte Carlo runs of the event matrix. This describes real world relationships better. For many applications, the major limitation is that the cross-impact method deals with only a limited time frame. The probabilities of the analysis are presented for some future year, but no information is generated about the transition from the current situation to the future. (Fowles, 1978, p. 320-321)

There are various approaches that deal with the development of a dynamic or continuous form of cross impact. Gordon and Enzer (1970) added trends to the events in the cross-impact matrix. Each variable was identified as having dynamic behavior of one of three types: S-shaped growth, exponential growth, and constant value. Cross impacts were computed each year of run for each variable and resulted in fixed growth curves for each variable. (Fowles, 1978, p. 321)

Julius Kane (1972) developed a dynamic approach that deals with the time factor rather than events. In this approach, called KSIM, each variable is assigned a value between 0 and 1, which depicts the physical limits of variable. Cross impacts are defined as the strength of the effect of one variable on another. Impacts are calculated by weighting the strength of the effect of one variable on another by the distance from minimum value to the first variable. The results are in the form of values of each variable versus time. (Fowles, 1978, p. 323) Building the KSIM model provides the format in which experts can structure the discussion of a complex issue and they can combine judgment and hard data (Porter et al., 1991, p. 243).

4.7.4. Limitations of Cross-Impact analysis

Cross-impact analysis has been used successfully and the heuristic nature of the procedure itself, when new information is gained from the runs of the matrix considering the events and interactions between them, often makes the use of this technique advisable. But the cross-impact analysis has it own limitations. As mentioned above, it, in most cases, deals only with events and most future cases cannot be described only with events. Therefore, it is recommended that the cross-impact analysis should be combined with other forecasting methods, particularly with the scenario construction. (Fowles, 1978, p. 327)

4.8. Morphological analysis

The morphological approach was developed by a Swiss astronomer, Fritz Zwicky, 1942, for a systematic exploration of technological possibilities. The morphological analysis is a model for breaking a problem down into parallel fragments. The Relevance tree method breaks the problem into hierarchical parts and therefore these methods should be treated independently. (Martino, 1983, p. 239) The method basically makes a series of questions about a technological development. The set of questions should contain all possible questions about the technology. Conceivable answers should be provided to all the questions. The analysis then proceeds by systematically selecting all permuted combinations of the answers to each question. (Fowles, 1978, p. 408)

4.8.1. Basics of the morphological analysis

The method is concerned with the totality of all of the solutions of a given problem and the analysis proceeds as follows: (Jantsch, 1967, pp. 174-176)

1. An exact statement is made of the problem to be solved. For this, if one specific device, method, system is asked for, an extensive enquiry to all possible devices, methods which provide the answer to a more generalized request will be generalized.
2. The exact statement of the problem to be solved will provide the characteristic parameters depending on the solution.

3. In this phase, each parameter p_i is collected to possess a number of k_{pi} different independent minimum values $p_i^1, p_i^2, ..., p_i^k$ and matrices are formulated as follows:

$$
\begin{array}{l}
[p_1^1, p_1^2, ..., p_1^k] \\
[p_2^1, p_2^2, ..., p_2^k] \\
\ldots\ldots\ldots\ldots\ldots\ldots \\
[p_n^1, p_n^2, ..., p_n^k]
\end{array}
$$

4. When matrices have been made and one element is circled in each matrix and the circles are connected and the resulting chain represents a possible solution of the problem. The selection of the preferable variables is made by using expertice of the area.
5. This phase represents the determination of the performance of the all of the derived solutions in the analysis.
6. Finally, there is the choice of particularly desirable solutions and their solution, e.g. for an R & D program.

It is obvious that the number of all the combinations of the parameters increases rapidly with the numbers of the parameters. For example, when there are three parameters, each with five possibilities, the number of combinations is 5 x 5 x 5 = 125 and when adding the fourth parameter, the number of combinations increases to 625. Some of the solutions are not really possible and the number of combinations decreases but still remains quite high. This can also be seen as the strength of the method. (Martino, 1983, pp. 239-240)

4.8.2. Morphological analysis and forecasting

"Morphological analysis combines features of fractionation and checklists and expand them in powerful new directions (Porter et al., 1991, p. 105)". It is intended to provide a framework for creativity. The morphological analysis, when structuring thinking in such a way that new information is generated, is not restricted to any level of technology transfer or to technological forecasting generally. For technological forecasting problem, the application of morphological thinking to the impact levels of technology transfer or social systems, appears feasible and fruitful. (Jantsch, 1967, p. 178-179) "Ayres (1969, pp. 85-86) sees that the method can be used especially for the development of scenarios, and the aid to intuitive thinking."

4.9. Scenario analysis

The term 'scenario' has several definitions, but Kahn and Weiner (1967) gave it a detailed definition: it is a hypothetical sequence of events constructed for the purpose of focusing attention on causal processes and decision points. A scenario is hypothetical. It bases on a present hypothesis about future. A scenario is a sketch. It seeks branching points of the future. A scenario should be holistic in its approach to the future. (Meristö, 1991. pp. 40-41)

4.9.1. Scenario analysis vs. forecasting

As Godet (1987) defines, "a scenario is the description of a future with the progress of the events leading from the starting situation to the future situation". Scenarios usually try to identify a set of possible situations in the future. They could be plausible but not certain. Forecast usually provides qualitative and contextual description about the way the present will evolve into the future. A scenario may be subject of an assessment expressed in figures, i.e. a forecast. (Hartikainen, 1994, pp. 9-12)

	Classical Forecasting	**Prospective Scenarios**
Viewpoint	Piecemeal, provides direct input for decision-making.	Overall approach, a tool for thinking, needs processing during decision-making
Variables	Quantitative, objective,, know. Source for uncertainty are not specified.	Qualitative, subjective, known or hidden, not necessarily quantitative. Attention is on variable and their action.
Relationships	Static, fixed structures	Dynamic, evolving structures
Explanation	The past explains the future.	The future is the raison d'arte of the present.
Future	Single and certain	Multiple and uncertain
Method	Deterministic and quantitative models. Statistical summary of expert opinions.	Intentional analysis, qualitative and stochastic models usually a narrative about possible futures.
Attitude of the future	Passive or adaptive. It is possible and useful to forecast the future.	Active and creative. The future cannot be forecast or it is not useful.

