LAPPEENRANTA UNIVERSITY OF TECHNOLOGY
Department of Industrial Engineering and Management

USE OF SCENARIO ANALYSIS IN STUDYING EMERGING TECHNOLOGY - CASE GRID COMPUTING

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ABSTRACT

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The objective of this thesis was to explore how the scenario analysis can be used for studying emerging technology. The main issues defining the applicability of using scenario analysis in the case of emerging technology were the level of technological change and the nature of information available. In studying emerging technologies, scenarios outplay many other futures research tools. The main reason to this is the great amount of uncertainty, complexity and paradigm shift inherently relating to emerging technologies.

In the empirical part of the thesis scenario analysis was used to study the future of Grid computing. Grid computing was seen potentially disruptive technology. As a radical innovation it can change the traditional product-based computing to service-based. This would have major impact on the industry especially because of the emergence of utility computing. The timeframe of the study was the next seven years.

From the basis of theoretical part and current knowledge four different scenarios for Grid computing were created. Scenario analysis is based on expert information. The themes of the scenarios were: "Brave New World", "Commercial Dodo (New welfare society)", "Dead Duck", and "Trust Me!". In these scenarios the commercial success of Grid computing was clearly questioned. Trust and value creation were identified as the most important factors influencing the development of Grid computing.

TIIVISTELMÄ

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Tutkimuksen selvitettiin miten skenaarioanalyysia voidaan käyttää uuden teknologian tutkimisessa. Työssä havaittiin, että skenaarioanalyysin soveltuvuuteen vaikuttaa eniten teknologisen muutoksen taso ja saatavilla olevan tiedon luonne. Skenaariomenetelmä soveltuu hyvin uusien teknologioiden tutkimukseen erityisesti radikaalien innovaatioiden kohdalla. Syynä tähän on niihin liittyvä suuri epävarmuus, kompleksisuus ja vallitsevan paradigman muuttuminen, joiden takia useat muut tulevaisuuden tutkimuksen menetelmät eivät ole tilanteessa käyttökelpoisia.

Työn empiirisessä osiossa tutkittiin hilaverkkoteknologian tulevaisuutta skenaarioanalyysin avulla. Hilaverkot nähtiin mahdollisena disruptiivisena teknologiana, joka radikaalina innovaationa saattaa muuttaa tietokonelaskennan nykyisestä tuotepohjaisesta laskentakapasiteetin ostamisesta palvelupohjaiseksi. Tällä olisi suuri vaikutus koko nykyiseen ICT-toimialaan erityisesti tarvelaskennan hyödyntämisen ansiosta. Tutkimus tarkasteli kehitystä vuoteen 2010 asti.

Teorian ja olemassa olevan tiedon perusteella muodostettiin vahvaan asiantuntijatietouteen nojautuen neljä mahdollista ympäristöskenaariota hilaverkoille. Skenaarioista huomattiin, että teknologian kaupallinen menestys on vielä monen haasteen takana. Erityisesti luottamus ja lisäarvon synnyttäminen nousivat tärkeimmiksi hilaverkkojen tulevaisuutta ohjaaviksi tekijöiksi.

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When I started working this thesis in Telecom Business Research Center over a year ago, I never guessed it would take such a long time to finish it. Now looking the printed thesis one cannot see the confronted challenges and problems during the process. There are only two black covers with text, figures and tables between them. Because of that illusion, people who helped me to overcome all the different obstacles deserve to be commended.

I would like to thank my instructor Liisa-Maija Sainio for spurring and advising me during the whole process as well as Professor Tuomo Kässi for his encouragement and guidance when it was needed. I also want to express my gratitude to all the participants of scenario session in Geneva for their special contribution.

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The views expressed in this paper, and all the potentially remaining errors are of sole responsibility of the author.

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1 INTRODUCTION

Today's economy is distinguished from past economies because of its global characteristics and because of the rapid changes taking place in technology. The importance of technological futures research in today's fast changing global environments is perhaps greater than even before. Technological development is challenging because the world has become more complex and at the same time it presents ever-larger elements of ignorance or unfamiliarity. This means that technological uncertainty relates more deeply in every emerging technology and the technological forecasting has become almost impossible in many cases. This is reality especially in the information and communication (ICT) -industry, where a great deal of uncertainty and risk surrounds every new promising technology. Corporate planning as well as major investments and other resource allocation must be done in companies and their R&D departments often without any clear market data or evidence of the possible commercial success (this development is analogous e.g. with the emergence of Internet or 3G mobile phone markets in Europe). Thus, new tools are required to reveal the possible futures.

Futures research and its methods have been developed to answer these mentioned challenges and to help organizations to survive in this world. As Porter et al. (1991, pp. 62-69) have written, the unique challenge of technological futures research is "to anticipate the consequences or capabilities of inventions not yet fully conceived or imagined". Given the uncertainty inherent in the future, expectations placed upon these visions should be realistic. This means that futures research should indicate ranges of future possibilities, not point values.

The fundamental interest of futures research is instrumental. It does not try to find the absolute truth of the future, but to have an influence on decisions made today. In this context, futures research may have either direct effect as a tool in decision making or planning or it can have indirect effect and work as catalyst for general discussion (Mannermaa 1999, pp. 21-22). Hence, futures research is helping companies by enhancing their decision making and ability to see possible changes in their operating environment in the future.

The futures research method studied and used in this thesis is called scenario analysis. Scenarios are focused descriptions of fundamentally different futures presented in coherent script-like or narrative fashion (e.g. Heijden et al. 2002; Schoemaker 1995; Schwartz 1996). Their purpose is to illustrate possible pictures of the emerging future based on the analysis of the key factors and driving forces surrounding the examined issue. With scenario approach the companies can take the advantage to see possible discontinuities ahead and to understand better their operating environment. This should lead to better decisions, to enhanced conversation in the organization and eventually to better results.

Already for decades the scenario approach has been used in variety of cases in many different contexts. Used examples differ from the Finnish forest industry strategies (Meristö et al. 2000) to vocational education strategy of Australia (Johnson et al. 2000) or even to scenarios made by the national intelligence agencies (National Intelligence Council 2004). In this thesis the scenario analysis is used to study new potentially disruptive information technology called *Grid computing*. The written scenarios were made as a part of Helsinki Institute of Physics´ (HIP) NetGest[1]-project, which was funded by National Technology Agency of Finland.

The development and implementation of Grid computing started in research communities years ago, but until now the true commercial potential has been hidden. Grid computing refers to linking the computers together and making them work as one supercomputer. This opens new world full of opportunities and possibilities both in research and business. In research Grid computing is already proved to be a new valuable tool, but commercially the development is still in its early stages. Scenario analysis was used to develop different paths to possible futures.

[1] Network Identity, Grid Enabled Services and Trust Networks

1.1 Objectives

The main objective of this thesis is to study *the applicability of scenario analysis method in studying emerging technology*. Scenario analysis is one of the most important methods in the field of futures research. This thesis uses Grid computing as a case example in concentrating to scenario analysis method and its applicability in studying emerging technologies. Because the novelty and uncertainty relating to Grid computing, it is first more important to understand the basis of this development and to clarify the relevant issues and operational environment of Grid computing than e.g. trying to estimate the specific size of the Grid computing market. The main research question and its sub-questions as well as objectives of this thesis are formulated in the Table 1.

Table 1. The research problem.

Research question	
How can scenario analysis be used to study emerging technology?	
Sub-questions	**Objectives**
What are the characteristics of emerging technology in a context of technological uncertainty and innovation?	To analyze the basics and logics of technological change and innovation.
What is scenario analysis and how it, as a futures research tool, suits for studying emerging technology?	To analyze scenario analysis and its applicability in studying emerging technologies.
What internal and external factors and forces have influence on the development of Grid computing and how will these factors or forces shape the future Grid computing market?	To identify and analyze the key uncertainties and major driving forces of Grid computing
What kind of environmental scenarios can be built for the Grid computing on the basis of the current knowledge?	To construct environmental scenarios based on the expert information and their tacit knowledge.

The underlying concept in this thesis is technological change. It relates closely to different ICT-technologies and industries by explaining their dynamic nature, in this case Grid computing. Futures research is developed to study these dynamics and emerging changes. Among the number of different futures research methods, this thesis concentrates on the scenario analysis. Thesis studies these mentioned relevant issues, focusing on the intersection of scenario analysis and Grid computing. Figure 1 presents the framework of the study and the relationship of futures research and Grid computing. Its purpose is to outline the research questions.

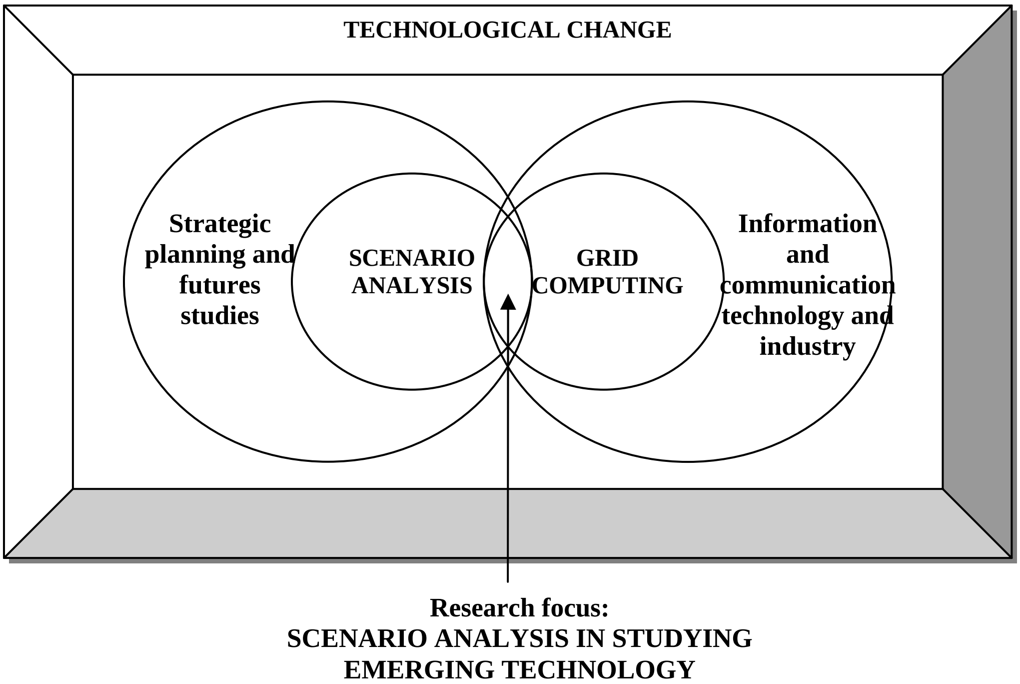


Figure 1. The framework of the study.

1.2 Limitations of the study

From the number of futures research tools and methods, this thesis concentrates on scenario analysis and other methods are only slightly discussed. From the different possible scenario methods especially computer aided and strictly formal methods were not taken into account. Morphological and combinatorial approaches are also only shortly described as the thesis focuses on intuitive logic approach. From the perspective of technological change this thesis concentrates on emerging technologies.

The empirical part of the thesis focuses on Grid computing among the ICT industry and its technologies. The empirical objective of the study is to create logical scenarios and learn more about its commercial potential. The timeframe of the scenarios was kept relatively short in six years. This is justified because the ICT industry is changing rapidly and the application speed of new technologies is high. A too long timeframe could easily lead to a situation where the results of the study would be inapplicable and useless (Mannermaa 1999, p. 20). In this period of time the driving forces and key factors are still easy enough to deal with in order to create a rational chain of events (for the sake of comparison, oil company Royal Dutch/Shell[2] (2001, p. 1) has 50 years long and United Nations (Glenn & Gordon 2000, pp. 78-79) even 1000 years long scenarios about their operational environment!).

The created scenarios are environmental, which means that they are not written from any certain actor's perspective. Instead, they are trying to capture the most relevant issues from the Grid computing environment from a general point of view. Thus, this study gives an overall view on the Grid computing development but does not discuss how certain organizations should use and benefit from the results and implications.

1.3 Used methodology

The thesis consists of theoretical and empirical part. First, the literature study builds ground for the empirical studies. The theoretical part of this study is constructed relying on information gathered mostly from the current literature. The purpose is to clarify the issues relating to studying emerging technology with the scenario analysis.

The main empirical contribution provides insight in using scenario analysis in studying emerging technology. In this thesis Grid computing is used as a case example. The empirical part of this thesis leans strongly on information and knowledge of ICT industry and Grid computing experts. From the methodological point of view the case section of this study relates to intuitive scenario approach (see e.g. Masini & Vasquez 2000, pp. 50-56 or chapter 3.2.1). In addition some formal structure is included in the process. Most of the data was qualitative but some quantitative secondary data was also used as input during the process. The study is explorative, which means that the perspective is from the present to the future.

[2] Later referred as Shell.

The empirical part started with analyzing the operational environment of Grid computing. This was done mainly based on current knowledge (information was gathered from the literature, articles and expert questioning). The scenarios themselves were created during an interactive group session with ICT and Grid computing experts, because it was assumed that in the case of Grid computing where we have to deal with high uncertainty, experts should have the best possible knowledge and visions. Because of that, the study is not easily repeatable and the perspective is rather subjective reflecting strongly experts' thinking about the future.

1.4 Structure of the study

This thesis comprises of seven sections. Section 1 introduces the thesis and its objectives as well as limitations. Section 2 concentrates on technological change and its uncertainties. The same section also covers characteristics of different types of innovation and their linkages to futures research. Section 3 presents the theoretical framework of scenario analysis. Section 4 defines Grid computing and the motivations behind it and introduces the readers to the basics of Grid computing, such as the resources and the architecture. The section also discusses the emergence of utility computing and its impact on current IT provision models. Section 5 presents the applied part of this study and handles the issues related to four constructed scenarios about the Grid computing and their implications. Section 6 outline the conclusions obtained in this study and discuss the limitations of the study and proposals for the further research. Finally, the summary of the thesis is presented in Section 7. Figure 2 shows the outline of the thesis.

INPUT		OUTPUT
Overview Motives	Section 1 Introduction	Research problem Objectives Limitations
Theory of technological change	Section 2 Technological change	Description of emerging innovations
Definition and theory of scenario analysis	Section 3 Scenario analysis	Basis for the case study
Definition and characteristics of Grid computing	Section 4 Grid computing	Understanding of Grid computing and its market
Knowledge of Grid computing experts Interviews	Section 5 Grid computing scenarios	Alternative futures for Grid computing
Scenarios and value networks	Section 6 Conclusions	Analysis of the key findings
The whole of the study	Section 7 Summary	Major findings summarized

Figure 2. Outline of the thesis.

2 TECHNOLOGICAL CHANGE

Today organizations operate in very challenging world. The changes in their operational environment are faster and more radical than ever before, thus having a major impact on organizations' capabilities to survive. The importance of innovation and knowledge management is emphasized especially in high technology industries such as the ICT-industry (see e.g. Day & Schoemaker 2000; Burgelman et al. 2001; Tidd et al. 2001).

The direct consequence of this development is that the investments needed to keep up in the leading edge of the competition are more substantial and uncertain than before. Hence, this is a major challenge from the resource allocation point of view as well. Managers have to know which technologies are going to make the difference and which kind of business models are needed to create true value for the users. Technologies by themselves have no inherent value. Value only arises when they are commercialized through viable business models, as Chesbrough (2003, p. 7) states.

2.1 Innovation typology

Garcia and Calantone (2002, p. 112) define innovation as "an iterative process initiated by the perception of a new market and/or new service opportunity for a technology-based invention which leads to development, production, and marketing tasks striving for the commercial success of the invention". According to Tidd et al. (2001, p. 6) above all innovation means change. Technological changes are either *product/service innovations*, *process* innovations or something between these two, because the dividing line is not clear. The second dimension of innovation is its *perceived degree of novelty*. This means that every innovation has its own "amount of change" depending on who perceives it. The degree can vary from *incremental* (minor improvements in things) to *radical* (transform the way we use and see these things) and even to the degree of *transformation* (so radical and far-reaching changes that they can change the basis of society – e.g. information and communication technologies today) (Tidd et al. 2001, pp. 6-7). The two main dimensions of innovation space are presented in Figure 3.

Garcia and Calantone (2002, pp. 120-124) have classified innovations from the micro versus macro and marketing versus technology perspectives. They argue that if the technology is radical, it should cause marketing and technological discontinuities on both a macro and microlevel. Incremental innovations instead occur only at a microlevel and cause either marketing or technological discontinuity but not both. Some of these innovations include also technology fusion. It means convergence of different technological streams, such that products which used to have a discrete identity begin to merge into new architectures (Tidd et al. 2001, pp. 12-13).

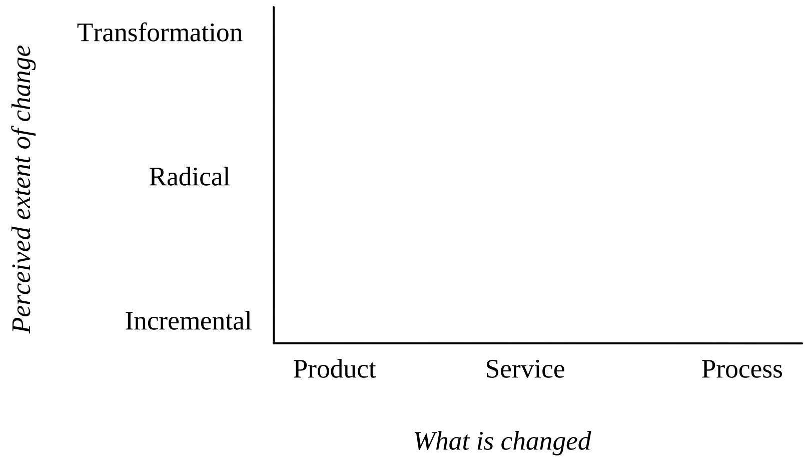


Figure 3. Dimensions of innovation space. (Tidd et al. 2001, p. 7)

According to Schoemaker and Day (2000 p. 2) technologies where (1) the knowledge base is expanding, (2) the application to existing markets is undergoing innovation, or (3) new markets are being tapped or created are *emerging technologies*.