Table 4. Differences between the forecasting and scenarios (Hartikainen, 1994, p. 13)

According to Godet (1987), the scenario analysis can be combined with forecasting for strategic management. A scenario can be used as a framework to use classical forecasting techniques. The forecast is a possibility to process a scenario and convert qualitative contents of a scenario into quantitative terms. This combination of the techniques works only in this direction. (Hartikainen, 1994, p. 26)

4.9.2. Types of scenarios

Approaches to construct scenarios are often distinguished into two types: 1) *explorative* and 2) *anticipate*:

1. *Explorative scenarios* include the basic assumptions of the present and by using these assumptions in different combinations, possible futures into the future can be provided. They can be divided into two different types: firstly, tendency scenarios in which the basic assumptions are that the tendencies continue and the system is stable and secondly, framework scenarios that aim to define the sphere between the extreme futures.
2. *Anticipative scenarios* can be divided into normative and contrasted scenarios. A normative scenario includes a set of realizable objective and using them can be described the desirable future situation combining the present and the future. A contrasted scenario explains desirable futures that are in the limits of realized.

Explorative and anticipative scenarios do not exclude one another. They can be used together and this combination is called a “willed future”. Using the combined scenarios you can avoid the risk that the explorative scenarios are descriptions about the present situation and anticipative scenarios, which are normative, describe the desirable future that will be impossible in every circumstances. (Meristö, 1991, p. 42-43)

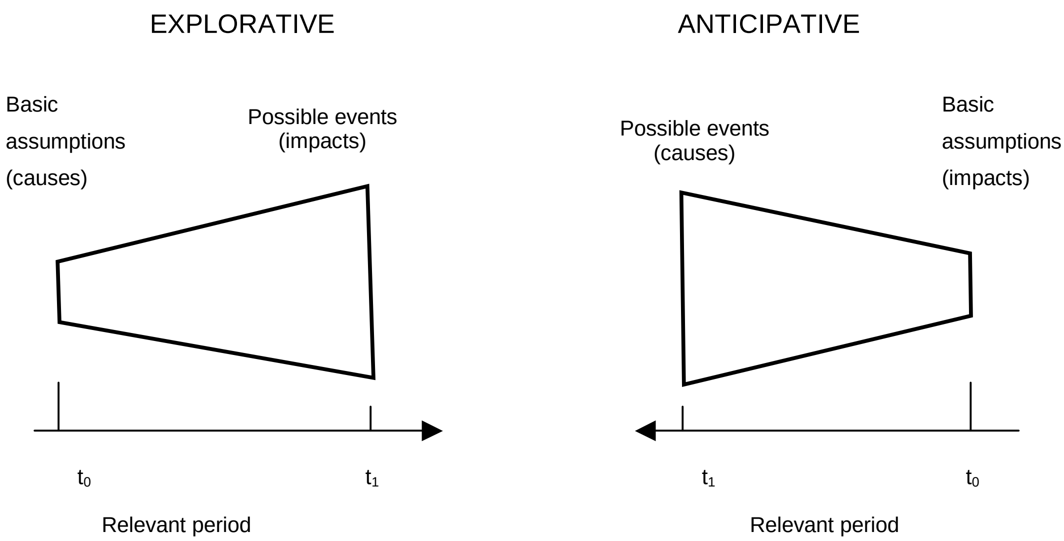

Figure 16. Comparison of the explorative and anticipative scenarios (Meristö, 1991, p. 43)

Scenarios are often used for planning and management function and they can be divided also in this point of view. Then scenarios can be classified according to the threats and opportunities described in the scenario, the levels of reference and the generation of strategies. (Meristö, 1991, p. 11)

Meristö (1991, p. 35) classifies scenario types into three categories when using scenarios for strategic planning. Then each of the scenarios has its own function:

1. Issue scenarios scan the environment for each business area and help setting objectives.
2. Mission scenarios provide background for defining the organization mission and selecting business area.
3. Action scenarios give a range for marketing strategy decisions.

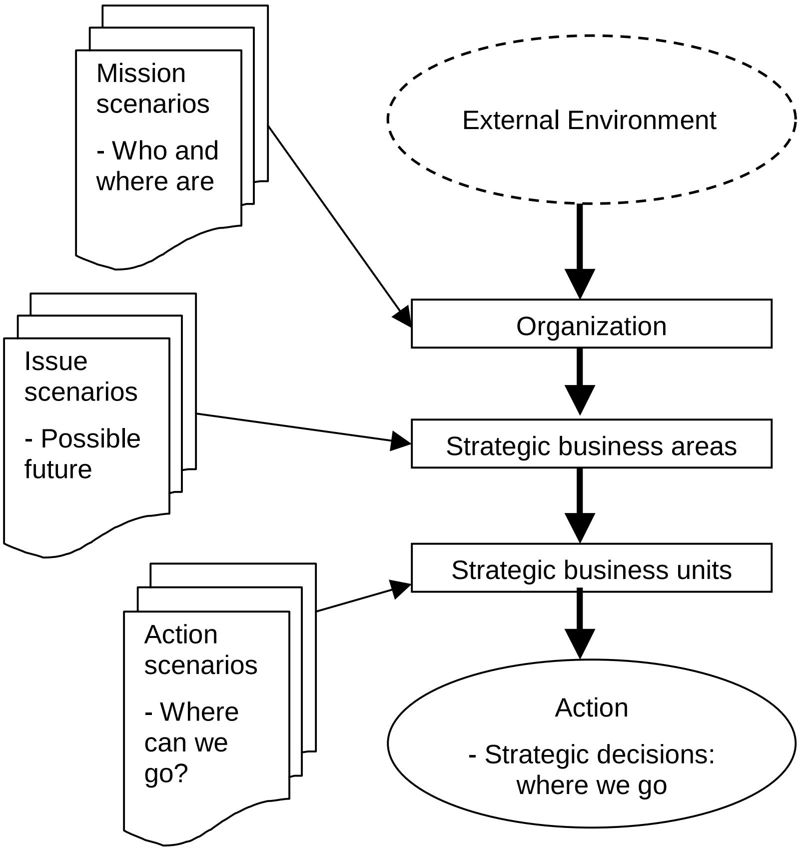

Figure 17. Strategic planning and scenarios in strategic management (Meristö, 1991, 111)