2.2 Innovation cycles

As Anderson and Tushman (1991, pp. 1-2) state, an industry evolves through a succession of technology cycles. A cycle starts with a *technological discontinuity.* Discontinuities are breakthrough innovations that advance by an order of magnitude the technological state-of-the-art, which characterizes an industry. The basis for these discontinuities lies on new technologies whose technical limits are inherently greater than those of the previous dominant technology, along economically relevant dimensions of merit (i.e. emerging technologies).

The breakthrough initiates an *era of ferment*, characterized by two processes. First, the new technology displaces its predecessor during an *era of substitution*. The second partly overlaps the first. An era of design competition follows a discontinuity. Radical innovations are usually crude, and are replaced by more refined versions of the initial product or process (Anderson & Tushman 1991, p. 2).

The design competition culminates in the appearance of *dominant design*[3]. The design is a single basic architecture that becomes the accepted market standard. Dominant designs are not necessarily better than competing designs, and they often pioneer no innovative features themselves. Rather, they represent a *combination* of features, often pioneered elsewhere, that sets a benchmark to which all subsequent designs are compared. The emergence of a dominant design marks the end of the era of ferment and the beginning of a period of incremental change (Anderson & Tushman 1991, pp. 2-3).

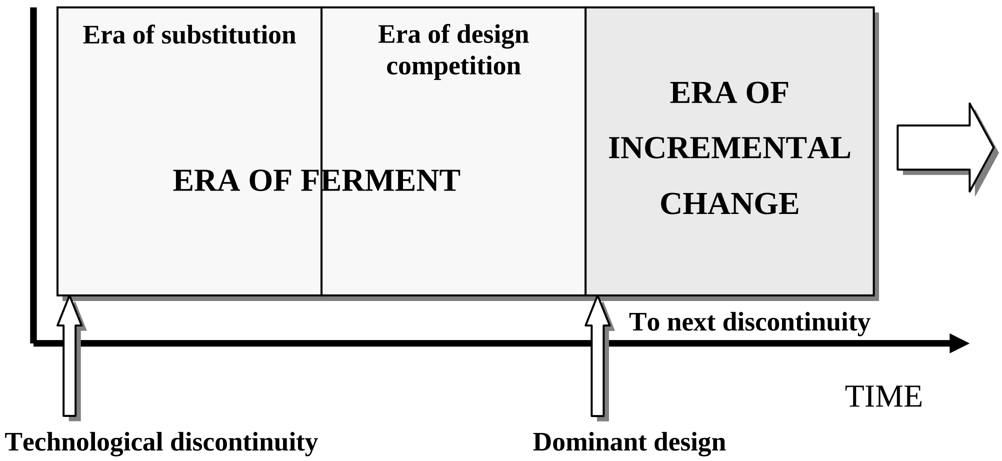


Figure 4. Technology cycles and technological discontinuities (Anderson & Tushman 1991, p. 3).

2.3 Influence of competences

The nature of the technology cycle is dramatically affected by the cutting dimension of *competence*. Some discontinuous innovations are *competence-destroying* or *disruptive.* They obsolesce existing know-how, which means that the mastery of the old technology does not imply mastery of the new. Firms must move to a new learning curve, which is

[3] The term “Dominant design” was introduced by Abernathy and Utterback in 1975.

essentially unaffected by the firm's existing know-how, and technical professionals require new training. Other discontinuous innovations are *competence enhancing*. These breakthroughs push forward the state-of-the-art by an order of magnitude, but build on existing know-how instead of obsolescing it (Anderson & Tushman 1991, pp. 3-4).

Tidd et al. (2001, pp. 14-15) refer to Christensen's ideas in the influential book called The Innovator's Dilemma (1997) when they argue that the larger companies have been noted to perform well in the case of competence enhancing innovation, but with the competence destroying innovations smaller companies are more successful. The reason behind this phenomenon is what Christensen calls as the "Innovator's dilemma". The term refers to the dual nature of the innovation management. First of all companies should improve their existing innovation management systems in the direction of "doing what they do better". This often means structuring these processes more towards the "steady state" of change, improving only incrementally. On the other hand organizations should be able to take advantage over discontinuities when radical or disruptive innovations take place as well. And because the resources are scarce and innovations need large investments, wrong decisions can be devastating for the organizations.

Both product and process innovations may either enhance or destroy existing competences. Yet there is a fundamental difference between product and process innovations. Product innovations normally affect more links in the value chain than do process innovations. Process innovations usually make the product better and cheaper without necessarily disrupting upstream and downstream linkages. Thus, a key factor is not only whether the core technical know-how of an industry is disrupted by an innovation, but whether links in the value chain are overturned or reinforced by the new technology (Anderson & Tushman 1991, pp. 3-4).

2.4 Effects of emerging technologies on strategies

The art of strategy making in disruptive environment is always a dynamic process. The accelerating pace of emerging technologies is shrinking the timeframe in which every strategy remains viable (Szulanski & Amin 2000, p. 189). As the technology emerges, organizations closely relating to its development have to notice it.

According to Schoemaker and Day (2000, pp. 26-37) the organizations (especially established organizations) have to face four pitfalls of emerging technologies. The first trap is delayed participation to the development of new technology, second is sticking with the familiar while the development is already going, third reluctance to fully commit on the development of technology and the fourth is the lack of persistence needed to achieve leadership. From the strategic point of view these pitfalls of the emerging technology can be summarized to three questions for the manager of an organization, respectively:

- Whether to allocate resources to the development of the new technology or not?
- How can the organization use that investment effectively to develop or acquire a new technological capability?
- How that technology is commercialized? (Tripsas 2000, p. 184)

These questions have to be answered in the organization's strategy. Although no amount of planning can guarantee the success of a strategy, the changes can certainly be improved through the use of *discipline imagination.* It means that different imagined strategies and options have to be first created and then tested and evaluated with a set of certain rules (Szulanski & Amin 2000, p. 191).

Lynn and Akgün (1998, pp. 11-16) have studied the applicable innovation strategies in different situations according the type of innovation. According to them technological uncertainty refers to the extent to which product form, performance and costs are understood. They use uncertainty matrix[4] as a basis for their research and state that in the extreme forms of innovation (i.e. radical innovation or emerging technologies) a learning-based strategy is the best approach. They argue that in order to be successful companies have to be continuously innovative and create knowledge, disseminate it

[4] See the definition of uncertainty matrix by Ansoff (1987, pp. 108-110).

throughout the organization and embody it in new technology and products. These different applicable strategies are presented in Table 2.

Table 2. Applicable strategies with different types of innovation (Lynn & Akgün 1998, p. 15)

Evolutionary market innovation Applicable strategy: - *Learning-based* - *Market-based*	**Radical innovation** Applicable strategy: - *Learning-based*
Incremental innovation Applicable strategy: - *Process-based* - *Quantitative-based*	**Evolutionary technology innovation** Applicable strategy: - *Learning-based* - *Speed-based* - *Technology-based*

3 SCENARIO ANALYSIS

“Studying futures is not really a question of knowledge and facts at all, but rather one of conjectures” (Ratcliffe 2000, p. 1). Thus, a special approach towards projecting potential futures, so as to improve present decisions, is required. Scenario analysis is such a technique and it has become one of the most important futures research tools. This section describes the basics of the scenario analysis as a futures research tool and its main features. The scenario principles, types and methodologies are presented as well as its usage targets from the point of view of new technologies.

3.1 Futures research in a complex and uncertain environment

Heijden argues (2000, pp. 31-36) that the reason why we find it useful to discuss and study future is that we consider at least something in the future predictable. During the last decades the world and different social systems have become more complex than ever before and this has meant changes to the fundamentals of futures research as well. Before there was a common view that the future could be seen as a linear and regular, but during the last decades it has been obvious that this view or assumption is far too simple. Different actors and events are too complicated to fully understand them and planning for uncertainty increasingly poses the question, "What has already happened that will create the future?" instead of asking, "What is most likely to happen?"

This means e.g. that these organizations have to make constantly right choices with even faster pace. Further this means that instead of seeing uncertainty as a problem, it should be seen as the basic source of future success. By seeing the future more clearly with the help of futures research, companies can achieve and sustain competitive advantage and because of that, outplay their rivals (Heijden et al. 2002, pp. 13-39).

Futures research have changed from pure prediction into the direction of becoming aware of the facts and values and taking them into account when comparing different development paths of the future. The main thing is not to see the future as one possible deterministic future, but to see it as a group of futures which form a variety of alternatives, which can be studied with different tools and methods (Mannermaa 1999, pp. 18-19).

Traditional planning, especially forecasting based on probabilities, has become purposeless because of the great deal of uncertainty. However good the research methods may become, one shall never be able to escape from the ultimate dilemma that all knowledge is about the past, whilst all the decisions are about the future. And of course, the futures research tools do not come with a guarantee. The natural talent, common sense, and intuition of the futurist also count, as Godet reminds (2000, p. 1).

As mentioned earlier the fundamental interest of futures research is instrumental. It tries to have an impact on general conversation and decision making. In doing this futures research have certain basic assumptions which can be found in all futures research projects with different emphasis. According to Mannermaa (1999, pp. 22-23) these are:

1. The objects under examination (economical, technological, social or human) are too complex to be thought as only one possible way. This is the starting point of futures research: there are several different alternative futures which all can realize.
2. A human being has the ability to think rationally and vision the future with different periods of time. So it is possible to think sensibly different chains of events with different assumptions. Thus, the future is not only unforeseeable chaos.
3. People have a clear effect on the future, i.e. they are ‘actors’ (Kuusi 2003). This means that future can be changed as one lives it and for example prevent unwanted chain of events or taking advantage of emerging opportunities.
4. Most of the futures researchers have a common ethical principle that people have not only the option but the responsibility to judge and anticipate the future and to influence into its development. That is why different calculations and estimations are made in order to avoid the worst scenarios.
5. The object of futures research, people and their systems (technology, economy, society) should be always seen as a system and interactive entity.

3.1.1 Different futures research tools

As there are many different possible paths to the future, there are many futures research techniques as well. Mannermaa (1999, pp. 36-37) has classified the different futures research methods according to following three dimensions:

1. The nature of the empirical data (is the data quantitative or qualitative?)
2. The futures' forecasting or evaluation process (is the process mathematical and repeatable or is it subjective and non-repeatable?)
3. Point of view to the future and meaning of the study (is the study explorative, from the present to the future, or normative, from the future to the present?)

Traditional econometric forecasting is based on the quantitative data, is repeatable and explorative. Scenario analysis, the method used in this thesis, in the other hand uses qualitative or quantitative data, it cannot be easily repeated and the perspective is usually from the present to the future. Among the dozens of futures research methodologies are field investigations, historical surveys, pattern discovery, public hearings, surveys, expert panels, the Delphi technique, brainstorming, check lists, morphological analysis, cross-impact analysis, trend analysis and extrapolation, projections, regressions, growth curves, correlation methods, systems analysis, modelling, technology assessment, cost-benefit analysis, risk analysis, decision trees and relevance trees (e.g. Martino 1993, pp. 15-242; Coyle 2004, pp. 47-85). Many of these allegedly new techniques are actually refined and elaborated versions of classic techniques. Mannermaa (1999, pp. 37-42) gathers all of the futures research techniques and tools into three groups:

- *trend analysis* represent the traditional forecasting and are based on current information and knowledge
- *expert evaluations* includes cross-impact analysis and Delphi-techniques and are used widely in the futures research
- *multi-alternative analysis* like scenarios are popular methods as well

In the Table 3 below the scenario technique is compared to other common strategic thinking enhancing techniques. According to Schoemaker (1993, p. 3) scenarios can be used as a systematic thinking tool especially in the cases with broad problem scope and bounding uncertainty. They can identify strategic issues as well as be used as a tool in internal communication in organizations.

Table 3. Techniques to enhance strategic thinking (Schoemaker 1993, p. 3).

	Systematic thinking tool?	Internal communication device?	Identifier of strategic issues?	Problem scope?	Uncertainty bounding?
Lateral thinking and brainstorming	No	No	Somewhat	Broad	No
Synectics and morphological analysis	Medium	Perhaps	Perhaps	Limited	No
Delphi method	High	Yes	No	Narrow	Yes
Dialectic reasoning	Perhaps	Perhaps	Yes	Broad	Perhaps
Scenario analysis	Medium	Yes	Yes	Broad	Yes
Requisite decision modelling	High	Yes	Perhaps	Narrow	Perhaps
Dynamic systems analysis	High	Yes	Perhaps	Medium	Perhaps

3.1.2 Choosing the right futures research tool for the right situation

As this thesis concentrates on technological change from the futures research point of view, the criteria for choosing the right tool are to be discussed. Many technological futures research methods have been reported in literature, and they have been applied widely. Levary and Han (1995, p. 14) argue that because the results of futures research are typically influenced by the used method, it is important to determine the futures research method that will be most appropriate to a given situation. The main factors affecting technological futures research and the choice of a futures research method can be found in the Table 4.

Table 4. Main factors affecting the choice of technological futures research method (Levary & Han 1995, p. 14).

Factor	Reason
Money available for development of technology	The more resources are allocated by the organizations (i.e. the more money they spend) on the development of a given technology, the higher the likelihood of realizing the technology.
Data availability	As different technological futures research methods require varying amounts of data, the extent of available data will affect the choice of method.
Data validity	As all technological futures research methods are not equally dependent on the same degree of data validity, the degree of data validity affects the choice of method.
Uncertainty surrounding the success of technological development	Varying degrees of uncertainty surrounds the success of every technological development. Some technological futures research methods are better suited to high uncertainty than others. As a consequence, the degree of uncertainty surrounding the eventual success of the technological development will affect the choice of method.
Similarity of proposed and existing technologies	The greater the similarity between a proposed technology and existing technologies, the higher the likelihood of realizing the proposed technology. And further, the greater the similarity, the shorter the expected development time
Number of variables affecting the development of technology	As technological futures research methods is equipped to handle different numbers of variables, the number of variables affecting the technology development affects the choice of method

It is also important to realize that the extent of data availability, the degree of data validity, and the degree of uncertainty surrounding the success of technology development are all dependent upon the stage of technology development. The later the stage of technology development, the more information available regarding the extent of data availability, the degree of data validity and the degree of uncertainty surrounding the success of technology development. Depending upon the stage of technological development (i.e., early, middle, late), it is occasionally desirable to update the analysis (Levary & Han 1995, p. 14).

3.2 Introduction to scenario analysis

This section gives an overview on scenario analysis, its history and its place in the field of futures research.

3.2.1 The background and history of scenario analysis

Originally term “scenario” comes from theatrical vocabulary, where it means a script for a film or play (Schwartz 1996, p. 3). The use of scenario technique in futures research started in 1960s when Herman Kahn, while working in the DARPA[5] and RAND Corporation[6], introduced scenarios as an institutional or organizational device for clarifying thinking about the future. Back then Kahn used scenario thinking as a tool for managing the complexities of potential nuclear war (Coates 2000, p. 2). Kahn’s legendary phrase from the 60s: “scenarios help us to think the unthinkable”, has motivated the users of scenario technique ever since.

The real breakthrough of scenario thinking in enterprise use as a strategic planning tool happened in 1970s after Pierre Wack refined Kahn’s methods to corporate use in Shell and predicted correctly how the oil markets would operate (Kleiner 1999a, p. 77). And indeed, probably the most famous example of successful scenario planning in business is still Shell, which has consistently used scenarios in strategic planning process since the early 1970s for generating and evaluating its strategic options (Schoemaker & Heijden 1992, pp. 41-46). After that Shell has had many successes in forecasting the future: for example it was the first company to realize the overcapacity in the tanker business. In use at Shell since the late 1960s, scenario thinking is now widely accepted as a valuable decision support method (Schoemaker 1995, p. 26). American companies are in the leading front in the usage of scenario working and it is often a systematic part of their strategic planning and leading policies. In Finland the usage of scenario working is still quite random, although the interest is growing all the time (Mannermaa 1999, p. 35).

3.2.2 Definition of scenario

Today people use a term ‘scenario’ in many different occasions ranging from movie scripts and loose projections to statistical combinations of uncertainties. Although

[5] The Defense Advanced Research Projects Agency is the central research and development organization for the Department of Defense (DoD) in the USA.

[6] The RAND Corporation is a non-profit research organization providing analysis and solutions that address the challenges facing the public and private sectors around the world.

scenarios are very popular today, the definition of scenario is still multi-faceted. Longman's Dictionary of Contemporary English (1987, p. 932) defines a scenario as follows:

1. A written description of the action to take place in a film, play etc.
2. A description of a possible course of action or events

Here, the latter is simplified definition of scenarios used in the strategic planning. According to Coates (2000, p. 1) many people see scenarios as forecasts of some future condition while others disavow that their scenarios are forecasts. Kleiner (1999a, p. 76) argues that scenarios are not predictions or forecasts (although facilitators enjoy telling how one or another scenario got it right). Watts (2001, p. 1) also reminds that scenarios are not predictions. Rather they are a way of challenging our assumptions. They are a tool for focusing on critical uncertainties, the unexpected discontinuities or unknown possibilities which could transform the operational environment. Heijden et al. (2002, p. 63) define scenarios clearly that they are not forecasts of the future. Instead they are "pen-pictures of a range of plausible futures. Each individual scenario has a probability of actual occurrence but the range of a set of individual scenarios can be constructed in such a way as to bound the uncertainties that are seen to be inherent in the future, like the boundaries or edges of a multidimensional space." According to this view a set of multiple scenarios provides alternative frames on the nature of the future.

As mentioned with scenario thinking and writing the main goal is to explore the edges of "the future space" in order to prepare organizations to very different outlooks of the future which actually happen (Mannermaa 1999, p. 66). Scenarios are stories about the future embodying a wide variety of ideas and integrating them in a communicable and useful way. They help people in decision making, linking the uncertainties of the future to the decisions made today (Schwartz 1996, pp. 14-15).

Perhaps the most popular and often quoted definition in literature is made by Schwartz (1996, p. 4). He writes that scenarios are ‘‘tools for ordering one's perceptions about alternative future environments in which one's decisions might be played out''. Alternatively, scenarios are "a set of organized ways to dream effectively about our own future”. In general, Schwartz emphasises the narrative and creative nature of scenarios. Also Schoemaker (1993, p. 3) agrees on that and writes that scenarios are meant to be “focused descriptions of fundamentally different futures presented in coherent script-like or narrative fashion”. Porter et al. (1991, p. 68) also share the same view by defining that scenarios “blend insight with storytelling skill to provide a relatively complete picture that illustrates possible outcomes”.