4.9.3. Scenarios in planning

According to Godet (1987), planning is an anticipatory action that is for analysis of future reveals threats and opportunities in the future environment. These actions are to achieve the goals set by the organization and to avoid the threats against the organization. The planning process has also indicative and proactive characteristics when it provides the possible means of taking action to the desired direction. Planning could also be a good way to active decision-making. (Hartikainen, 1994. pp. 13-14)

Gode (1987) lists several factors that have made futures research important in planning process and therefore suggests scenarios for planning process: (Hartikainen, 1991, p. 15)

1. The acceleration of technical, economic, and social change.
2. Inertial factors relating to organizational structures and behavior demand a longer incubation period before results occur.
3. Rising uncertainties in technical, political, economic, and social fields.

Planning in managerial level defines an organization's long-term mission and development of its resources. The strategic planning emphasizes the long-term goals and these associate it with the future research. Present turbulent environment has caused the problem that the traditional planning process is insufficient and it needs more analysis of discontinuations and future environment. Along with these, the scenario planning has come up also as an auxiliary method. (Meristö, 1991, p. 20) Scenarios in strategic planning aim to identify the general environmental framework for the organization. The framework ensures the holistic nature of scenarios. (Meristö, 1991, p. 158)

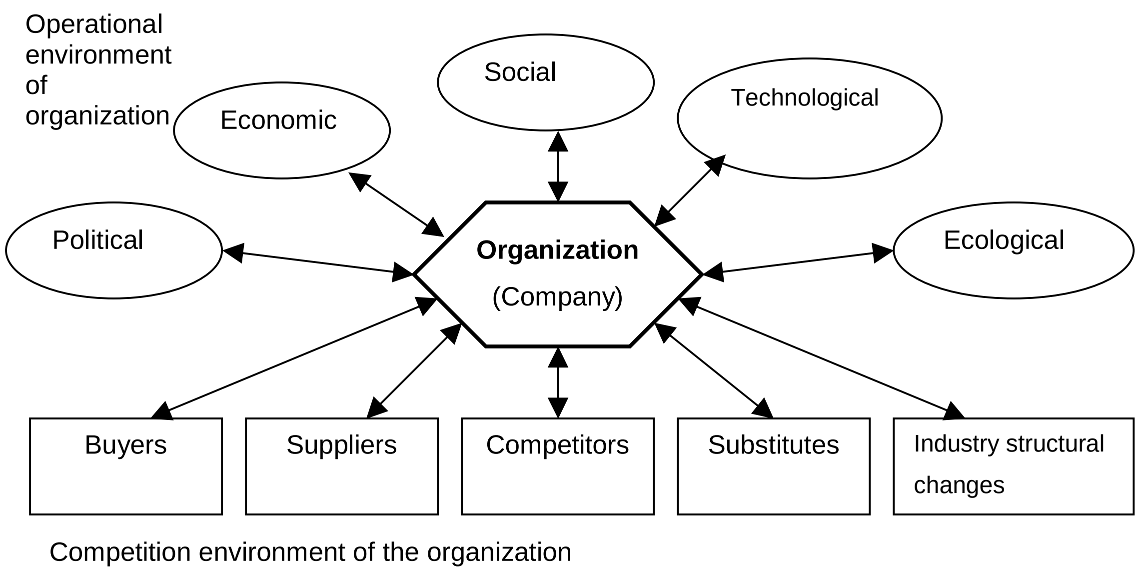

Figure 18. Environmental framework of an organization (Meristö, 1991, p. 158)

4.9.4. Constructing scenarios

Scenario writing denotes a technique that attempts to set up a logical sequence of events in order to show how, starting from the present situation, a future might evolve step by step. Scenario writing can be regarded as an extension of contextual mapping to the information of a synoptic view of as many developments as can be grasped and as may appear relevant to an experimental simulation of a possible reality. Scenarios are always performed in an explicit time frame. (Jantsch, 1967, p. 180)

According to Codet (1987), while constructing scenarios the main task of the process is to perform the environmental analysis of the organization and define the internal and external key variables and relationships between them and identify the most relevant combinations of variables for the possible scenarios. (Hartikainen, 1994, p 36)

When constructing scenarios, different auxiliary methods for the systematic analysis and gathering the most relevant information for the scenarios can be used. The morphological analysis has been developed for analyzing the structure of the problem. Morphological analysis is a scheme for breaking a problem down into the parallel parts and the solutions of each part (Martino, 1993, p. 239). “Using the Morphological analysis the most relevant factors for the scenarios can be selected and combining these factors in such way that they meet the goals of the study, the possible and most appropriate scenarios can be found”. (Porter et al., 1991, p. 266)

There is no single method to construct the scenario, but Porter et al. (1991, p. 263-265) outline a typical set of steps for scenario constructing:

- Identify the topical dimensions that are usually determined by the purpose of scenario.

- Identify the interests of the users of the scenario.
- Determine the timeframe that is typically 5 to 20 years for technological assessment.
- Specify the assumptions on which scenarios are based. Assumptions can be identified into two categories: general societal assumptions and specific assumptions relating to the area of the study.
- Determine the dimensions of the scenario that base on the users and the purposes of the scenarios. When determining the dimensions, completeness is important.
- Select the number of scenarios and their emphases.
- Construct and represent the scenarios. The major concern is to represent the situation without using too many scenarios.