In short, scenario planning attempts to capture the richness and range of possibilities, stimulating decision makers to consider changes they would otherwise ignore. At the same time, it organizes those possibilities into narratives that are easier to understand and use than great volumes of data. Above all, however, scenarios are aimed at challenging the prevailing mind-set (Schoemaker 1995, pp. 2-3).

Scenarios can be defined also by their common structure like many of the famous scenario experts have done. Godet (2000, p. 7) has defined a scenario as follows: “A scenario is the set formed by the description of a future situation and the course of events that enables one to progress from the original situation to the future situation”. Porter et al. (1991, p. 96) also share this same view, when defining scenarios as “sets of snapshots of some aspects of the future and/or sets of credible paths leading from present to future”. This same view is shared by Kuusi (2003) as well as Mannermaa (1999, p. 57) when he emphasizes that they all should share following three elements: a description of the present state of the company or operational environment, description of the future state and a description of the process which links these two together. In addition to the different definitions above, Heijden et al. (2002, p. 288) especially remind what the scenarios are *not*: stories about the strategy of the organization, predictions, extrapolations, good/bad futures or “science fiction”.

In the following Table 5 different definitions have been summarized according their emphasis. Scenario definitions are divided by four dimensions: *process* (how the scenario should be created), *nature* (are they forecasts or not), *style* (should scenarios be narrative) and *content* (what should they embody). The scenarios in this thesis rely strongly on the Schoemaker’s (1993) definition.

Table 5. The emphasis of different definitions of scenarios.

Emphasis / Author	Process	Nature	Style	Content
Godet (2000)	X			X
Heijden et al. (2002)	X	X		X
Kuusi (2003)	X	X		
Mannermaa (1999)	X		X	
Porter et al. (1991)			X	X
Schoemaker (1993)		X	X	X
Schwartz (1996)		X	X	
Watts (2001)		X		X

3.2.3 Using other futures research methods to support scenario analysis

Many different futures research tools can be used also in creating scenarios. The challenge to those engaged in conducting a scenario building exercise is to choose the right tool for the right job. Different techniques are required at different times for such varied tasks as creative thinking, information analysis, projection, optimisation or decision-making. Some of the most popularly used methodologies and techniques in scenario analysis can be listed as follows (Ratcliffe 2000, pp. 13-14):

- *The Delphi technique*[7] draws together the collective knowledge and insight of a group of experts. An interactive feedback effect, anonymity of participants and attainment of consensus are the main characteristics of the technique, which is widely used in various forms (Coyle 2004, p. 53).
- *Cross-impact matrix* involves systematically impacting a data set upon itself or another set in order to study and assess a field of interactions. It is a subjective method tracking the implications of scenario builders' decisions.
- *Teamwork techniques*. There exists a whole cluster of "creativity" techniques, which are mostly variants on the familiar brainstorming approach, widely used in scenario building.

[7] Named after the ancient Greek oracle.

- *Environmental scanning*. It consists of a systematic scanning of the environment for precursors, events, signals of many kinds (e.g. the driving forces of change) and interpreting their significance.
- *Systems thinking*. The fundamental principle of systems thinking is that the world should be viewed simultaneously from three levels: event, patterns of behaviour, and structure. This is brought to the practice of scenario building. It has been argued that profound and rapid learning can occur when scenario planning and systems thinking are employed together.
- *Network analysis*. Given the complexity and interdependency of scenario elements, the approach lends itself to the use of network analysis and associated techniques such as dependency, consistency and stability analyses, as well as the application of sensitivity analysis.
- *Simulation modelling*. A range of simulation models have been developed as tools for scenario building and analysis. These might not reveal the "truth" about the future, but used sensibly and selectively they can greatly facilitate and expedite the scenario process.

Increasingly the advances in information technology have been used to enhance the creativity of traditional scenario approaches. Especially different teamwork techniques and simulation models can be improved easily with the information technology (see e.g. Bergman et al. 2004).

Scenario planning differs from other planning methods. First of all, scenarios explore the joint impact of various uncertainties, which stand side by side as equals. Second, scenarios change several variables at a time, without keeping others constant and try to capture the new states that will develop after major shocks or deviations in key variables. Third, scenarios are not just output of a complex simulation model. Instead they attempt to identify patterns and clusters among the millions of possible outcomes a computer simulation might generate. They often include elements that were not or cannot be formally modelled, such as new regulations, value shifts, or innovations. Hence, scenarios go beyond objective analyses to include subjective interpretations (Schoemaker 1995, p. 2).

3.3 Characteristics of scenario analysis

In this section the most important and relevant issues characterizing scenario analysis (e.g. typology and benefits) are presented.

3.3.1 Typology of scenarios

There are many ways to classify different scenario types. Coyle (2004, pp. 58-77) introduces four different approaches to scenario development as a whole:

1. *Drivers of change* – one can identify significant aspects of a socioeconomic system and attribute to them the ability to shape the future.
2. *Intuitive logic* – the scenario is derived by consideration of the important uncertainties but without using a formal analytical process.
3. *Combinatorial approaches* – considers all possible combinations and retaining those with strong consistency.
4. *Morphological approaches* - eliminates anomalies and develops time-line scenarios from the remaining consistencies.

This study handles only the first two approaches, which are seen in the thesis as one. E.g. Heijden et al. (2002) and Schwartz (1996) have the similar view as they combine these two approaches. Combinatorial and morphological approaches are not studied more deeply.

Normally the classification of scenarios is based on the time perspective (explorative – normative) or on their "nature" (e.g. optimistic, pessimistic and probable). Coates (2000, pp. 2-3) presents a good example of the classification from the actor point of view. He divides scenarios as used in business, other organizations, and government planning into two broad categories. In the first one, scenarios tell about some future state or condition in which the institution is embedded. That scenario then is used to stimulate users to develop and clarify practical choices, policies, and alternative actions that may be taken to deal with the consequences of the scenario. The second form assumes that policy has been established. Policy and its consequences are integrated into a story about some future state. This second type of scenario, rather than stimulating the discussion of policy choices, displays the consequences of a particular choice or a set of choices. The first category of scenario largely stimulates thinking and the second is a tool for explaining or exploring the consequences of some policy decision.

Godet (2000, p. 9) identifies also these two major categories of scenarios in the same way, but more clearly based on the mentioned time perspective. This presented classification (see Figure 5) is probably the most common in scenario literature. According to him, scenarios are either:

1. *exploratory*: starting from past and present trends and leading to likely futures or
2. *anticipatory or normative*: built on the basis of alternative visions of the future they may be desired or, on the contrary, feared

As it can be seen, Godet comprises the above mentioned "nature of the scenarios" into this classification especially in the normative class. These exploratory or anticipatory scenarios can moreover, indicate a trend or be contrasted, depending on whether they take into account the most likely or extreme developments (Godet 2000, p. 9).

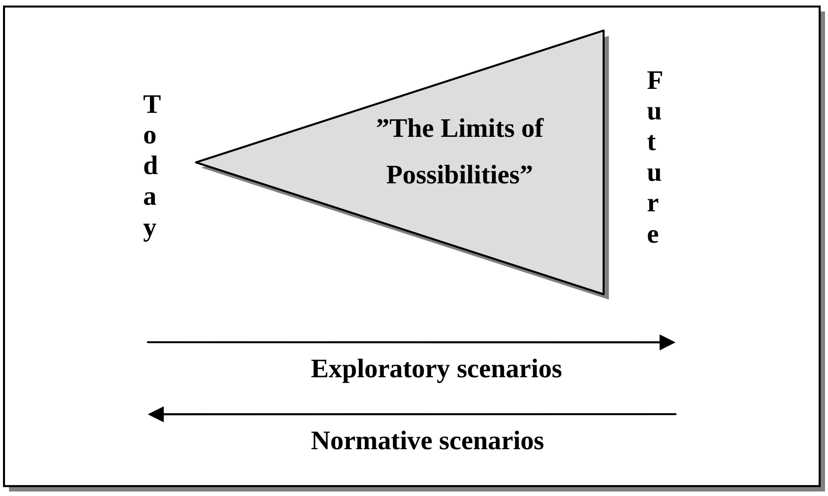


Figure 5. Two basic forms of scenarios.

Masina and Vasquez (2000, p. 55) have identified and made a broad classification of all different types of scenarios according to their characteristics. These types and their authors and schools are presented in the table below (Table 6). The main classes in their classification are explorative and normative scenarios, probable and desirable scenarios, first- and second generation scenarios and trend, optimistic, pessimistic and contracting scenarios.

Table 6. Different types of scenarios (Masina & Vasquez 2000, p. 55).

Extrapolative and normative scenarios (Erich Jantsch)	
Extrapolative scenarios	- use data referring to the past and present - studies what is possible and probable - also contain what is desirable
Normative scenarios	- are projected from the future to the present, and thereafter back to the future again - explores what should happen
Probable and desirable scenarios (French school)	
Probable scenarios	- correspond to what will happen in the future, knowing the activity of the actors
Desirable scenarios	- indicate the horizon to which the efforts must be directed in order to change wanted things significantly - provides a solution for the problems arising in the system, if going beyond the prognostics of the probable scenario
First- and second-generation scenarios (Shell-SRI school)	
First-generation scenarios	- are exploratory - help to obtain a better understanding of reality - do not provide further help in decision making - strive for understanding not action
Second-generation scenarios	- are based on a solid analysis of reality - are educational tools because they change the assumptions or suppositions of decision makers
Trend, optimistic, pessimistic, and contrasting scenarios (H. Kahn and Human and Social Futures Studies)	
Tendential-inertial or trend scenarios	- describe the prolongation of the present situation (what is present now) - presuppose no change, as if everything were to continue constant, exactly the same - do not show structural changes - are the “hard core” scenario, methodologically speaking - show the consequences which may arise if things do not change and slowly worsen
Utopian scenarios	- describes the best of possible worlds - are usually unachievable and most desirable scenario - shows what is NOT achievable
Catastrophic scenarios	- describe the worst of possible worlds - worsens the trend scenario
Normative scenarios	- describe a desirable and achievable situation - improves the trend scenario - structure the objectives for the future
Contrasting scenarios	- describe different situations starting off from the variations of certain of the key variables - are the opposite of the trend scenario, and present extreme situations - focus on discovering by means of a rational analysis, relationships between facts that may not be sufficiently visible

Notten et al. (2004, pp. 9-10) combine many different approaches of scenario analysis in a comprehensive way. According to them, scenarios can be classified according to three criteria: *project goal, process design,* and *scenario content*. The typology can be used to help specify the type of scenario study that should be conducted when considering the project goal and the available resources. On the other hand, it can be used to compare past scenario studies and to draw conclusions about the various scenario approaches.

The project goal describes a scenario study’s objectives. Here is distinguished between exploratory and agenda-setting scenarios. Exploratory goals might include awareness rising, and the stimulation of creative thinking. Agenda-setting scenarios examine paths to futures that vary according to their desirability. *The process design* involves used methods and techniques such as expert workshops, expert interviews, Delphi studies, or computer models. Here sorting is done between intuitive and formal process designs. The intuitive scenario process leans strongly on interactive group sessions and qualitative knowledge. Formally developed scenarios usually involve a predetermined process that combines expert-based and/or quantified knowledge. The computer-model-based scenario study is a common type of formal process design. *The scenario content* addresses the developed scenarios themselves. A distinction is made between complex and simple scenarios. Complex scenarios elaborately demonstrate the action–reaction mechanisms of a broad range of actors, factors, and sectors. Simple scenarios are more limited in scope. The term simple in the context of scenario development does not indicate poor quality. A simple scenario can be more effective in communicating its message than a complex scenario (Notten et al. 2002, pp. 3-10). An overview of the typology is provided in Figure 6. The scenario characteristics are clustered for easy use.

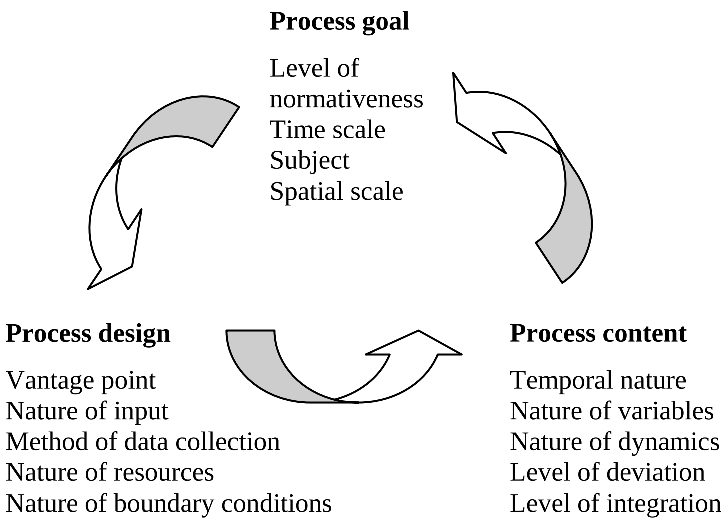


Figure 6. The scenario typology (Notten et al. 2004, p. 10).

Scenarios can be categorised also in four different groups according their scope. *Global scenarios* offer guidance to a number of distinctive future environments that each have different implications for long-term investments, operating decisions and options analysis. *Industry scenarios* enable managers to identify plausible future states of an industry and differences between them, to examine how these distinct industry states might evolve, and to determine what the organisation would have to do to win within each industrial future. *Competitor scenarios* offer a unique method of identifying and testing plausible competitor strategy alternatives in various circumstances. *Technology scenarios* help management to make better technological decisions by better understanding the opportunities, risks and choices in preparing for a dynamic, turbulent and uncertain future market (Ratcliffe 2000, p. 6).

3.3.2 When to use scenario planning?

In short, the scenario analysis technique is applicable to virtually any situation in which a decision maker would like to imagine how the future might unfold. People can use the technique to make individual decisions or a function, say, information system, can also use scenario development to anticipate changes in its role. But perhaps most beneficial is its use in corporate-wide *strategic planning* and *vision building*. For example they can be used for evaluating proposals: corporate executives might ask the strategic business units to submit investment proposals that project cash flow in each of several scenarios

(Schoemaker 1995, p. 3). Organizations facing the following conditions will especially benefit from scenario planning:

- Uncertainty is high relative to managers' ability to predict or adjust
- Too many costly surprises have occurred in the past
- The company does not perceive or generate new opportunities
- The quality of strategic thinking is low (i.e. too routinized / practised / experienced or bureaucratic)
- The industry has experienced significant change or is about to
- The company wants a common language and framework, without stifling diversity
- There are strong differences of opinion, with multiple opinions having merit
- Your competitors are using scenario planning (Schoemaker 1995, p. 3)

In the Figure 7 below is illustrated (Davis 1998, p. 5) the usage of scenario analysis in the companies. This highlights clearly the linkage between the scenario analysis and company's strategy. The building phase starts from the current strategic agenda and leads to a set of different scenarios. After that these scenarios work as a starting point or basis for creating new strategic agenda for the company.

Scenarios have many applications. First, they can enrich debate and widen the 'strategic conversation' in the organisation. The aim here is to bring new concepts and understanding to users, and to change mental maps. Second, they can search for corporate resilience, including making risky decisions more transparent. This involves identification of threats and opportunities and the creation and assessment of options. Third, they can be used to trigger a formal strategic planning process, including the assessment of existing strategies and plans (Davis 1998, p. 5).

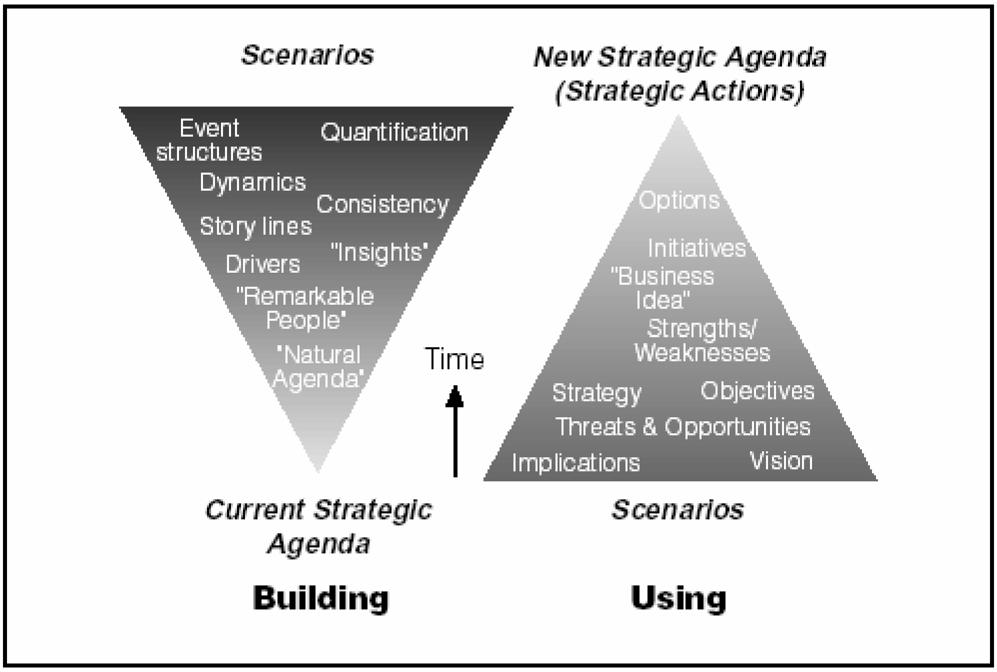
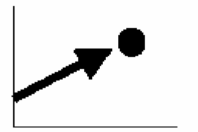
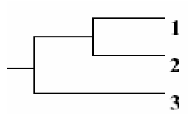


Figure 7. Building of using scenarios (Davis 1998, p. 5).

In the following table (Table 7) different possible situation of futures research are presented with their characteristics and suitable analytic tools. There are many situations in which possible futures cannot be reduced to a series of discrete possible outcomes like in the situations 1 and 2. These cases described as situation 3 in the table (a range of futures), are the ones in which there is a wide range of possible outcomes or futures, with no true theoretical, or evidential basis for making a clear choice of which is the more likely, or which factors will have a particular effect. In these cases scenario planning is the most appropriate tool to use for planning (Courtney et al. 1997, pp. 69-71). Under these circumstances to apply the tools appropriate to situation 1 or 2 can have a misleading, and possibly even disastrous consequence. They will provide an appearance of mathematical precision which can be incorrect because the underlying system does not exist, or cannot be characterised, as the product of a limited set of interacting variables (Courtney et al. 1997, p. 70). Situation 4 describes the true ambiguity where there is no basis to make a logical forecast of the future.

Table 7. The most useful futures research techniques in different situations (Courtney et al. 1997, pp. 69-71).

				
Situation	**1. A clear enough future**	**2. Alternate futures**	**3. A range of futures**	**4. True ambiguity**
What can be known	A single forecast precise enough for determining strategy	A few discrete outcomes that define the future	**A range of possible outcomes**	No basis to forecast the future
Analytic tools	“Traditional” strategy tool kit	Decision analysis, option valuation models, game theory	**Scenario planning, latent demand research**	Analogies and pattern recognition, nonlinear dynamic models
Examples	Population, Moore´s law	NASA, capacity strategies for chemical plants	**Fast changing markets, developing emerging technologies in electronics**	Russia in 1992

After deciding to use scenarios, one often has to think about the purpose of the scenarios (i.e. “why we are using scenarios and what is our main goal?”). Heijden et al. (2002, p. 233) divide the purposes of scenario projects in four different categories according two following main dimensions:

- projects can be used either to *specific aims* (as one-off problem-solving projects) or *process-like*, promoting longer-term survival capability in the organization
- projects can be undertaken either to *open up minds* for exploration or to *achieve closure on decisions and action* in an organization

In the Figure 8 these dimensions provide four different combinations of the areas of purpose. First, there are scenarios which make sense of a puzzling issue. These scenarios are meant to open up conversation by taking an iterative process of intuitive exploration on wanted issue (Heijden et al. 2002, p. 236). Second the purpose can be to develop strategy. In that case different stakeholders and strategic aims must be evaluated and analyzed carefully (Heijden et al. 2002, pp. 239-254). Another purpose can be to improve organizational anticipation (Heijden et al. 2002, pp. 255-266). Most challenging way and highest level of exploiting scenario analysis is to build an adaptive learning organization on that basis. This means questioning the intentional strategies and rationalistic organizations and accepting the limitations of our capabilities in making all the right strategic decisions[8]. The use of scenarios should be ongoing process in this option (Heijden et al. 2002, pp. 266-275).

	Once only Problem solving	**Ongoing** Surviving/thriving
Opening up exploration	**Making sense**	**Anticipation**
Closure decisions	**Developing strategy**	**Adaptive organizational learning**

Figure 8. Purpose of scenario projects (Heijden et al. 2002, p. 233).

Meristö (1991, p. 38) has studied the linkage between corporate strategy and scenario planning. In enterprises scenario thinking can be linked with their strategy in many ways. Meristö has grouped scenarios in three different groups according their usage in the strategy process. First of all, scenarios can be used as *mission scenarios*, when they are involved with formulation of the company's mission statement. Secondly they can be written and used as *theme* or *environmental scenarios* in company's environmental analysis describing the possible future environments of the organization. Scenarios used in company's business analysis are called as *action scenarios*. In the following Figure 9 is illustrated the linkage between strategy and scenarios.

[8] This view is strongly emphasized e.g. by Mintzberg in his influential book "The Rise and Fall of Strategic Planning" (1994).

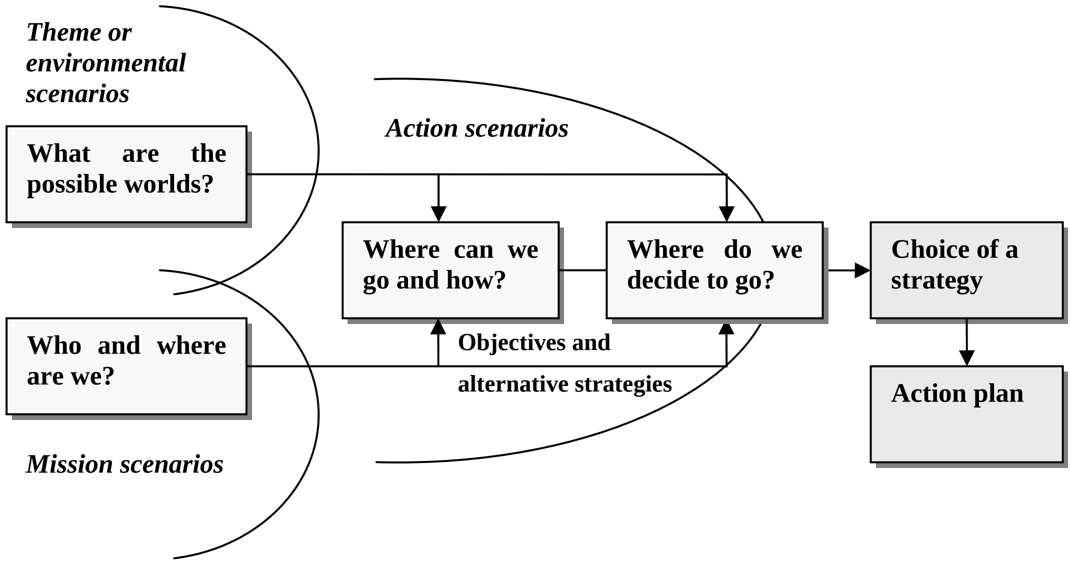


Figure 9. Linkage of scenarios and strategy (Meristö 1991, p. 38).

3.3.3 Benefits of scenario thinking

The use of scenario analysis has certain clear benefits which are discussed in this section.

In short, the great value of a scenario is to be able to take complex elements and weave them into a story which is coherent, systematic, comprehensive, and plausible (Coates 2000, p. 116). The most important benefit of scenarios is that they stretch as well as focus people's thinking. Organizations can have the capability to perceive what is going on in their environments, to think through what it means for them, and then to act and make decisions upon this knowledge (Schwartz 1996, pp. 3-4). Scenarios reduce overconfidence by making available to the mind futures not yet considered as well as by challenging those presumed likely. Scenarios can also help overcome the so-called availability bias, according to which people undervalue that which is hard to imagine or recall from memory. Third, scenarios can shift the anchor or basis from which people view the future. The typical mental anchor is the past and usually people do not adjust thinking very far from this starting point (Schoemaker 1993, pp. 8-9).

Scenario planning simplifies the large amount of data into a limited number of possible states as well. Each scenario tells a story of how various elements might interact under certain conditions. When relationships between elements can be formalized, e.g. a company can develop quantitative models. It should evaluate each scenario for internal consistency and plausibility (e.g. high visibility and heavy snowdrifts are an implausible combination). Although a scenario's boundary might at times be fuzzy, a detailed and realistic narrative can direct attention to aspects that would otherwise be overlooked (Schoemaker 1995, p. 2).

Heijden et al. (2002, pp. 142-146) summarize all these discussed benefits in six different issues from the organizational point of view. According to them scenario analysis can/is:

1. Enhance perception
2. Integrate corporate planning
3. Make people think by questioning assumptions and developing fresh insight
4. A structure for dealing with complexity
5. A communication tool for developing shared understanding
6. A management tool for rehearsing responses and developing robust strategies effective if circumstances change

Scenario technique is also versatile because it can be used whether good time series, data, experts, and useful models exist or not. According to Porter et al. (1991, p. 56) scenarios can integrate forecasts produced by other techniques and engage quantitative data as well as qualitative information and values. A wide range of presentation methods can be used as well. Scenarios may employ literary artifice and imaginative descriptions or even multimedia techniques to deliver scenarios effectively to diverse audiences. Further, scenarios can be used when no other technique is available. Moreover, forecast users who are not technically trained, scenarios are a technique of choice.

Schoemaker (1995, p. 3-4) argues that there are two common errors in decision making: underprediction and overprediction of change, and that scenario planning attempts to compensate for those two. Most people and organizations are guilty of the first error.

Scenario planning, then, allows us to chart a middle ground between under- and overprediction. It helps expand the range of possibilities that can be seen, while keeping from drifting “into unbridled science fiction” (Schoemaker 1995, pp. 3-4).

3.3.4 What makes a good scenario?

There are several lists of characteristics of good scenario. In general good scenarios are ones that explore the possible, not just the probable – providing a relevant challenge to the current wisdom of their users, and helping them to prepare for the major changes ahead (Mannermaa 1991, pp. 57-58). According to O’Brien (2002, p. 720) good scenarios are multidimensional and capture a broad range of uncertain factors. They challenge participants’ implicit assumptions about what will not change in their current world and help move their audience beyond it. Also engaging scenarios titles and narratives are more likely to capture the imagination of the reader and thus influence the way they understand how the future may develop.

Godet (2000, pp. 7-16) argues that scenario approach can be credible and useful only if its hypotheses meet five prerequisites:
Relevance – each scenario should contribute specific insights into the future that help make decisions.
Iimportance – the written scenarios should have clear meaning for their creators.
Coherence or *consistency* – the scenario must be logical and ensure that there is no built-in internal inconsistency that would undermine its credibility.
Plausibility – the selected scenarios must be capable of happening.
Transparency – the concept of scenario must always be stated clearly.

Using these criteria, it is usually possible to select quite quickly the few scenarios that are most worthy of further development. This list above by Godet can be complemented with few other criteria. The following two additional criteria have been suggested by Ratcliffe (2000, p. 9):
Differentiation – they should be structurally different and not simple variations on the same theme.
Challenge – the scenarios should challenge the organisation’s visions about the future.

Scenarios will live in an organization if people use them in their day-to-day work. One particularly important area is aligning the research and intelligence-gathering operation of the organization to watch emerging trends or discontinuities flagged by the scenarios. Otherwise even technically good scenarios can be easily forgotten (Ringland 2002, p. 178).

3.3.5 Limitations of scenario analysis

Not all experiences with scenarios are positive. Scenario analysis is in tight linkage with the critical issues of the organizations, so it is important to notice also possible restrictions and limitations of this tool. Scenarios are often used in decision making or strategy formulation, and failures in these can in the worst case be devastating for the organization.

The future itself contains a major limitation from the researcher point of view. It cannot be studied empirically. You cannot interview it, ask it to fill out inquiry forms nor can it be observed with microscope. The definition of futures research refers to perspective, where the present time and knowledge is approached on the basis of past. The research material consist of statistics, time series, expert interviews and among others theories about the dynamics of the development of economy, technology and society (Mannermaa 1999, p. 20). In skilful hands scenario thinking is an effective tool for exploring the future. Even so, although scenarios have become popular, many enterprises do not keep the technique at the forefront of their long-range planning. David Mercer (1995, p. 32) argues that the main reason for this is the complexity of the process itself and that is why it is important to keep the process as *simple* as possible.

Ringland (2002, pp. 174-175) states that two common mistakes in using scenarios are adopting one external scenario and getting bogged down with alternative action options. The former refers to situation where organizations often develop several external scenarios at great expense, but strategic planners get discouraged at the thought of really thinking through the implications of multiple futures, because often the pressure from top managers to express planning situations in simple decision models contributes to this. So, the planners settle on one external scenario too quickly and let the success of the strategies they develop be dependent on the occurrence of this particular scenario.

The latter error is made by organizations that develop and present action options in the form of internal scenarios and try to follow all of the action options at the same time. This way of proceeding violates the strategic principle of the concentration of power and the competitors who just follow one direction and who consequently use their resources for the acquisition of capability to follow this direction will have an advantage. Often also the negative scenarios are hard to envision and accept. Many times they are not accepted whether they are useful or not (Schoemaker 1993, p. 8).

Mannermaa (1999, pp. 32-34) points out the main limitations and "the rules of thumb" of futures research as a whole with the emphasis on scenario analysis. First of all, the size of empirical material and data does not define the credibility and plausibility of the results. Many times large amount of empirical material leads to superficial results, while on the other hand with too small material, the results may be hard to generalize.

The optimal amount of information is always case sensitive and depends on the object of the study, used methods and goals of the study. He argues also that the precision of forecasts may easily mislead the researcher. There is no such thing as an exact estimation like it has been seen e.g. in many forecasts of economists. Mechanical trend exploration probably misleads in most cases. The reason for this is growing complexity in our society and economy and the surprises are more common than ever before. Still it is important to identify and follow the major lines or "megatrends" of development, although complete surprises may well appear in their details (Mannermaa 1999, p. 32).

Forecasts and scenarios are always incomplete. They can never include all the influential factors and forces. Scenarios, forecasts, planning, decision making and human actions have strong interdependency between each other. Forecasts affect on decision making, which changes again forecasts etc. It is a continuous process where forecasts and scenarios give only interim information, not the final result. (Mannermaa 1999, pp. 32-33).

Heijden et al. (2002, p. 3) emphasize the importance of execution. They argue that poorly-executed scenario work leaves managers feeling that not much has been achieved. One common problem is that people often focus on the scenarios themselves, while the benefit needs to derive also from the process gain. All emphasis must be on the quality of “strategic conversation”. This means the scenario work should always be a customised activity. In their experience and research they have come to the conclusion that a lack of such purposefulness is the most common problem with less than professional scenario work. They state that scenario work is not particularly difficult, and many have used it to great advantage. What is often lacking is the sense of purpose.

3.4 Constructing scenarios

As mentioned earlier, scenarios are creative by their nature both in thought and expression, but they are likely to be more useful if they have structure. There is a number of ways how the scenarios can be created and none of them is more wrong or more right than other. Often these tools resemble each other and are only slightly different. According to Godet (2000, p. 11), in the scenario planning the choice of tools depends on the problem, context, and usual limits of available time and information. Each tool is functional but its logical follow-up in the sequential approach is rarely carried out. Similarly, the scenario method is rarely carried out from A to Z. There usually is not enough time. Fortunately, the tools can be selected and used either individually or in combination. In addition, Godet encourages tinkering with the toolbox and even innovating with new applications for the same tools to answer questions.

When developing scenarios, it is a good idea to start from the inside out rather than from the outside in. That is, begin with a specific decision or issue, and then build out toward the environment. In addition Schwartz (1996, p. 241) reminds that scenarios developed on the basis of differences in the macro-economy (e.g. high growth versus low growth) may not highlight differences that make a difference to a particular company.

The time spent on creating scenarios varies greatly. They can be undertaken on an immediate basis in order to surface general issues and options or in the other hand; they can be constructed continuously as an iterative process in an organization. Heijden et al. (2002, pp. 194-197) present one possible technique to utilize scenario thinking with different problems especially when the problem requires immediate attention or the available time is limited (as in the empirical section of this thesis). In this *instant scenario* technique phases of the process are shorter and more dynamic than normally. Instant scenario technique is suitable e.g. in short one-day long sessions. Normally scenario writing takes time and because the time restriction the results of instant scenarios are sometimes too rough to be used in decision making and determining action (Heijden et al. 2002, p. 197). Instead, they can be ideal for opening up our minds to our knowledge and information gaps, setting an agenda for further research and investigation. This research could feed into a further, more in-depth and more informed full-scenario iteration (Heijden et al. 2002, p. 215).

3.4.1 Different approaches to scenario process

As there are many different "schools" or types in scenario analysis (see chapter 3.2.1), there are also many different approaches to scenarios process itself. Although the many differences and variations in the process, they all share same basic fundamentals in their structure. These fundamental steps are presented in the left column of Table 8. Different methodologies used by most famous scenario experts (Schwartz, Heijden, Schoemaker, Godet) are also presented in Table 8. In addition, the steps of each method are classified and compared.

Scenario approaches can be classified into two opposite groups according their characteristics: intuitive logic scenarios and formal or statistical models. Intuitive approach concentrates on story-like narratives which are created in relatively informal ways. For example Schwartz (1996) emphasises the intuitiveness of the scenario working and narrative writing. He encourages to intuitively create logical stories quickly rather than spending time on formal tools and procedures. Although this approach is useful to get results and visions rather quickly, it also needs skills and experience especially from the facilitator in order to be applicable and helpful.

Best example of statistical and formal models is French school and especially Michel Godet with his *la prospective*[9] approach. Over the past 25 years, they have contributed

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[9] *La prospective* refers to a proactive approach. The English term *foresight* is perhaps the closest translation, yet the idea of proactivity is less present (Godet 2000, p. 4).

by creating or further developing various more formal methodologies and procedures (e.g. Mactor and MICMAC) for use in scenario building. According to Godet (2000, p. 1) these tools are “doubly powerful in that they stimulate the imagination, reduce collective biases, and promote appropriation”.

Schoemaker (1995, pp. 24-41) argues that either of these “extreme” approaches is better. Intuitive approach leads often too irrational results, because it lacks the discipline. A statistical method in the other hand is too mechanical requiring little use of imagination. Instead he recommends the heuristic approach, which combines discipline and imagination in the same process. It has some structure to it, but still exploits the benefits of creative mind.

Table 8. Different scenario approaches with their steps (Adapted from Bergman 2004).

Intuitive ← ***Heuristic*** → ***Formal***

	Schwartz (1996)	Heijden (2002)	Schoemaker (2000)	Godet (2000)
Defining the scenario process and focus	1. Exploration of a strategic issue	1. Structuring of the scenario process	1. Framing the scope	1. Delimitation of the context
			2. Identification of actors and stakeholders	2. Identification of the key variables
Analyzing the scenario context	2. Identification of external key forces	2. Exploring the context of the issue	3. Exploring the predetermined elements	3. Analysis of past trends and actors
	3. Exploring the past trends		4. Identification of uncertainties	4. Analysis of the interaction of actors and the environment
	4. Evaluation of the environmental forces			
Scenario writing	5. Creation of the logic of initial scenarios	3. Developing the scenarios	5. Construction of initial scenarios	5. Creation of the environmental scenarios
	6. Creation of final scenarios	4. Stakeholder analysis	6. Assessment the initial scenarios	6. Building the final scenarios
		5. System check, evaluation	7. Creation of the final learning scenarios	
			8. Evaluation of the stakeholders	
Impli-cations	7. Implications for the decision making	6. Action planning	9. Action planning	7. Identification of strategic options
	8. Follow-up research		10. Reassessment of the scenarios and decision making	8. Action planning

In the earlier mentioned instant scenario approach, Heijden et al. (2002, pp. 194-197) encourages to go through all the phases above in the table, but to reduce the time used in every phase. I.e. the only difference between other approaches and instant scenario is the efficiency and the time used during the session(s).