“Simplistically, building the scenarios means defining the set of most relevant assumptions and then using them developing an imaginative conception of what the future would be like if these assumptions were true”. (Makridakis, 1983, p. 651)

5. EVALUATING THE FORECASTING METHODS

There is no a simple method or simple criteria to evaluate the forecasting methods because the purpose and need of forecasts are always individual. Conceptually, there are several ways in which criteria for selecting and comparing forecast methods can be organized. The major criteria of evaluation process can be stated when selecting one method over others. Accuracy is given top priority, data collection, costs of methods, and ease of use of methods are the most common criteria when evaluating forecasting methods.

5.1. Accuracy of forecasting methods

The accuracy of technological forecasting is often impossible to measure but Ayres gives a list of possible pitfalls in technological forecasting: lack of imagination, overcompensation, failure to anticipate converging developments, concentration on specific configurations, incorrect calculation, and intrinsic uncertainties and historical accidents. (Jantsch, 1969, p. 102-103)

“The only chance to get indications of the possible competence of forecast is to examine how well the chosen model would have predicted the future in the past. Such consideration is useful for comparing alternative techniques and for obtaining a perception of the “perfection” if the technique to be used”. (Pitkänen, 2001, p. 21)

It is appropriate to remind that the accuracy is not the only and the best measure of the rightness of a forecast, but one of them. A good forecast is one that provides useful information and guidance to the planner and decision maker. (Fowles, 1978, p. 295)

5.1.1. Measures of accuracy

The accuracy of methods can be measured using error equations. A typical procedure to compare the forecasting methods is to compute the error values for each method and to compare it with other forecasting. For example, means squared error (MSE) 15 % might be very good indeed if the next best model has an error of 30 %. Another possibility is to use two thirds of actual values for modeling the method and saved values (one-third) for accuracy measures. This method only tells the validity of the chosen equation. The second statistical possibility to measure the accuracy of forecasts is to compare the results of different methods from the past one to another. However, one of the difficulties dealing with the criterion of accuracy in forecasting situation is absence of a single universal acceptance measure of accuracy.

The standard error measures used in forecasting include Mean absolute deviation (MAD), Mean squared error (MSE) and Mean percentage error (MPE), which are defined as follows:

$$\text{MAD} = \frac{\sum_{t=1}^{h} \left| A_t - F_t \right|}{h} \quad (4)$$

$$\text{MSE} = \frac{\sum_{t=1}^{h} \left(A_t - F_t \right)^2}{h} \quad (5)$$

$$\text{MPE} = \frac{\sum_{t=1}^{h} \frac{\left| \left(A_t - F_t \right) \right|}{A_t}}{h} * 100 \quad (6)$$

Where *A* is the actual result
F is the forecast
t is the time interval
h is the number of periods in the time horizon

According to the enquiry in Quebec in 1981 that lists the criteria for evaluating extrapolative methods, the most frequently mentioned criterion among the participants of the survey was accuracy, and within this category mean square error (MSE). Two-thirds of the participants in the survey mentioned the qualitative criteria like ease of use or implementation and ease of interpretation. (Armstrong, 1985, p. 359)

5.1.2. Qualitative assessment of the forecasts and forecasting methods

These assessments based on different types of analysis and individual decisions. The first and the most essential question to answer is: does the forecast provide needed information? This is a very complicated question because methods are under the influence of various inside and outside factors. A major assumption is also that the forecaster must know the given technology.

In a planning process, decision makers must know which method is a good one. When a forecast is needed, the outcome is not known and therefore the accuracy of a forecast cannot be measured. As stated in section two, the decision-making process needs the best available information about the possible future. Therefore, the criterion of judging a forecast must be based on its utility for decision-making process. Martino (1993, pp. 333-337) represents a model that searches for the items that are the most important in each case. This model is called an interrogative model. The model includes several steps:

1. Interrogation for need. This focuses on the decision maker and clarifies the main reason why the forecast is needed.
2. Interrogation for underlying causes. Determines the subject area of the forecast and identify nature of the occurring change.
3. Interrogation for relevance. During this, the researcher is trying to find irrelevant and relevant but absent material, e.g. the forecast has originally made for larger decision area.

4. Interrogation for reliability.
    - First you must confirm that the method is replicable and formally consistent.
    - Secondly, the assumptions must be adequately defined.
    - Thirdly, you must confirm in which way the assumptions are supported by expert opinions, evidence from examples, by principle or axiom.
    - Fourthly, the method is evident to support a realistic, humanistic assumption, and evident to support principles and credibility of experts.
    - Fifthly, the data must be accurate and available, and confirm or deny assumption.

The model determines the needs for forecasts and points out all sources of change. This model is for decision makers, but it is very suitable for forecasters to use it for evaluating the forecast. (Martino, 1993, p. 337)

5.2. Data collection

The accuracy of extrapolations is usually affected by two major conditions: the accuracy of the historical data and the extent to which underlying conditions will change in the future. Available data is often inaccurate and it directly affects the result of forecasting. Therefore, it is important to know the source of the data, the relevance of the data, and the completeness of the data. If this information is available, the decision maker is more likely to accept the forecast. (Armstrong, 1985, p. 153-157) “There are no exact list of the acceptable values, but F. S. Pardee has developed very useful guidelines for selecting measurements of performance” (Lanford, 1972, p. 34):

Comprehensiveness. A single variable is preferable if it adequately represents progress in the area.

Ease of measurement. Consideration should be given to the ease with which projected parameters can be measured to determine degree of accomplishment.

Operational significance The characteristics or characteristics selected should bear a direct relationship to a perceived need, for example, a major design specification.

Probable accuracy. This quality can be assessed through informal checks for reasonableness, formal tests of statistical validity, and other suitable means.

Identification and measurement of interdependencies.

In some instances, a pacing characteristic can be identified and other variables related to it in a fixed fashion, for example, heat-resistant material, measured by temperature, is the pacing parameter.

Armstrong (1985) has represented the list of data sources and has rated them against five criteria. This table provides a good summary of data types that can be used for extrapolations. But usually there are no alternative sources to choose data from.