3.4.2 How many scenarios?

One essential part of the scenario thinking is that you create more than one possible vision about future in order to capture those driving forces and their different values which will have the biggest impact in the future (Porter et al. 1991, p. 68). However there are no strict limits how many scenarios one should have and appropriate number varies along the writer. Although the view is not supported in the leading scenario literature (Schwartz (1996); Heijden (2002); Schoemaker (2000); Coyle (2004)), it is common to provide a set of three scenarios that span what the forecaster believes to be the range of possible futures:

1. a surprise-free projection
2. the worst case projections
3. the best case projections (Porter et al. 1991, p. 68)

When answering the question “how many scenarios?” there are also reasons to think whether one should choose even or odd number of scenarios. The even numbers avoids the temptation to choose a middle one (Coates 2000, p. 4). For example with three scenarios there is a common trap: as said above, three different scenarios tend to be often optimistic, realistic, and pessimistic. This approach draws the user to prefer or emphasize the middle case while other scenarios are more or less kept as unrealistic.

While Coates (2000, p. 3) argues that the minimum number of scenarios should be four and that there can easily be as much as 10 different scenarios, Godet writes (2000, pp. 6-18) that it is often advisable to limit the scenarios to several key hypotheses, say four to six, depending how much there is uncertainty. The principle is, the greater the uncertainty, the higher the number of scenarios. Another view from Schwartz suggests that eventually there should be two or three different scenarios, because people’s minds cannot cope with more possibilities. In some rare occasions he advices to consider four scenarios. Any more and you will get a hopeless muddle, writes Schwartz (1996, p. 140). Mannermaa (1999, p. 66) argues that suitable amount is from three to five. With two scenarios you get easily just the good and the bad one and with more than five scenarios it gets too hard to handle them.

In corporate use Shell has experimented with four, three and two scenarios in their strategic planning. What Shell found was that:

- four scenarios encourage divergent thinking and are useful for creating vision
- three scenarios lead to the expectation that one is "the forecast"
- two scenarios allowed two very distinct (not necessarily "low" or "bad" vs. "good" or "high") scenarios to be developed (Ringland 2002, pp. 22-23)

Today Shell creates two clearly different scenarios about their operational environment as a basis for their strategy process (Shell 2001, p. 1). In overall, as there are many ways to use and create scenarios, the number of the scenarios varies as well.

3.4.3 Timeframe of scenarios

In the literature the used timeframe of scenarios ranges from few years to Shell's over sixty year long views of the future. It all depends on where and how these scenarios are going to be used. Mannermaa (1999, p. 20) states that especially with the ICT technologies already a five year long timeframe is well justified because of the fast changing nature of ICT.

Internet, for instance, had breakthrough only in few years with a phenomenal speed. A too long scenario perspective can make scenarios inapplicable, e.g. twenty years may embody so many "wild card"[10] possibilities that it is difficult to care about them (Kleiner 1999a, p. 77).

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[10] Wild Cards are low-probability, extremely high-impact events that are social and technological developments or natural phenomena (Petersen 2004).

3.4.4 Forming the scenario group

In the beginning of the scenario process one has to form a scenario group which carries out the process. This group should consist of persons who have strong visions of the future or like Heijden et al. (2002, pp. 201-202) state, they should be "visionaries and extraordinary persons, remarkable people[11]". If the scenarios are made in companies, then the participants should have influence and authority as well (Mannermaa 1999, p. 63). The size of the group is case sensitive, but usually the number of participants should be limited from five to ten. With fewer than five participants it may be hard to get a wide knowledge and expertise and with over ten people the working process change easily too slow, hard and vacant (Mannermaa 1999, pp. 63-64).

In order to make the process work, the people who are involved should be strongly committed to it. In addition, there should always be somebody who masters the used methods and also basics of futures research. This means often the presence of an external expert in the group. This expert should bring two kind of added value in the work process: first he/she should know the methods and be able to lead the working process ahead (Mannermaa 1999, p .64).

3.4.5 Fleshing out the scenario

The scenario story requires a broad logic or theme (Coyle 2004, p. 61). Schwartz (1996, pp. 135-162) gives an overall guide to fleshing out the plots of the scenarios, which ties together the elements of the system. First of all, the writer should converge forces and understand how and why they intersect, then extend that imagination into coherent pictures of alternative futures. Schwartz suggests few common plots how this can be done. The concepts of *winners and losers*, *challenge and response* and *evolution* are the most popular ones. Other often used plot types are *revolution* and *cycles*.

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[11] Remarkable people are the ones who "know the industry structure, language, driving forces and key uncertainties". In addition they trigger scenario teams to surface intuitive knowledge and then scaffold it into existing cognitive structures, i.e. they can move thinking "out of the box" (Heijden et al. 2002, p. 287).

As Coyle (2004, p. 61) states, it is critical to think of a simple, memorable name for each scenario, which helps to remember its essence. One should avoid calling scenarios as “best case”, “worst case” or “business as usual”.

Chermack (2004) gives more specific requirements to good scenario writing by identifying that well-written scenarios are internally consistent and link historical and present events with hypothetical events in the future. In addition they carry storylines that can be expressed in simple diagrams and reflect predetermined elements or ‘‘those events that have already occurred…but whose consequences have not yet unfolded” (Wack 1985, p. 4). Also they should identify signposts or indicators that a given story is occurring.

3.5 Scenario planning for emerging technologies

Scenario analysis can be used to explore and analyze the emerging technologies as well. The strength of scenarios is the ability to combine information from different sources and simplifies the pile of data into a limited number of possible states. This means that with scenario analysis the whole system (e.g. the interaction of market and technological data) can be studied in the case of emerging technology (the characteristics of emerging technologies can be found in chapter 2.2).

According to Schoemaker and Mavaddat (2000, p. 208) the uncertainty relating to emerging technologies “goes off the chart”. This means that in the case of these technologies the challenge is not to draw a detailed picture of a single future but to sketch a vision of many futures. The organizations can then adjust their strategies for this portfolio of futures. The scenario approach is the most applicable because the main question is “which set of multiple futures” might be likely, not “which future”.

Scenario planning has been used to study the implications of new technologies in diverse industries. Emerging technologies inherent three distinct challenges that scenarios can confront better than the other planning techniques:

1. *Uncertainty*. Scenario planning embraces is as the central element in its process.

2. *Complexity*. Scenarios explore how a diverse set of forces (from social to economic) dynamically influence each others over time as a complex system.
3. *Paradigm shift*. Scenario analysis challenges the prevailing mindset and core assumptions by amplifying weak signals that would otherwise be unnoticed (Schoemaker & Mavaddat 2000, pp. 211-212).

These challenges suits well for the scenario analysis if compared to applicability criteria for studying technologies. According to Levary and Han (1995, pp. 15-17) scenario analysis is highly adequate when the technology is:

- emerging or at an early stage,
- a small amount of low- or medium-validity data is available,
- a medium number of variables are affecting technological development, and
- there is no clear similarity between the proposed technology and existing technologies.

In those cases as mentioned above, it is necessary to rely on information available from experts. As a prerequisite for use of scenario analysis in studying technology Levary and Han (1995, p. 15) write that scenario developers should have *expertise* in all aspects of the proposed technology.

With the technological scenarios you should always take into account that people need to learn to value and use these new technologies. That is why technological growth is often a process of evolution. Schwartz argues (1996, p. 149) that it is also evolutionary because new tools fit within an existing system. For example, if you want to make major changes to computers you must also think about changing the web of systems that supports the existing computer. Technological change is always combined with changes in social and cultural systems. Similarly, any scenario for technologies must include an understanding of the political and social systems around it. Scenarios can help provide a means for managers to examine the technological, organizational and strategic impact of important technologies whose exact evolution and significance remains uncertain (Schoemaker & Mavaddat 2000, p. 241).

In the evaluation of technologies, the applicability and the value of scenario analysis can be illustrated by combining the presented innovation typology (Tidd et al. 2001, pp. 6-7 or chapter 2.1) and their characteristics to prerequisites of scenario analysis (Levary & Han 1995, pp. 15-17). The more radical is the level of technological change, the more one has to exploit expert knowledge because codified knowledge is not useful and/or available. In those situations the scenario analysis is more applicable and valuable compared to other techniques. The relation is illustrated in Figure 10.

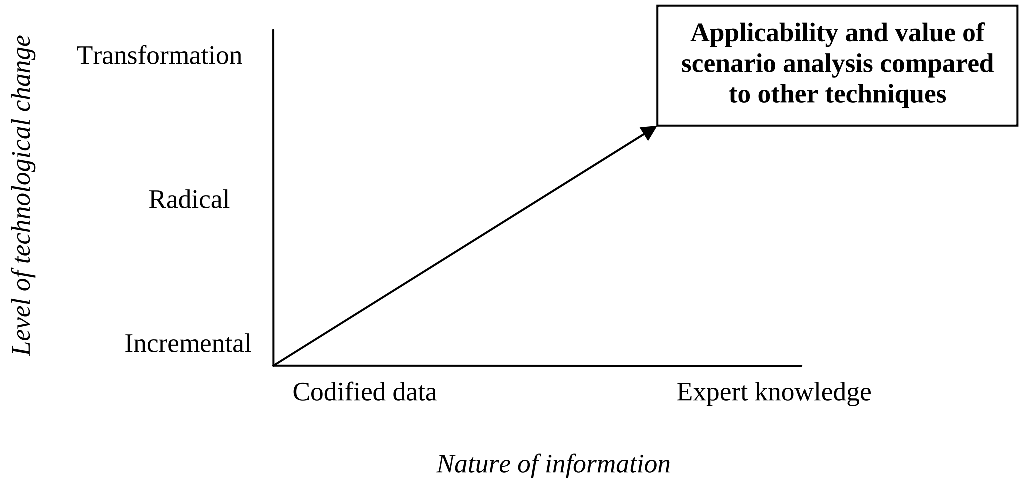

Figure 10. The relation of the nature of information, the level of technological change, and the applicability of scenario analysis.

4 GRID COMPUTING

This chapter gives an overview to *Grid computing*. The first part takes a closer look to its technical background, while the other part concentrates on its business implications called utility computing.

4.1 Introduction to Grid computing

In the information and communication technology (ICT) industry the changing pace of technologies is perhaps faster than in any other industry. One of the biggest changes in our everyday living in the 1990s was definitely the breakthrough of Internet. Instant access to information around the world changed our thinking in so many ways. Now after the Internet there is a new computing paradigm arising in the ICT-industry called Grid computing.

Grid computing is one of the most promising new ICT technologies and it is fast becoming better known among the general public as well. With Grid computing your entire computing infrastructure can be used as a single, intelligent "virtual computer" which utilises under-used resources on someone's machine to enable someone else's problem to be calculated a bit faster (Cartwright 2004).

First Grid computing was solely pursued by academic and research communities but quickly it got the interest of business people as well and today it e.g. forms a cornerstone of IBM’s *utility computing* strategy (utility computing is the business implication of Grid computing). Some ICT industry analysts are calling Grid computing even as the foundation of fourth wave in ICT (Insight Research Corporation 2003, pp. 2-3) or “next big thing” after the (third wave) Internet (Economist 2004).

Several promising technologies can be identified and placed in *the technological hype curve*. The curve shows the current state of technology compared to visibility and maturity. The estimated timeframe in which the technology will be mature enough to reveal the expected market potential is indicated as well. According to Seppälä (2004, p.

39) Grid computing has two positions: Intra-grids are already deployed in the market, while Inter-grids are just reaching their peak of inflated expectations (Figure 11). The difference between these two types of Grid is discussed later on in a chapter 4.5.

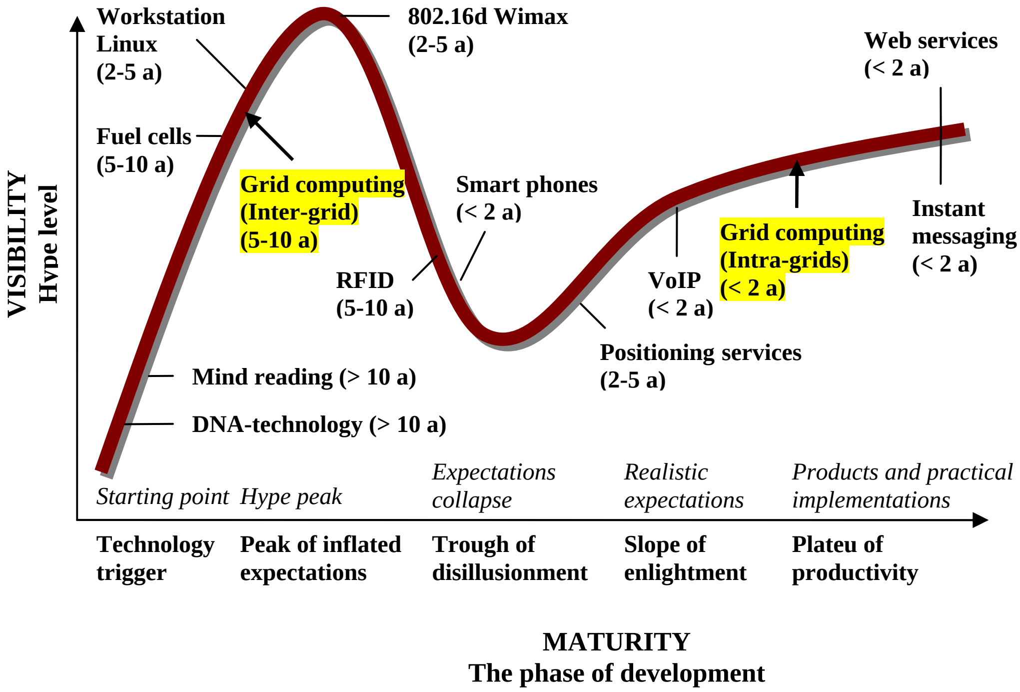

Figure 11. The hype curve of technology (Adapted from Seppälä 2004).

4.1.1 The history of Grid computing

In computing the grid concept is nothing new. The idea of computing resources being linked together and thus computer facilities operating as one large supercomputer "like a power company or water company" was already envisioned in 1960s by many different computing visionaries (see e.g. Licklider & Taylor 1968). Originally the term "*Grid*" was introduced in 1999 by Foster and Kesselman. First it designated new distributed computing infrastructure for advanced science and engineering, but today it is used in commercial sector as well. The name "Grid" is chosen by analogy with the electric power grid: plug-in to computing power without worrying where it comes from.

The early Grid computing efforts started as projects to link supercomputing sites; at this time this approach was known as metacomputing. At the same time, application developers began to pushing the resource limits of even the fastest parallel computers, some groups began looking at distribution beyond the boundaries of the machine as a way of achieving results for problems of larger and larger size The early to mid 1990s mark the emergence of the early metacomputing (or later Grid) environments. Typically, the objective of these early projects was to provide computational resources to a range of high-performance applications (Berman et al. 2003, p. 12).

If everything goes as it is planned, Grid computing has a potential to change the way information and communication technologies are managed and used. If in the future Grid computing brings us computational power from the plug like a commodity, this development would transform science, business, health and society as we know it.

4.1.2 Definition

As mentioned earlier, the idea of connecting computer resources together is nothing new. However the definition of Grid computing is quite obscure, especially in commercial use where it is often used in wrong context.

A popular definition is that a "Grid *system* is a collection of distributed resources connected by a network" (Grimshaw et al. 2003, p. 266). A Grid computing system, also called in many occasion a computational grid or just a *Grid*, gathers resources (desktop and handheld hosts, devices with embedded processing resources such as digital cameras and phones or tera-scale supercomputers) and makes them accessible to users and applications in order to reduce overhead and to accelerate projects. Grid computing enables users to collaborate securely by sharing *processing, applications* and *data* across the systems with the above characteristics in order to facilitate collaboration, faster application execution and easier access to data (Grimshaw et al. 2003, pp. 266-267).

According to Foster et al. (2003, p. 9), "Grid infrastructure will provide us the ability to dynamically link together resources as an ensemble to support the execution of large-scale, resource-intensive, and distributed applications." Foster (2001, p. 2) also states that the real and specific problem that underlies the Grid concept is "coordinated resource sharing and problem solving in dynamic, multi-institutional virtual organizations". These "virtual organizations" are enabling communities groups of organizations that use the Grid to share geographically distributed resources for specific purposes (Seidel 2004). This means that these problems (normally scientific or technical) are solved with computing grids which are worldwide collections of high-end resources, such as supercomputers, storage, advanced instruments and immersive environments. These resources and their users are often separated by great distances and connected by high-speed networks (e-Science 2004). Scandinavian collaboration project *NorduGrid* (see Figure 12) is a good example of computing resource sharing between different locations over a geographically wide area.

Figure 12. Connectivity map of NorduGrid (NorduGrid 2002).

Foster and Kesselman (1999, p. 2) see also the wider aspect and the future possibilities when they state that the Grid is “the computing and data management infrastructure that will provide the electronic basis for a global society in business, government, research, science and entertainment”. Grids integrate networking, communication and computation and information to provide a virtual platform for computation and data management in the same way that the Internet integrates resources to form a virtual platform for information (Thompson & Clavenna 2003). This structure of resources is illustrated in Figure 13.