Source of data	Estimate the current status	Forecast Small Changes	Forecast Large Changes	Effects of researcher's biases	Costs
Historical	1	1	4	1	1
Analogous situations	2	4	3	2	2
Laboratory simulations	4	3	2	4	3
Field tests	3	2	1	3	4

Table 5. Ranking of data for extrapolations (1=most and 4=least appropriate) (Armstrong, 1985, p. 157)

5.3. Costs of forecasting methods

Elements of costs are often the key criteria that are opposite to such factors as accuracy and easiness of application, and the pattern. The costs of forecasting depend very much on the methods itself and their inherent complexity as well as on their data requirements and the number of items to be forecast. (Makridakis, 1983, 762) When assessing costs of forecasting methods, there are three basic elements: development costs, maintenance costs, and operating costs (Armstrong, 1985, pp. 366-385).

Development costs

Three major factors influence costs:

1. Data needs. Methods that require more data costs because of added collection and processing costs.
2. The complexity of method. More complex methods require more highly trained people and more time for analysis.

3. Implementation. For both analysts and users to gain confidence in the model, significant time and money must be invested.

Maintenance costs

Maintenance costs often parallel the costs used for development. It is obvious that the more complex methods are also the more expensive ones to maintain. They require more data and more effort to document and keep up to date. (Armstrong, 1985, p. 370)

Operating costs

Operating costs are not usually much higher for complex methods. When a complex method is developed, the method can be used repeatedly and therefore operating costs are lower. Operating costs are of particular interest when a large number of forecasts or alternative assumptions about the future environment is needed. (Armstrong, 1985, p. 371)

6. ANALYSIS OF THE METHODS

6.1. Trend forecasting

Trend projection has several advantages. First of all, in trend extrapolation combining the results for execution is relatively easy compared to other techniques. Data requirements are minimal here, because only a single variable for many problems is needed. Costs of data analysis are often quite minimal with trend methods. Execution is very simple and inexpensive in contrast to many other methods; it can be done merely with pen and paper. (Fowles, 1978, p. 269)

“This method is more easily understood and used than less clear-cut techniques. It also has the advantage of objectivity and simplicity and is applicable to forecasting functional capabilities”. (Lanford, 1972, p. 32)

Another benefit of initial application of trend extrapolation is that it often forces the researcher to learn more about the history of his subject in preparation for forecasting its future. (Fowles, 1978, p. 270)

Disadvantages of trend forecasting techniques include the possibility that this technique may become a simple kind of model that can be manipulated intuitively. Another drawback stems from the assumption that the factors that shaped the past will continue to hold true in the future. Trend forecasting therefore cannot show unpredictable interactions. The method does not consider the causal factors for the trend pattern or possible constraints. (Lanford, 1072, p. 33)

Obviously, the use of this technique alone cannot significantly advance rigorous forecasting and causal analysis. Nonetheless, simple tools can be powerful when used with care and insight. As a vehicle for exploring and refining many forecasting problems and as a “first-cut” approach to defining the boundaries of the issue, trend methods have a lot to offer. (Fowles, 1978, p. 271)

6.2. Delphi method

The Delphi method, as it originally was introduced and practiced, tended to deal with technical topics. The objective of the method was to obtain a reliable consensus of opinion from a group of experts, while at the same time minimizing the aspects of group interactions. This method replaces direct debate by careful designed program of sequential individual interrogations (questionnaires), interspersed with information and opinion feedback derived from earlier parts of the program. The feedback procedure permit experts also argue and change their responses. (Makridakis, 1983, pp. 652-653)

As mentioned above, Delphi method bases on the opinions of individual and therefore has some disadvantages. Inevitably, individuals reflect the cultural attitudes, subject biases, and knowledge of those who formulate the method. The forecasts made by the Delphi are inclined to be pessimistic on the long-range estimations and optimistic on the short-range estimations. It also discounts the future and makes it simpler than it really is, because of human nature. (Fowles, 1978, p. 296-298)

Despite the deficiencies, Martino (1983, p. 15) describes three situations when Delphi method is more suitable than formal forecasting methods:

1. When no historical data exists and a forecast may be needed. This situation appears usually with the new technology.
2. When the impact of external factors are more important than the internal ones of the phenomena.
3. When ethical and moral considerations dominate the economical and technological goals of the development.

The Delphi method has been successfully used in the area of technological forecasting. But there are some basic difficulties in this method, and Harold Sackman (1975) expressed strong criticism against the traditional Delphi method. In his study, he emphasized that there is no guarantee that the attained consensus is consistent, responses of the panelists are based more on associations than extensive consideration, and the responses of the panelists does not take into account the effect of one phenomenon on another. The recent development of the Delphi method is mainly due to Sackman's critique. (Mäenpää, 1977, pp. 42-43)

Today Delphi method emphasizes the pursuit to find relevant arguments concerning future developments. Turoff (1975) introduced the Policy Delphi, which seeks to generate the strongest possible opposing views on the potential resolutions of a major issue. The Policy Delphi presents all the options and supporting evidence for decision maker's consideration. It is a tool for analysis of policy issues. (Kuusi, 1999a, p. 77)

The use of the Delphi method is quite simple and straightforward. The Delphi method is neither cheap nor easy, but it can be done with reasonable cost and effort. Most of the problems consider the selecting of the panel group and making the questionnaire and turnaround time between questionnaires. The turnaround time between questionnaires might be a significant factor when running the Delphi process. When using the mail, Delphis usually take about a month between successive questionnaires. In Delphis that are performed within organizations turnaround time is usually shorter. (Martino, 1983, pp. 24-30)

According to Garry Waissi (1979, p. 23), the Delphi method is very useful for forecasting the means to achieve desired goals. When using the Delphi method, the expenses are lower and less time is needed than when using many other methods. The Delphi method also offers the possibility to study the problem divergently from different points of view. "The Delphi procedure is a feasible and effective method of obtaining the benefits of group participation in the preparation of a forecast while at the same time minimizing or eliminating most of the problems of committee action (Martino, 1983, p. 33-34)".

6.3. Cross-Impact analysis

The motivation for cross-impact analysis has arisen on the basis of long-range forecasting. There are usually strong interactions among the technological events and among the social developments. Therefore a method has been needed to assess the likelihood that any given event or development will occur taking account the interaction with other events. (Linstone and Turoff, 1975, p. 327)

Cross-impact analysis is very widely used and has applications in many areas, e.g. institutional change, organizational goals, communication capability, computer capabilities, strategy and tactics for warfare and so on. Cross-impact analysis provides usually information for another technique, e.g. scenarios. (Porter et al. pp. 222-223)

The basic concept of the method is simple, but its applications are generally quite complex. To construct the matrix, you must define all relevant events and their probabilities. The problem is how the relevant events and their occurrence or nonoccurrence can be defined. Another problem is the difficulty of presenting a complex phenomenon by a limited number of hypotheses. (Porter, 1991, pp. 222-224) The cross-impact analysis requires careful preparation of background information. This information is basically subjective and therefore, events and probabilities are examined by the experts of the area. (Hartikainen, 1994, pp. 39-40)

The major benefit of the cross-impact analysis is that with the method, more complex issues can be analyzed than with many other forecasting methods. It allows you to follow the numerous chains of impact that can occur and to determine the overall effect of these chains on the probability that each event will occur by the specific time. (Fowles, 1978, p. 301) Cross-impact analysis is not for gathering objective information. It is more a framework within which different future worlds can be examined. (Mäenpää, 1977, p. 67)

6.4. Morphological analysis

The more complex the problem is, the more difficult it is to visualize and understand. Morphological analysis represents an approach to systematic thinking and problem solving. The morphological analysis is a checklist that in a systematic manner enumerates all possible combinations of technologies. Its advantage is that it helps to find also hidden opportunities for technological opportunities (Makridakis, 1983, p. 664-665).

Morphological analysis is not a forecast *per se*, but it is a useful organization tool, a source of insights, and a starting point for a further analysis by other methods. Morphological analysis is very useful for scenarios when selecting the most relevant and consistent scenarios. (Ayres, 1969, p. 72-75)

Morphological analysis requires careful construction of the parameter matrices and their evaluation. The difficulty of the method is to find the most relevant possibilities and concurrently identify all the possibilities. The use of the method requires high expertise in the area, and because of the enormous number of all possible combinations of the parameters, sophisticated software is needed to perform the compilation.

Generally, the method is simply an orderly way of looking at things and so achieving a systematic perspective over all the possible solutions of a given large-scale problem. The method provides a framework for thinking in basic principles and parameters, which is growing in importance, even if practiced in a disordered or ac hoc fashion. (Jantsch, 1967, p. 177)

6.5. Scenario analysis

It is useful to specify some of the essential characteristics of scenario analysis. The first and perhaps the most important one is that scenarios are hypothetical. No scenario will ever materialize exactly as described because the best that a scenario can do is to explore alternative possible future. We cannot predict the future. A scenario is also only a sketch; it provides a synopsis of the action and brief descriptions of the basic characters. Scenarios are also holistic in their approach to the futures. They combine demographic changes, social trends, political events, economic variables, and technological developments. (Fowles, 1978, p. 226-227)

Scenarios can be seen as an inherent part of the strategic planning process and managerial decision-making. By using scenarios, the management of the company tries to identify signals, which will serve as early warning systems and for which contingency plans can be prepared. (Meristö, 1991, p. 29) "A scenario provides an assessment of the future context in which an optimal corporate fit can be determined". (Fowles, 1978, p. 228)

According to Porter et al. (1991, pp. 269-270) there are two major criteria for evaluation: utility and validity. Utility addresses the usefulness of the scenarios to the users. Scenarios must meet the user's strategies and they must be avail to the user. Thus, their contents must be of facts and data relevant to the problems of the user. Validity means that scenario must assess what it claims to assess.

Porter et al. (1991, p. 262) see two general uses of scenarios: integration and communication. Firstly, scenarios can collect and integrate information from different sources into the single use. Secondly, scenarios can serve as a communication tool to express situations clearly and in an integrated and understandable way.

According to Ian Wilson, scenario only seeks to find out the key points of the future, to highlight the major determinants that might cause the future to evolve form branch rather than another and to determine the main consequences of a causal chain. (Fowles, 1978, p. 226)

One problem is how to assess the goodness of scenarios. According to Meristö (1991, p. 166), the goodness of scenarios can be assessed when comparing the decisions, done by the help of scenarios, and without their help. “Scenarios can improve the ability of an organization to see the future as a whole rather than as a piecemeal (Fowles, 1978, p. 230)”.

The results of the survey (Meristö, 1991, p. 164-166) show that scenarios are very useful in the strategic planning process, but concurrently they can also be quite complicated. The survey also points out several requirements to perform scenario analysis successfully:

1. Commitment of the management to achieve the scenario process.
2. Allocation of resources to achieve the scenario process
3. Scenario analysis should start before strategic planning
4. Scenarios are not predictions. They are alternative descriptions about the possible future worlds.

7. SUMMARY

In this study the aim was to clarify the role of forecasting methods in the technological planning process and to find the most suitable methods for gathering information about the future technological progress. The second objective of the study was to provide initial information about future research methods for further studies.

The role and position of forecasting methods can be described using the *adapted picture* of the umbrella of vision and strategic planning (Meristö, 1991, p. 155). We can play with the idea that if the vision about the future does not exist, the planning has no effect on the work of the organization.

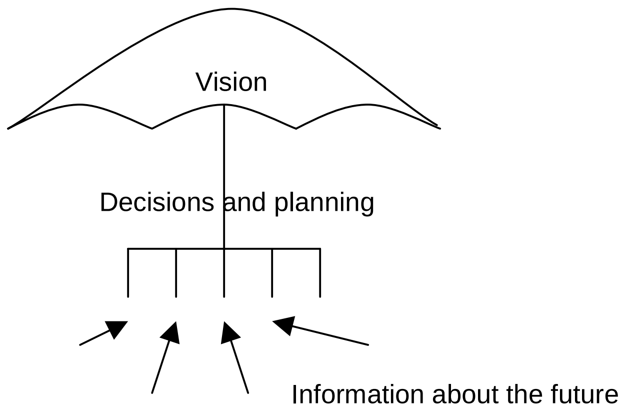

Figure 19. Forecasting and vision in decision-making and planning process.