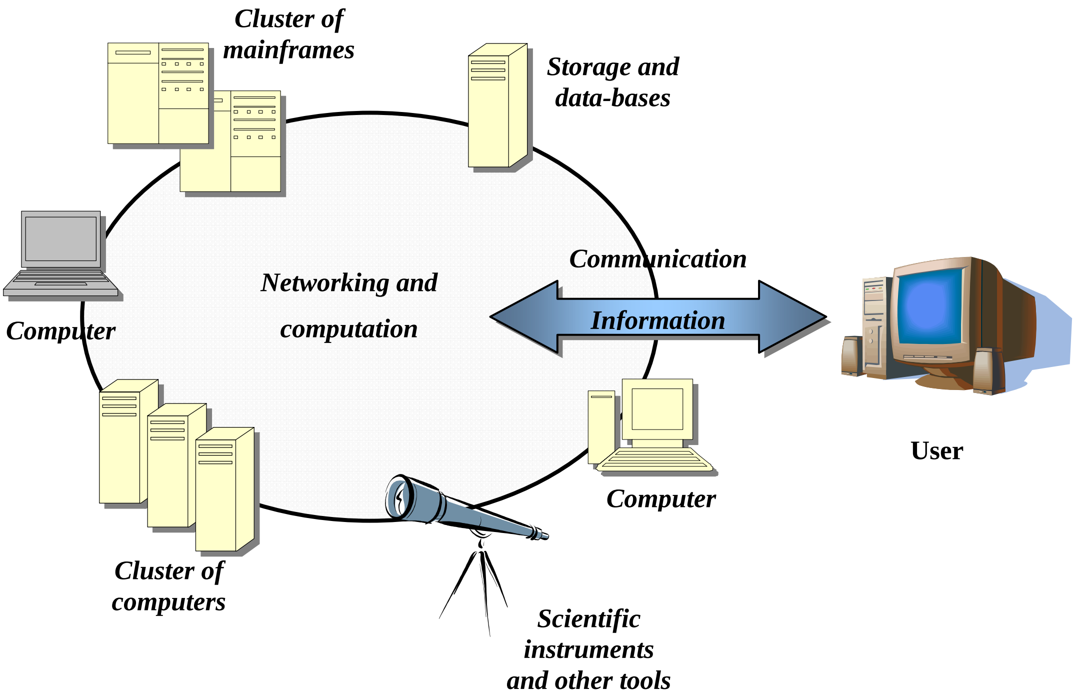

Figure 13. Grid computing structure.

There is a difference between *the Grid* and Grid computing, although in literature they are often used as synonyms. While “the Grid” refers to one large supercomputer, often the vision by the scholars, which can be used as a new tool e.g. in research, Grid computing instead means a whole new paradigm of computing techniques and methods which are used to build grids of computing resources whether these grids are large or small. So “the Grid” is just one embodiment of Grid computing although as mentioned, the popular vision is that some day all the computer resources form one large Grid. That is why researches (see e.g. Foster et al. 2001 or Berman et al. 2003) often use only the term “*Grid*” instead of Grid computing although they often mean the whole paradigm of computing. The same kind confusion of terms occurs also when Internet and World Wide Web are used as synonyms.

Eventually from the technological point of view the basic idea of Grid computing is rather simple: it is a hardware and software infrastructure that clusters and integrates many different components like high-end computers, networks, databases and scientific instruments from multiple sources to form a virtual supercomputer on which users can work collaboratively. Above all the Grid computing is a new class of infrastructure

(Foster 2003, p. 52) which will exploit the revolutions driven by Moore's law[12] for CPU's[13] as well as Gilder's law[14] for networks.

Although some developers call Grids as "super Internets" for high-performance computing (e-Science 2004) and the Grid is often compared to Internet, there is a clear difference between them: Internet provides seamless access to information that is stored in many millions of different geographical locations, the Grid in contrast, is an emerging infrastructure that provides seamless access to computing power and data storage capacity distributed over the geographically wide areas (e-Science 2004). So, the Grid is not a next-generation Internet, but rather a set of additional protocols and services that are build on Internet protocols and services to support the creation and use of computation- and data-enriched environments (Foster et al. 2003, p. 189).

4.2 Motivations and challenges of Grid computing

Many science and engineering problems today require that widely dispersed resources be operated as systems (Dongarra 2004). The development of technological infrastructure may be in line with the laws of Moore and Gilder, but this just is not enough to keep up with the demand. There is an increasing demand for better computational resources by researchers as their problems become increasingly complex. In addition, the lack of collaboration presents obstacles to progress in the field of research and development (R&D). The Grid approach is seen as a new way to accelerate the technological progress and respond to this demand. From the industrial point of view there are several particular reasons why the Grid-related commercial development is currently important:

- The emerging applications are significant, coming from compute- and data-intensive industries and increasingly important vertical markets including energy and oil, financial services, government, life sciences, and manufacturing

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[12] Doubling of transistors/chip every 18 months

[13] Central Processing Unit

[14] Bandwidth capacity doubles every six months

- The potential market size is substantial, predicted to grow from today's size of several hundred million dollars (see e.g. Insight Research Corporation 2003)
- Strong investment commitment and development focus from the industry's largest computing players, including HP, IBM, and Sun, is an indicator that this is a growth market
- There is increasing pressure for enterprise IT organizations to cut costs and increase utilization of existing infrastructure
- Network infrastructure advances, which mean increased bandwidth, reduced costs, more reliable infrastructure and availability of needed equipment etc.
- Advances in storage capacity (continued steps towards storage virtualization and shared access to large data sets) (Thompson & Clavenna 2003)

Research and business communities have different motivations for developing and using Grid computing. In science the need of computing power is today one of the biggest obstacles in a way to better results. Science relies more in computers than ever before and many of today's most important fields of research, e.g. genetic and physics, are fully dependent on computers. In addition, the research is done today often in major collaboration networks, because the scientific problems need larger resources. For example CERN's[15] new Large Hadron Collider produces 40 petabits (25 km high pile of CDs) of raw data every year (Tuisku 2003). Simulating and analyzing this amount of data in reasonable time needs more computing power than it is possible to get out of any computer or even cluster of computers. That is why the researchers are waiting this new paradigm of computing to arise.

In business use Grid computing is not only sheer computing power. Companies are instead interested more in enhancing their competitive advantage; improving productivity and achieving cost reductions. Today's operating environments must be more resilient, flexible and integrated than never before. Organizations around the world are experiencing substantial benefits by implementing Grids in critical business

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[15] CERN is the European Organization for Nuclear Research, the world's largest particle physics centre located in Geneva, Switzerland.

processes. According one of the leading Grid vendors, IBM (2004), these benefits can be categorized in two groups, *business* and *technology* benefits (Table 9).

Table 9. Benefits of Grid computing (IBM 2004).

Benefits	
Business	**Technological**
Accelerate time to results: - can help improve productivity and collaboration - can help solve problems that were previously unsolvable	**Infrastructure optimization**: - consolidate workload management - provide capacity for high-demand applications - reduce cycle times
Enable collaboration and promote operational flexibility: - bring together not only IT resources but also people - allow widely dispersed departments and businesses to create virtual organizations to share data and resources	**Increase access to data and collaboration**: - federate data and distribute it globally - support large multi-disciplinary collaboration - enable collaboration across organizations and among businesses
Efficiently scale to meet variable business demands: - create flexible, resilient operational infrastructures - address rapid fluctuations in customer demands/needs - instantaneously access compute and data resources to "sense and respond" to needs	**Resilient, highly available infrastructure**: - balance workloads - foster business community - enable recovery and failure
Increase productivity: - can help give end users uninhibited access to the computing, data and storage resources they need (when they need them) - can help equip employees to move easily through product design phases, research projects and more — faster than ever	
Leverage existing capital investments: - can help to improve optimal utilization of computing capabilities - can help to avoid common pitfalls of over-provisioning and incurring excess costs - can free IT organizations from the burden of administering disparate, non-integrated systems	

Although networking, distributed computing, and parallel computation research have matured to make it possible for distributed systems to support high-performance applications, there are many challenges ahead because resources are dispersed, connectivity is variable and dedicated access is not possible. Kowalkowski and Laakso (2003) bring forth this set of challenges as they state that several things must be in place for the Grid business to evolve and provide substantial benefit:

1. Several convergent technologies must be in place to make this happen for a business (commercial components, connective logic, bills of material, managed metadata etc.). These capabilities are not all at the same point of evolution.
2. There must be a supply of standardized components that businesses can use not just hardware platforms.
3. There must exist a set of “build instructions” like the bill of materials in a manufacturing firm and a matching routing list that shows how the build is accomplished.
4. There must be a matching form of governance to deal with the administrative control issue of various shared, exchanged and purchased computing assets.
5. There are unexplored political implications for this form of computing. If business crosses state lines the federal government may conclude it has the right to tax transactions. There needs to be a period of legislative tolerance as is now on the web to delay the taxing piranhas looking for new sources of revenue.
6. There may be considerable cultural issues with the use of a Grid concept.
7. Finally, and perhaps most important, there must exist business models that exploits the Grid approach.

In the case of data grids the security is a main issue, because organizations would have to locate their data outside the organization. Especially the business communities may find it easily too risky for them to store their business-related information outside (Schindler 2004). And although the infrastructure was perfect, it means nothing without applications which can take full advantage of it. This is the case in Grid computing as well. Applications codes will need modifications for the Grid computing, depending on how much of it one wants to be able to exploit. This means that programmers should write new codes with the Grid in mind and consider using frameworks which are already Grid-compatible (Seidel 2004). So, as there are clear benefits there are also major challenges in order to have a new robust computing infrastructure.

4.3 Grid architecture

Grid approach consists technically of three different components, which all need to work as one if the vision turns to reality. These components are computing nodes, storage nodes, and network connections between them. This combination forms the foundation of these systems. This system can be illustrated also as architecture.

Grid architecture (see Figure 14) can be divided and described in terms of four layers of different widths, which all provide a specific function. In general, the higher layers are focused on the user (user-centric), whereas the lower layers are more focused on computers and networks (hardware-centric). At the lowest, *fabric layer* comprises all the resources geographically distributed and accessible from anywhere on the Internet. They could be computers (such as PCs or workstations running operating systems such as Linux), clusters running cluster operating systems or resource management systems, storage devices, databases, and special scientific instruments such as a radio telescope (Foster 2002, p. 56).

Above the fabric are the *resource and connectivity layers*, which contain a relatively small number of key protocols and application programming interfaces that must be implemented everywhere. The surrounding layers can, in principle, contain any number of components. The connectivity layer contains the core communication and authentication protocols required for Grid-specific network transactions. These protocols enable the exchange of data between resources, whereas authentication protocols use secure mechanisms for verifying the identity of users and resources. The advanced software in the connectivity layer, or “the heart of the Grid”, is often called as *Middleware*. Resource layer contains the needed protocols that exploit communication and authentication protocols to enable the secure initiations, monitoring, and control of resource-sharing operations. Running the same program on different computer systems depends on protocols in this layer (Foster 2002, pp. 56-57).

The *collective layer* contains protocols, services, and interfaces that implement interactions across the collection of resources. Examples of collective services include directory and brokering services for resource discovery and allocation, monitoring and diagnostic services and membership and policy services for keeping track of who in a community is allowed to access resources (Foster 2002, p. 58).

At the top of any Grid system is *user applications layer*. A Grid application can be defined as an application that operates in a Grid environment or is "on" a Grid system (Grimshaw et al. 2003, p. 266). Applications and services in this layer are developed using Grid-enabled languages. Grid portals offer web-enabled application services – i.e. users can submit and collect results for their jobs on remote resources through a web interface. Grid development environments and tools offer high-level services that allow programmers to develop applications and brokers that act as user agents that can manage or schedule computations across global resources (Foster 2002, p. 58).

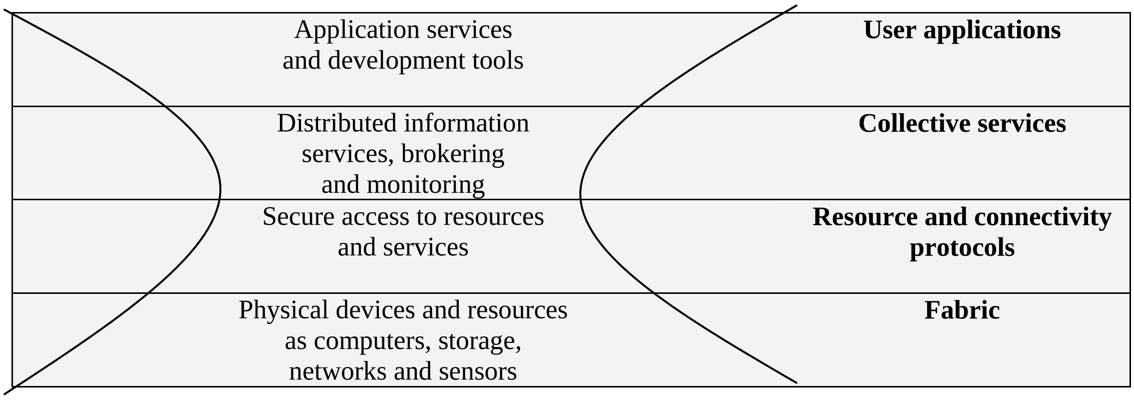

Figure 14. Architecture of Grid computing (Foster 2003, p. 57).

4.4 The requirements for Grid computing and its resources

Generally all Grids have to fulfil the broad requirements that are required for business or heavy-duty scientific needs. Such requirements include: *scalability*, *robustness*, *dynamicity* or *adaptability*, *self-healing*, *high integrity*, *business-strength security* and *trust*, *low effort threshold end-user interface* and *homogeneous access to heterogeneous resources and sources* (Desplat et al. 2002, pp. 19-20).

As mentioned earlier, Grid infrastructure will consist of a wide range of different resources. A *resource* may be a logical entity, such as a distributed file system, computer cluster, or distributed computer pool. In such cases, a resource implementation may involve internal protocols but these are not the concern of Grid architecture (Foster et al. 2001, p. 178). What defines then which computers and equipment form a Grid? The resources in a Grid typically share at least some common characteristics. According to Grimshaw et al. (2003, pp. 1-2) these characteristics are some of the following:

- they are numerous
- they are owned and managed by different, potentially mutually distrustful organizations and individuals
- they are potentially faulty
- they have different security requirements and policies
- they are heterogeneous, that is, they have different CPU architectures, are running different operating systems, and have different amounts of memory and disk
- they are connected by heterogeneous, multilevel networks
- they have different resource management policies and
- they are likely to be geographically separated (on a campus, in an enterprise, on a continent)

Foster (2001, p. 179) has proposed a simpler Grid checklist which is valid for individual components as well. For an aggregation of computers to be a Grid it must do the following:

- Coordinate resources that are not subject to centralized control
- Use standard, open, general-purpose protocols and interfaces
- Deliver quality service

4.5 Taxonomy of Grids

Grids are often classified according their scope. The main types are *Cluster-grid, Intra-grid* and *Inter-grid*. Grids may also be understood by the type of organization in which they are deployed. Insight Research's analysis (2003, p. 4) includes the type of organizational structures where Grid computing and telecommunications networks intersect. These types are clearly analogous with previous classifying as Intra-grid, Extra-grid and Inter-grid are called *Enterprise Grid, Partner Grid* and *Service Grid* respectively. The primary types of Grids are summarized in the Figure 15.

In the research communities the objective is to create geographically wide Inter-grid from the beginning in order to get a new powerful tool for researchers and access to scientific instruments in global scale. This is well underway and many different international Grid-projects are in progress. But in the business communities the evolution is just emerging. The first commercial Cluster-grids are being deploying at the present moment and also some Intra-grid initiatives are going to be ready in the near future. Of course, there are no hard boundaries between Grid types and often Grids may be a combination of two or more of these.

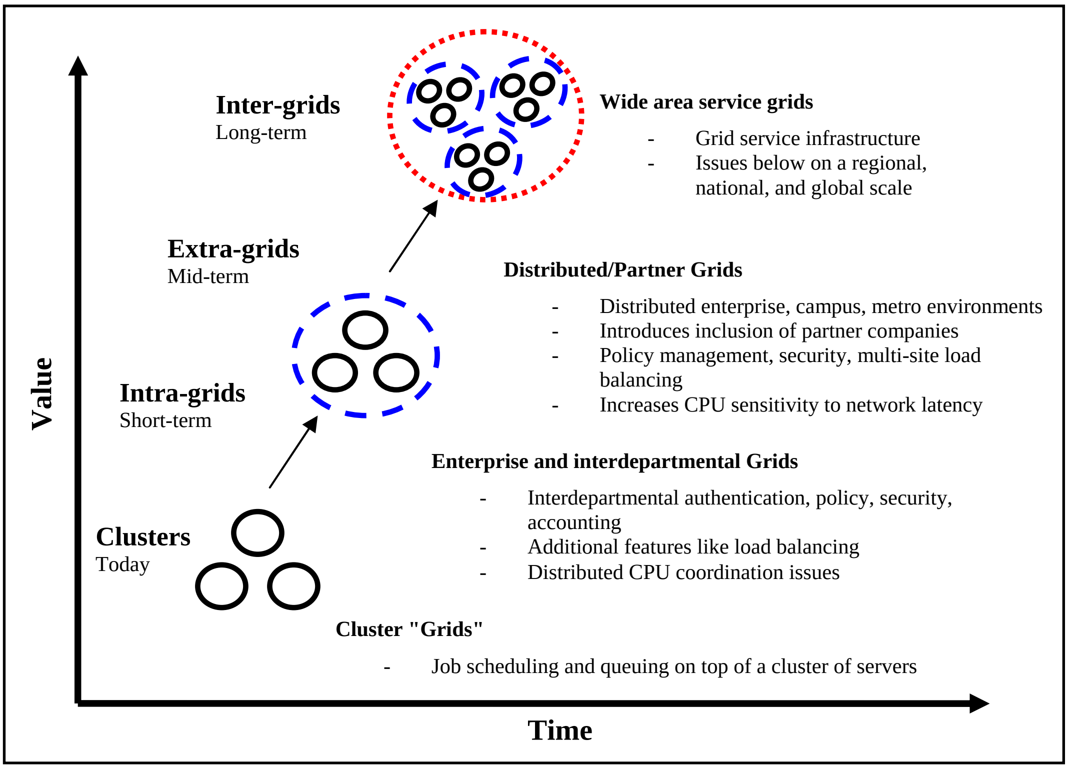

Figure 15. The evolution of Grids (Adapted from Ong 2003; Thompson & Clavenna 2003).

Clusters-grid is the simplest form of Grid. It consists mainly of homogeneous end systems (i.e. machines that share the same hardware architecture and the same operating systems). This system can be found in a single division of an organization where there exists one single administrative control over all the machines. The use of the Cluster-grid does not necessarily require special policies or security concerns since there is centralized control monitoring all the processes (Ong 2003, p. 35).

Intra-grid refers to merging Cluster-grids into an Intra-grid that is often within an organization. This is the current phase of the development. Computer clusters are deployed in many organizations already and the first announcements and references of commercial Intra-grids are published and new deals have been made. Perhaps the best example of this development is pharmaceutical industry, where the R&D is highly compute-intensive and Grids can bring clear benefits into their innovation processes. In this stage it is important to use standard middleware components in order to create robust platform for Inter-grid development (Ong 2003, p. 36).

Extra-grid enables resource sharing among selected enterprise partners. In this phase of development different Intra-grids in individual organizations are going to be connected with the other Intra-grids in organizations' other cooperation parties such as suppliers, partners etc. This is expected to happen in mid-term.

Inter-grid. The last step is to connect these Intra- and Extra-grids together and form large Inter-grid(s) that spans across organizations, regardless of location. This would mean basically internetworking to provide public resource sharing on a global scale. This would enable the large scale resource brokering and use of global computing power. This step is still uncertain especially in business community (Ong 2003, pp. 36-37).

Inter-grid is closest to the "Grid-vision", which means connecting all the computers around the world as one supercomputer (also known as *the World Wide Grid).* This would mean that different organizations would have access to use the same computer resources. While the research communities pursue strongly towards Inter-grids already today, in commercial side it is not going to happen at least in the short run.

However, as the Grids emerge, technology progress may provide increased capacity at the cost of increased complexity. There are orders of magnitude more servers, sensors and clients to worry about. This is an important aspect of Grid developments in the future. Berman et al. (2002, p. 43) point out that both the nodes of the Grid and their organization must be made robust and internally fault-tolerant, as well as resilient to changes and errors in their environment. Ultimately, the Grid will need self-optimizing, self-configuring, self-healing and self-protecting components with a flexible architecture that can adapt to change (Berman et al. 2002, pp. 42-43).

4.6 *Utility computing*

As the development of Grid computing continues, some of the potential applications can be identified. The application layer can be viewed from the industry segment perspective by putting forth the industries where the Grid computing is currently used or will have the greatest potential in the short-run. The few primary vertical markets that have shown the most interest in Grid computing this far include life sciences, energy and oil, manufacturing, financial services, and government. Applications vary based on the industry, but a few of the primary drivers are identified in Table 10.

Table 10. Potential driver applications of Grid computing (Thompson & Clavenna 2003).

Industry segment	Current or potential applications
Life Sciences	Bioinformatics, drug discovery, document sharing, process outsourcing
Energy	Gas and oil exploration, data-set visualization
Manufacturing	Simulation-based test and evaluation, partner collaboration
Financial	Enhance performance for intensive tasks like portfolio risk analysis
Government and R&D	Simulations and design, distributed database coordination, service utilities

Although from the pure technological point of view the development of Grid computing may be seen evolutionary, it can revolutionize the way this technology is used. Maybe the biggest business impact Grid computing will have, is that it will change the computing from product-based to *service-based*. Before the Grid computing if the organizations wanted to get more computing power, they had to buy more servers and other computers. But with the Grid computing they only buy more computing power without the hardware, just like the electricity. This service-based computing is called *utility computing*.

Emergence of the utility computing market is seen as a major driver also to Grid computing. Although these two terms are often used as synonyms, the utility computing is more comprehensive and business-oriented term. It is actually what the vendors are selling today and what the customers want: more flexibility and productivity into their

IT processes. This means that Grid computing is one (although very important part of the utility computing) tool among other technologies in this new way of delivering computing services. As Ong argues (2003, p. 36), “the difference between the two is that the Grid computing is really the enabling infrastructure that will help to further the business concept of utility computing”.

In the long term utility computing refers to the vision that a ubiquitous ICT infrastructure will deliver all the computing needs, whether they are for business or entertainment. People would own far less computing assets than they do now but would instead pay for access to services delivered by "utility computing". I.e. individuals and organizations would pay for what they use and no more. This would mean that the users would get computing resources like electricity or water from the tap, as a utility (UtilityComputing 2004).

This vision would change radically the computer business as we know it today. The ability to swiftly up- or downscale to meet demand would have a revolutionary affect on companies and the way in which they formulate their strategy. The concept would also be applied to individual users of computing, where they would no longer need to buy their own computers and do regular upgrades, but instead would be offered packages like they choose their satellite television services today. Thus, the business would be service-based as mentioned earlier (UtilityComputing 2004).

At present, the market for utility computing and *on-demand*[16] services is in its early stages and the infrastructure required to deliver that reality are beginning to be in place. IBM has been working on the idea for some time, but the major technology vendors are now all competing for position. At this early stage, their offerings may be seen as IT outsourcing, where large corporations allow dedicated service providers to take care of all their IT needs (UtilityComputing 2004).

The utility computing is becoming more popular all the time when the knowledge of it spreads. According to the results of an IDC study examining the services perspective of

[16] IBM calls their utility approach as “On Demand” and HP as “Adaptive Computing”.

utility computing nearly 65% of 34 potential large customers interviewed indicated that they are interested in leveraging this type of service (Grid Today 2003).

As utility computing market is emerges, also the players have been identified. Players of the utility computing market can be segmented into the following categories as shown in Figure 16 (Ong 2003, pp. 46-59). Players are explained shortly before the figure.

Grid resource suppliers are the ones who supply Grid resources in this whole utility computing system. They can supply either hardware (to provide computing power, storage and bandwidth) or software (such as software licenses or applications) to the utility service providers (later referred as USP). The Grid resource suppliers do not offer end-to-end solutions for IT problems that businesses meet but rather, they concentrate on developing hardware and software products that can be used by the USPs to deliver IT solutions to solve problems that end users face.

Grid infrastructure suppliers are the ones who make the Grids function by supplying the appropriate hardware and middleware. Their role in this value chain is to facilitate the connectivity of the Grid resources to the end users. They are also likely to deal directly with the USPs, rather than the end users. This group in the market consists mainly of Grid hardware suppliers and Grid middleware developers.

Utility service providers (USPs) would be the new name that IT outsourcers adopt in the new utility computing market. USPs still perform the role of an outsourcer but their responsibilities in this new market entail more than just providing the appropriate IT resources. They would also be responsible for upholding the terms of the Service Level Agreements (SLAs), monitoring the IT usage and billing the clients appropriately.

Re-sellers are another variant of the USPs. These providers are likely to operate on a smaller scale. The re-sellers (such as Internet Service Providers, ISPs) would repackage the services provided by the bigger utility service providers and sell them (e.g. adding on enhanced services on top of the bare-bone services provided by the USP). They act as the middleman between the end users and the USPs. For example telecommunication companies (Telcos) may have major difficulties ahead because Grids require bandwidth to scale. Unless network service providers find a way to offer value-added services related to computing as a utility, they may be relegated to a commodity role (Insight Reseach 2003, pp. 2-3).

End users. There are two distinct groups of end users – the business user and the leisure user. The business users would refer to enterprises that require an extensive array of IT resources on a daily basis whereas the leisure user has a relatively low demand as compared to their business counterparts. The leisure users would refer to users that use IT resources for personal purposes such as a college student running a simulation.

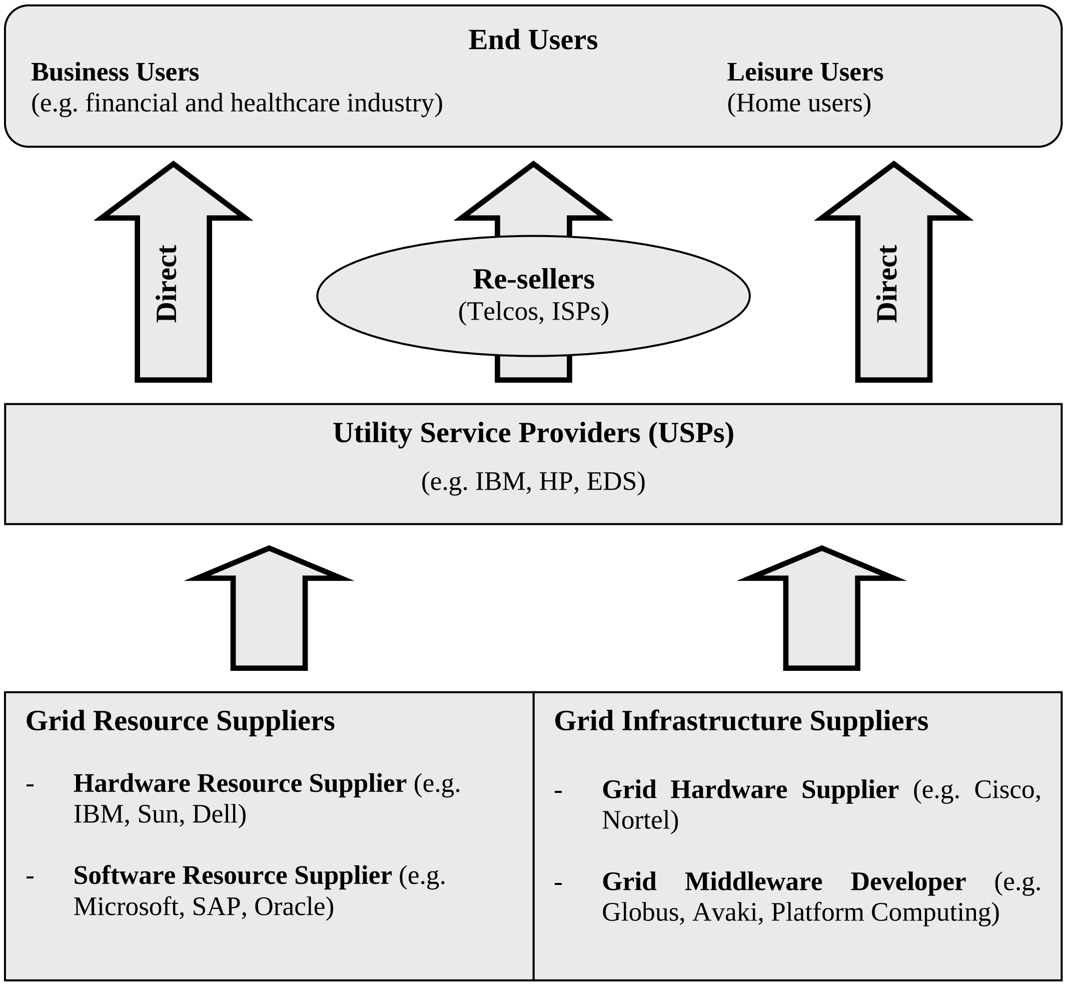

Figure 16. A general view of the utility computing players (Adapted from Ong 2003, p. 48).

4.7 *Grid computing as an innovation*

Information and communication technology as a whole is a transformation innovation for whole society and environment as Tidd et al. state (2001, p. 7). Grid computing has the potential to be one part of that major impact on society. Although Grid computing has analogies with extensively used technologies as Internet or power-distribution network, it is still long way from having the same extent of impact on people’s life. But in the long run the potential is truly substantial, although from the “pure” technological point of view Grid computing can be seen as a part of evolution. Technologically impact will not be shown as new machines or devices, but in the way the current devices are managed.

If this new paradigm, a vision of one “supercomputer” becomes reality, it definitely changes the way we see and use computers today. From that perspective Grid computing can be seen as at least radical innovation. Grid computing has clearly the potential to become even a transformation innovation within the ICT-industry, if widely adopted in other industries and users. It will change the way the distributed computing resources are managed and transforming computing power from product to *service*. Companies do not need to buy a set of hardware to have needed computing capacity; instead they can fulfil the same need with utility based service. Thus it is a new way of understanding and managing already pervasive computing technologies (e.g. Internet and PCs). This would mean a marketing discontinuity in both macro and microlevel if compared to criteria of radical innovation by Garcia and Calantone (2002, pp. 120-124).

People who do not need Grid computing (e.g. many home users) may probably see it just an incremental innovation as a part of normal development. But the ICT-industry vendors may well see very massive impact and a transformation in a way they serve their customers and in the way these services are being produced. Among them and some end users (especially business users who can improve their own processes with Grid computing as well, e.g. finance companies) it is perceived as a radical innovation.

If compared to the definition of Schoemaker et al. (2000, p. 2) Grid computing is definitely emerging technology with great uncertainty, complexity and paradigm shift relating inherently to it. In Figure 17 the change in computing is illustrated in the innovation space.

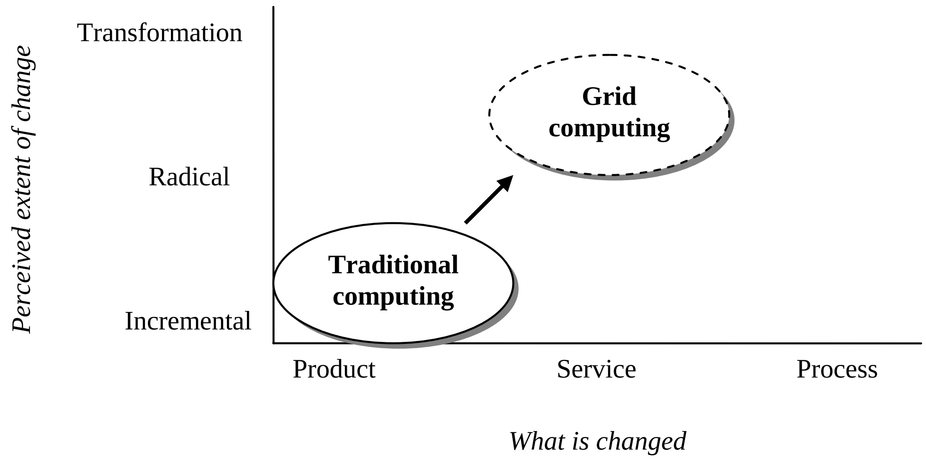

Figure 17. The change of computing (Adapted from Tidd et al. 2001, p. 7).

5 GRID COMPUTING SCENARIOS

This chapter provides an overview of the scenarios on commercial Grid computing in 2010. First the conducted construction process is outlined and finally the scenarios are presented and discussed.

5.1 Defining the scenario analysis project

The focus of the project was set to find out what kind of possible future worlds the Grid computing could have and what are the major drivers behind this development. According to Heijden et al. (see 2002, pp. 233-234 or chapter 3.3.2) the purpose of this kind of scenarios is "making sense" of the puzzling situation. In this case with Grid computing, it is necessary to rely on information available from experts, because there simply is not enough information available explicitly. Also it was preferred that the experience and the knowledge of the project members would be exploited. The best method in this situation was seen to be scenario analysis. This view is in line with the characteristics of the situation where the scenario approach is recommended in literature as well (see Levary & Han 1995, p. 14 or chapter 3.5).

5.1.1 Defining the scope

The process started with defining the scope of the scenarios. This was done together with the project management team. As a result the scenarios were set to describe the future of the Grid computing with the relatively wide scope, i.e. in a global scale, because the main goal was to raise general awareness on Grid as a technology among the research and companies. This meant that written scenarios were going to be *environmental* (or *theme*) scenarios, i.e. they describe Grid computing from neutral perspective without direct linkage to any organizations activities or strategy.

The timeframe for the scenarios was set to the year 2010. With that timeframe the development paths of the different elements could still be seen relatively logical and clear enough (e.g. Mannermaa shares this same view as well, see chapter 3.4.3).

5.1.2 The structure of the project

In the next phase the structure of the scenario project was planned. The writings of the most distinguished scenario developers (Heijden et al. 2002; Ringland 2002; Schwartz 1996) were used as helping guidelines, when developing the framework for our agenda and working methods. The structure of the project is illustrated in Figure 18. The conducted project can be divided in the five different stages:

Stage 1 – the scope of the study was defined, methods and tools were agreed. *Stage 2* – an environmental scan was conducted, leading to an analysis of the major drivers likely to shape the commercial Grid computing over the next six years, this was conducted partly based on literature and partly on brainstorming session in workshop, preliminary consultations were held by questioning the Grid and ICT experts. *Stage 3* – a facilitated workshop involving participation of Grid computing experts was used to develop four draft scenarios. *Stage 4* – identification of the key issues for Grid computing over the next years in every scenario. *Stage 5* – expert interviews to refine the scenarios and to identify the implications, preparation of a final scenarios providing an analysis of the major drivers shaping Grid computing, a set of scenarios of the future of Grid computing, and a emerging issues in Grid computing as implications.

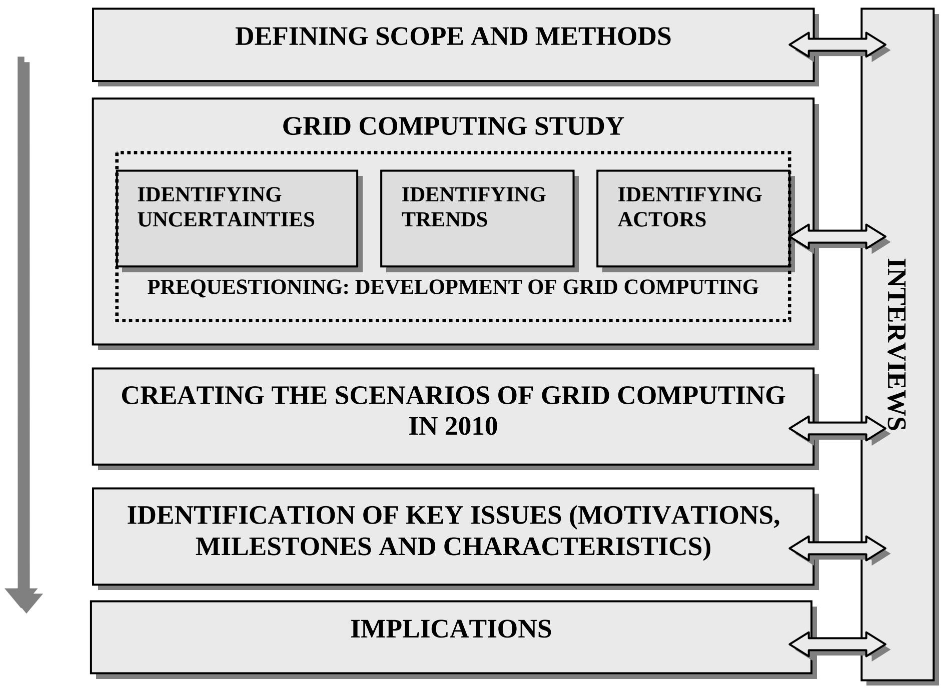

Figure 18. The Grid computing scenario process.