Technological planning has a major role in the organizational planning process. Planning requires decisions, and decisions cannot be made without information. Information about the future changes in high technology environment is more or less in tacit form; therefore the appropriate forecasting methods must be able to process the results into a clear and more illustrative form.

The literature used in this study unambiguously points out that the methods which base on intuitive thinking and human judgment are able to provide required information for far-reaching technological planning. Forecasting methods are usually based on information from the past and their capability to expand it into the future. Forecasting methods can be seen as a chain of methods. Forecasting methods provide information for the use other methods and finally a set of alternative descriptions of the possible and desirable future.

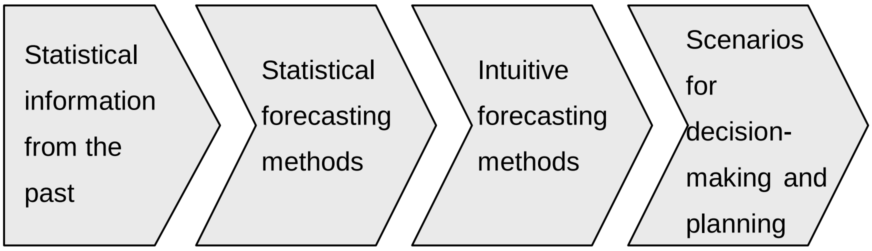

Figure 20. Combining forecasting methods to produce information for planning process.

8. CONCLUSION

The objective of this study was to examine the role of forecasting in planning processes and find the most suitable technological forecasting methods for decision-making and planning.

Using forecasting methods can provide useful information about the future to fill the gap between the present situation and the decisions concerning the organization's future goals.

Long-term technological forecasting requires methods that can be used when additional information is not available and the future is totally unknown. The appropriate and most frequently used forecasting methods for this purpose are those that base on human judgment and intuitive thinking: trend extrapolation, the Delphi method, Cross-impact analysis, Morphological analysis, and Scenario analysis.

With these methods, useful explorations about the behavior of the possible future environment can be made, and they provide fruitful information for decision-making and organizational planning.

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APPENDIX 1

Source: Porter et al., 1991, Forecasting and management of technology

Fitting the logistic curve in a set of data:

It is customary to straighten out the curve first. The formula is transformed into that of a straight line, the best straight line is then fitted in the transformed data.

Pearl curve has been transformed into straight line by taking natural logarithm as follows:

$$y = \frac{L}{1+ae^{-bt}} \quad \Rightarrow \quad Y = \ln\left[\frac{y}{L-y}\right] = -\ln a + bt$$

Transformed variable Y is then a linear function of time *t*, where the constant term is $\ln a$ and the slope is *b*. The coefficients *a* and *b* can be obtained using linear regression analysis (the least-squares method) as follows:

$$b = \frac{N\sum XY - (\sum X)(\sum Y)}{N\sum X^2 - (\sum X)^2}$$

$$a = \frac{\sum Y}{N} - b\frac{\sum X}{N}$$

where *X* is observed value

Y is observed value

N is total number of values

APPENDIX 2

Source: Laininen Pertti, 1980, Todennäköisyyslasku ja tilastomatematiikka (p. 223)

Confidence interval of the regression curve

$$ci = \hat{y}_x \pm t_{\alpha/2} s \sqrt{\left(1 + \frac{1}{n} + \frac{(x - \overline{x})^2}{\sum_{i=1}^{n} (x_i - \overline{x})^2} \right)}$$

$$s^2 = \frac{1}{n-2} \left\{ \sum_{i=1}^{n} (y_i - \overline{y})^2 - b \sum_{i=1}^{n} (x_i - \overline{x})(y_i - \overline{y}) \right\}$$

ci = Confidence interval

$\hat{y}$ = Estimated value of the regression curve (forecast)

$\overline{x}$ = The mean of the known x values

n = Number of known values

s = Sampling distribution = $\sqrt{s^2}$, where s^2 = variance

$t_{\alpha/2}$ = t-value of slope, depends on the degree of the freedom (available in tables)

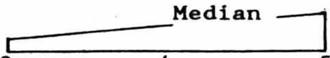
APPENDIX 3

Source: Porter et al., 1991, Forecasting and management of technology (p. 217)

DELPHI RESPONCES

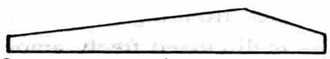
Round 2:

Lower Quartile Median Upper Quartile



```
     1          2          3          4          5
     I----------I----------I----------I----------I
Not very                                      Crucially
Important                                     Important
```

Round 3:



```
     1          2          3          4          5
     I----------I----------I----------I----------I
Not very                                      Crucially
Important                                     Important
```

More Important: - The variety of operating systems now available that have a common user interface would greatly enhance ease of use and willingness to use the system for different applications.

Less Important: - All command structures are somewhat arbitrary. Uniformity and intuitiveness would be nice, but not as important as other factors.

Round 4:

```
     1          2          3          4          5
     I----------I----------I----------I----------I
Not very                                      Crucially
Important                                     Important
```

More Important: - The variety of operating systems now available that have a common user interface would greatly enhance ease of use and willingness to use the system for different applications.

- Intuitiveness of commands would result in greater acceptance and less fear.

Less Important: - All command structures are somewhat arbitrary.

Uniformity and intuitiveness would be nice, but not as important as other factors.

Figure 11.2 Delphi responses by round regarding uniformity and intuitiveness of command structure.

APPENDIX 4/1

Source: Fowles, 1978, Handbook of futures research (pp. 276-279)

Long-range forecasting study

Delphi Questionnaire 1

Scientific Breakthroughs

One of the major problems of conducting a predictive study, which poses its questions on the basis of extrapolations of current technology is the almost unavoidable exclusion of discontinuous state-of-the-art advances.

In this current study of period of 50 years is being considered. It is possible that inventions and discoveries not yet visualized could have a major impact on our society during this interval. It is easy to observe that the pace of scientific and technological innovation has been steadily increasing and that the time between origination and application has been decreasing. Therefore we believe that many generations of inventions can find application during the period under study.

Some insight even into discontinuous state-of-the-art advances might perhaps being gained by examining the world's need for such advances, in view of the old truism that necessity is the mother of the invention. Therefore, you are asked to list bellow major inventions and scientific breakthroughs in areas of special concern to you which you regard as both urgently needed and feasible within the next 50 years.

Do you know of the existence of any information, in the form of tabulations or analyses that might be particularly valuable in reaching projection of the kind requested?

APPENDIX 4/2

Delphi Questionnaire 2

Scientific breakthroughs

Listed bellow in the table 1.2a is most of the scientific breakthroughs suggested by the respondents as potentially possible during the nest 50 years. Please indicate your judgment of the probability of implementation during each period. Note that the numbers inserted by you in each row should ad up to 100. (In the case of items involving gradual development such as synthetic food production or automated education, “implementation” should be interpreted as referring to the time from which the effect on our society will no longer be negligible.)

Consider the breakthroughs suggested in table 1.2a are there other potential breakthroughs, which you would care to add? When do you believe they will occur? Please make your additions in table 1.2b.

APPENDIX 4/3

Table 1.2a **Sociological**	1968-72	72-78	78-86	86-97	97-2013	Later	ot at any ime
1. Communication with animals							
2. Breeding of intelligent animals for low grade labor							
3. Education by automation							
4. Education by other means, such as direct information-recording on the brain							
5. Education or condition on social behavior to reduce the likelihood of war							
6. Automatic language translator							
7. Efficient idea-coding to convey precise information independent of language							
8. Popular use of personality control drugs							
9. Long-duration coma to permit a form of time-travel							
10. Solution to the problem of distribution of goods—computer identification of points of need							
11. Computing machines becoming the most significant source of intelligent on earth							
12. Discovery of life on mars							
13. Communication with extraterrestrials							
Physical							
1. Reformation of physical theory, eliminating confusion in quantum-relativity and simplifying particle theory							
2. Experiment with anti-mater							
3. Control gravity							
4. Reliable weather forecasts							
...							
Food and raw materials							

1. Rise in world agricultural gross yields by a factor of ten							
2. Economical useful desalination of sea water							
3. Economical working of low-grade metal ores							
4. Exploitation of ocean bottom through farming and mining							
Biological							
1. Chemical control over heredity-molecular biology							
2. Biological general immunization							
3. Synthetic generation of protein for wood							
4. New organs through transplanting or prosthesis							
...							

Table 1. RAND Delphi Questionnaires, Rounds 1 and 2.

APPENDIX 4/4

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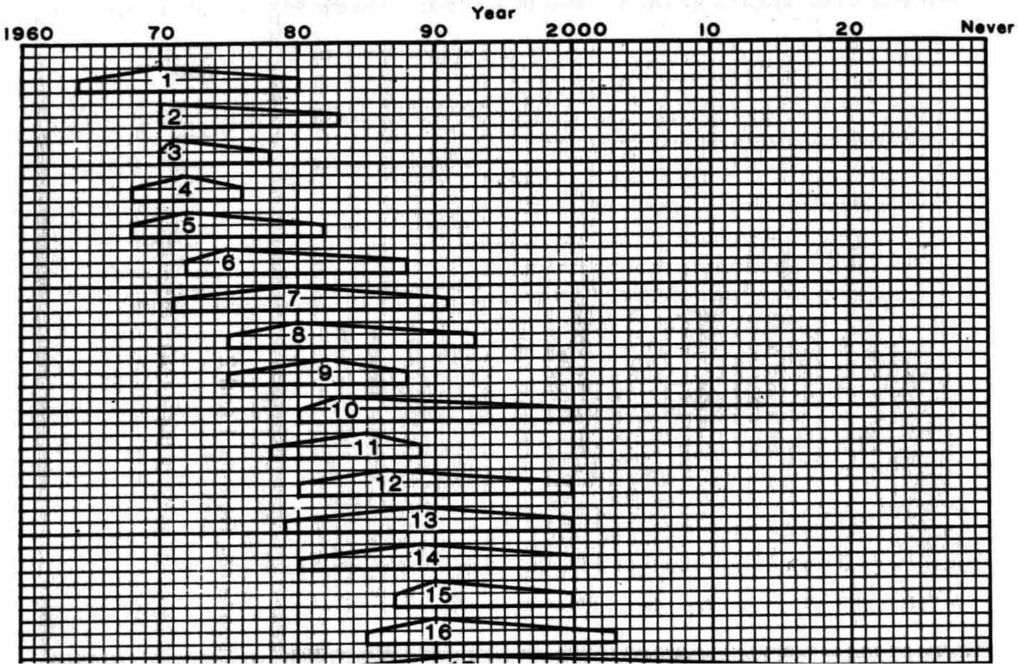

1. Economical useful desalination of seawater
2. Effective fertility by oral contraceptive or other simple and inexpensive means
3. Development of new synthetic materials for ultra-light construction
4. Automatic language translators
5. New organs through transplanting or prosthesis
6. Reliable weather forecasts
7. Operation of a central data storage facility with wide access for general or specialized information retrieval
8. Reformation of physical theory, eliminating confusion in quantum-relativity and simplifying particle theory
9. Implanted artificial organs made of plastics and electronic components
10. Widespread and social widely accept use of nonnarcotic drugs
11. Stimulated emission in X and gamma ray region of the spectrum
12. Controlled thermo nuclear power
13. Creation of a primitive form of artificial life
14. Economically useful exploitation of the ocean bottom through mining
15. Feasibility of limited weather control
16. Economic feasibility of commercial generation of synthetic protein for food

Figure 1. Consensus of panel 1 on scientific Breakthroughs (medians and quartiles) (Rand Corporation)