The main event of the scenario process was the workshop held in Geneva at CERN in 16th of December 2003. It was a one-day workshop and the main focus of the workshop was to create sketches for the scenarios to be refined ready later on. Scenarios are based on the thoughts of workshop participants who were ICT industry and Grid computing experts (see Appendix 1).

5.2 Pre-questioning

The pre-questioning was conducted before the main event via email. The main purpose of these questions was to get a starting point for the scenario session and also to get thoughts tuned up a little bit for the day. Workshop participants got the questions specifically developed for this session (see Appendix 3).

The questioning brought forward some certain issues which were seen important in the development of the Grid computing. Combining the current understanding of technology, sociology (e.g. needs of the end users, acceptability of the technology), business and politics into a coherent strategy was seen as a biggest challenge in making the Grid computing reality in the future. Like one respondent put it: "*The pieces of the puzzle exist, but at the moment the vision is limited to a subset of the fields*".

5.3 Environmental scan of Grid computing

Before the scenario session an environmental analysis was also conducted by the researcher. From the pre-questioning and literature some of the current factors which are affecting the development of Grid computing were gathered. These trends and assumptions form a basis for the written scenarios, although they were not particularly discussed in the session. These factors have been listed in the following PEST-analysis[17] (e.g. Johnson & Scholes 2001, pp. 99-102) framework in Table 11.

[17] PEST(E) = Political, Economic, Social, Technological (and Ecologic). It is a widely used tool for environmental scan. Also known as STEEP analysis.

Environmental analysis consists of a systematic scanning of the environment for trends, precursors, events and signals of many kinds.

Table 11. Current factors in the external environment of Grid computing.

Political	Economic	Social	Technological
Competition between nations is getting harder, e.g. EU wants to be leading economic zone in 2010	Service business becomes more important, e.g. outsourcing of IT grows	Virtual organizations, networking and alliances becoming more common, people work in global organizations	Growing need for larger computing and storage resources especially in research
Actions will be taken against cyber terrorism and other illegal activities (hackers, junk-mail etc.) e.g. censorship, law suits	Asian countries experiencing strong economic growth	Adoption and diffusion of new technologies is uncertain (e.g. the need for the critical mass)	Fast development of IT infrastructure: networks (e.g. wider bandwidth, availability), computing resources (e.g. memory), data (all-IP)
Legislation lagging behind the technological development of the IT industry	Global economy is very fluctuate and more short-termed than ever	People and companies are feeling insecure with IT, because of complexity and unsolved security issues (e.g. cyber terrorism)	Companies spend most of their IT budgets in security, integration software and storage solutions
Governments are investing in new technologies in order to find new sources of competitiveness	"New Economy" is becoming reality and companies are experiencing growth in their productivity because of IT solutions (e.g. Internet)	Growing interest in open source development (Linux etc.) and standardization	In most organizations, there are large amounts of underutilized computing resources
	IT industry is generally very dependent of global economic situation	Malicious activity is more professional and becoming bigger problem	Ubiquitous networks and computing are becoming reality
	Operational efficiency is the key for success in many industries		Wireless/mobile ICT and computing clusters are becoming more attractive

5.4 The scenario session

This section describes the scenario creating session and its results. The structure of the session is presented along with the developed driving forces as well as the chosen dimensions.

5.4.1 Participants

The workshop activities started with gathering the needed visionaries to form the scenario team. As a prerequisite, every participant had to have strong basis in technical issues, because otherwise the limits of the technology and possible development paths would have been too difficult to understand (see Levary & Han 1995, p. 15 or section 3.5).

The group consisted of eight persons who all had very good technical knowledge and up-to-date information on Grid computing and its environment. Most of the participants were Grid computing researchers at CERN. In addition two participants hold the executive positions in the leading ICT-companies with some academic background as well (see the list of participants in Appendix 1).

5.4.2 Creating scenarios

The written scenarios are *environmental*, concentrating on describing the possible future worlds of Grid computing market or industry, so they do not take any firm-specific point of view. The type of these scenarios is *explorative*, which means that they are directed towards the future on the base of certain set of current assumptions. By their logics created scenarios are *intuitive* with some formality (i.e. heuristic approach)

In planning the structure for the scenario session as well as for the whole process, the best overall guides that were used and adapted were the checklist in Schwartz's influential book called "The Art of the Long View" (1996, pp. 241-248). The same structure is also used by one of the leading scenario consulting company called Global Business Network (Kleiner 1999a, pp. 78-81). The main steps of the method are presented in Table 12.

Table 12. The intuitive scenario creating method (Adapted from Schwartz 1991, pp. 241-248).

Step	Description
1	Identifying focal issue or decision
2	Key forces and driving forces in the environment
3	Rank by importance and uncertainty
4	Selecting scenario logics
5	Fleshing out the scenarios
6	Implications
7	Selection of leading indicators and signposts

Instant scenario technique (Heijden et al. 2002, pp. 187-224) was applied to enhance the process as well. This was done because of the time restriction. The method is very practicable to get well-defined results with the expert group in a short period of time. These both guidelines were used in the scenario session with the expert group (see Appendix 2). This approach is very different from the "business as usual, best case, worst case" approach (Coyle 2004, p. 61), in that it concentrates on creating credible but different worlds for each scenario.

The written scenarios can be classified according their process, content and goal with the scenario cartwheel (Notten et al. 2004, p. 11). The created Grid computing scenarios may be located in the north-east corner (see Figure 19), i.e. they are explorative, intuitive with some formality (heuristic) and done through relatively simple process.

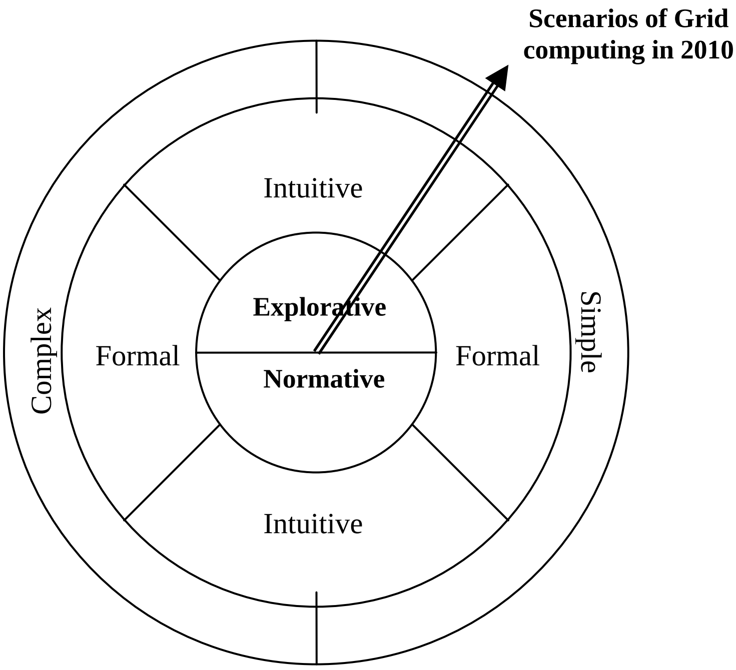

Figure 19. The scenario cartwheel (Adapted from Notten et al. 2004, p. 11).

5.4.3 Setting the definitions straight

In the beginning of the workshop the definitions and the goals of the day were discussed and agreed. This discussion raised questions about the definition of Grid computing business and further about the definition of "Grid" itself. After a conversation commercial Grid computing was seen to be:

Commercial services, products and solutions that are produced or offered with the Grid technology or enabled by the Grid technology.

As presented earlier in this thesis (see section 4), in literature this definition is quite close to concept of utility computing. The main difference between the two is that the Grids are really the enabling infrastructure that will help to further the business concept of utility computing (Ong 2003, p. 36).

5.4.4 Driving forces

The workshop started with a brainstorm session, where almost 80 different uncertain driving forces and factors were incubated. After a little conversation these drivers and factors were clustered into ten larger groups as follows:

- **New engines of growth**
    - China, India and South Asian countries are experiencing strong economic development with GDP growth rates approximately 6-9 % per year and their middle-classes are growing quickly. (IMF 2004, pp. 6-7) These countries want to be also in technology forefront, often with ambitious development projects (e.g. at the present moment China is deploying Inter-grid between all the major Chinese universities, which should working in 2005). At the same time USA and especially Europe are having problems with their economic growth, and many jobs and businesses are being transferred to lower-cost countries in search of efficiency. Grid computing can be seen as a tool for less developed countries to have an easier access to advanced scientific instruments and calculation power and international research projects as well as a new method to increase productivity e.g. in USA and Europe.

- **Regulation**
    - Often the legislation has lagged behind the rapid development. If especially global Inter-grids will be built, then there probably have to be global rules of the game as well. Will there be any regulations or do users define what is allowed to be done and what is not? In these outcomes governments' and authorities' responses to the development will be important. If access to Grids is regulated, it definitely will have a major impact on the development.

- **User/customer requirements**
    - Many promising technologies have failed to have a commercial breakthrough, because technology has not really fulfilled the needs and requirements of the users. With the Grid computing users want to have a robust technology that eventually has positive effect in their productivity, cost reduction and competitive advantage. If these benefits can be delivered in secure way to the customer so that they can trust vendor and the technology, there can be major business opportunities.

- Major issues are also the control of the resources and pricing. There need to be clear policies and robust systems to ensure that it is safe to companies to use Grid technologies without worrying about losing the control of their systems. Pricing strategies, policies and methods are always important as well, especially when entering to market and failing in any of these requirements can be devastating for the business.

- **Acceptance/scope of Grids**
    - Are companies and users really ready to accept Grid computing? And which kind of solutions and applications are companies willing to use? In research Grids are widely accepted as a new powerful tool and many of present projects are international, but in the commercial sector the more traditional approaches are still the more popular. Companies have to come up with wide range of new innovative applications and services in order to attract customers.

    - There are many visions of companies using large-scale Inter-grids, but in order to become reality before the year 2010, Grid computing has to go through very rapid technological and commercial development. With low progress even the commercial Intra-grids can be unrealistic, not to mention Extra-grids or Inter-grids. The clear and quick benefits of the Grid-usage are the best possible help in this diffusion. The expected evolution can be found earlier (Figure 15, p. 59).

- **Security**
    - Security and trust issues definitely play important roles in business related matters. If the Grids are to be accepted by corporate and government IT departments, a wide range of security concerns must be addressed. Technical issues are not the only things that have to be solved before users start to acquire these new technologies. Trust issues are mostly social and psychological and therefore they can be even more important than technical concerns. If there will be global data processing,

the data security must be shared as well. In order to Grid computing to be robust and acceptable to users, there have to be common trusted authentication, ciphering and security standardization.

- **General ICT infrastructure development**
    - As Grids evolve from clusters to virtualized enterprise data centres to distributed campus and wide-area deployments, the underlying network must cost-effectively grow, in scale and performance, to meet the demands along the way. High-performance Ethernet, evolving from ubiquitous networking technology, continues to track the cost, performance, and scalability curves set forth by Grid networking in pursuit of this evolution.

    - ICT is developing very quickly and new technologies keep emerging, so it is obvious that this infrastructure development is playing a big role. The development of the general infrastructure offers many opportunities but many threats as well for Grid computing. The Grid approach may be seen useless, if other technologies fulfil the same needs in more secure way.

- **Access to Grids**
    - In order to make Grids functional users must have access to them. Access to bandwidth will be critical, especially in the consumer sector. Broadband networks are diffusing fast and an international study shows that the very strong growth in the broadband penetration will mean that the market will grow to three times its current size over the next five years. This would bring the current revenues of $30 billion to $80 billion. Worldwide broadband penetration will grow by 22% per annum and in Europe by about 30% per annum for the next few years (Arthur D. Little 2004).

    - Mobile networks were seen important too, especially from the consumer point of view. The growing number of mobile/smart phones and wireless

LAN penetration can form a base for the business opportunities in Grid computing as well.

- **Global economy development**
    - Global economy is more complex and changing more rapidly than ever. "China phenomenon" has brought up many questions about the future of developed countries. Now it seems that there is going to be a period of economic growth at least for the next few years and companies are restoring their investments. This means that companies are more willing to invest in new technologies like Grid computing and utility services as well. However, the global economy development and its polar outcomes (slow/fast growth) have a limited effect in Grid computing investments because the enterprises have always the same need of efficiency and reliable services.

- **Cooperation in the development process**
    - It is crucial for Grid computing that different development parties and instances agree on common policies and technologies. Open source development and different forums are very important. If research and commercial sides cannot agree on outlines, there is a great possibility that the technology will be very fragmented and interoperability problems are likely to occur.

    - Cooperation is important especially in following three levels:

    1. International cooperation between counties and development instances are crucial in order to create nationwide standards and be able to build international Inter-grids.
    2. Cooperation between research and business side has been working extraordinarily well at this point when the technology has been emerging, but eventually it is more likely that the needs and objectives of these parties will differ in ways which can lead to two clearly different development paths.

3. Cooperation in standardization has always been difficult between the vendors because different companies want to push their technology upfront as a common standard, in many cases this has slowed down the diffusion process (e.g. standardization process of recordable DVD system or mobile phone industry).

- **Value creation**
    - In order to have a commercial success, Grid computing must be able to leverage more value than the existing systems and technologies. Adoption of new technologies is always a long process, because the companies have to first learn how to exploit the new possibilities in order to increase their productivity. One thing is that there must be needed value added applications which exploit the Grid computing approach. Utility services and products offered by vendors will include many different features and these can be delivered with many other techniques as well.

    - The Grid technology is already a success in the research and in many cases public sector has been active participant and financier of the grid projects. Governments and public sector (e.g. universities) are very eager to deliver their civic services more efficiently as well. This activity can lead to situation where public sector supports strongly this development with an idea to provide new kind of welfare society services with Grid computing approach. This development is more likely to occur in highly developed countries where governments and public sector have a major role, e.g. Scandinavian countries.

5.4.5 Dealing with the importance and uncertainty

After clustering the driving forces and factors the entire list of related uncertainties can be reduced and simplified into two orthogonal axes. Thus defining a matrix (two axes crossing) that allows us to define four very different, but plausible, quadrants of uncertainty. Each of these far corners is a logical future that can be explored.

We wanted to find out which two of these clusters play the most important role in creating scenarios, i.e. *key uncertainties*. According to scenario literature (e.g. Schwartz 1996; Heijden et al. 2002) those forces or factors are the ones with the *highest uncertainty and importance*. Here, importance of the force or factor is defined as an *impact* they have on the development of future. After having a discussion about the impact of the factors and the uncertainty of factors' possible outcomes the voting was carried out. Used scale was from 1 to 5. This phase was kept relatively brief, because all other factors come back into play anyway when building the scenario storylines. The two most important factors are circled in Figure 20.

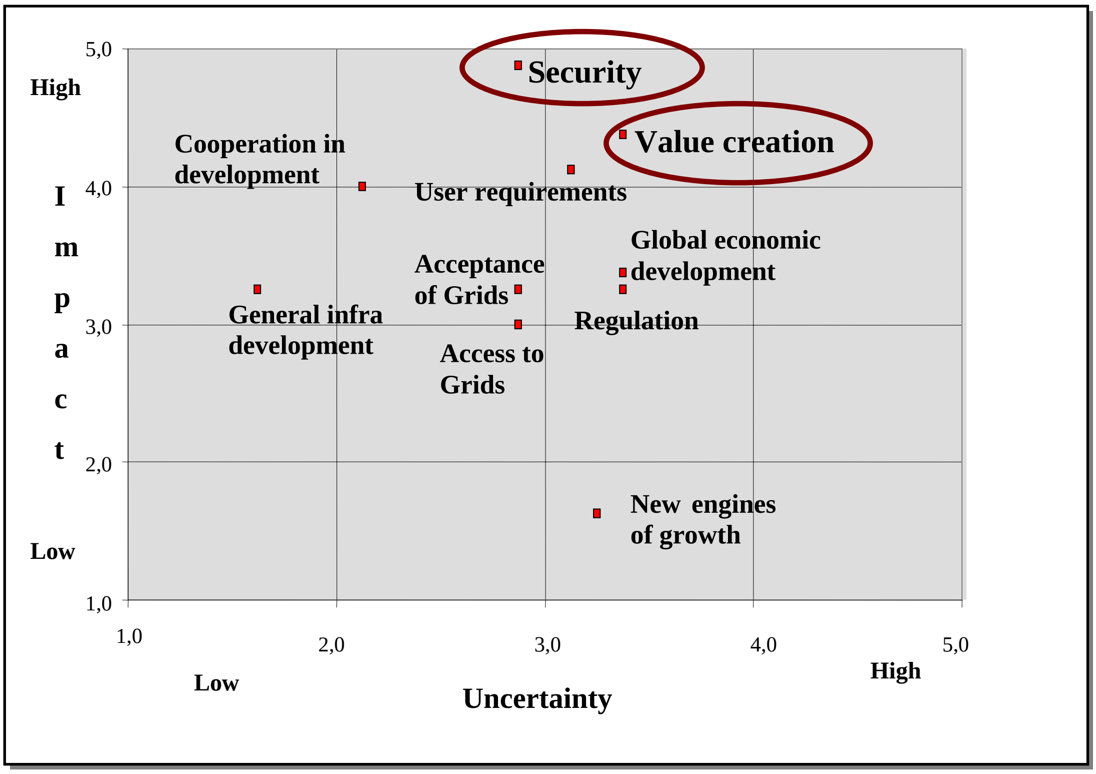

Figure 20. Results of voting (scale from 1 to 5). Chosen dimensions are circled.

5.4.6 Dimensions of scenarios

After voting there was a short discussion about the results and the most interesting factors. The issues looked for are located in the right upper corner. It was seen that the most important and the most uncertain issue in order to create commercial success was *security*. Here, security refers to not only technical issues which have to be solved but also trust issues which are more or less social and psychological. Trust is the key point when users (corporate and government IT departments) decide whether to use Grid computing enabled services and solutions. If the users do not have confidence and accept the technology, the commercial solutions are likely to be failures. The polar outcomes or dimensions for the security axis were *blind trust* and *mistrust*.

The other most important and uncertain issue was *value creation*. Services and solutions enabled by Grid computing have to have strong value added for the customers in order to be commercially successful. The found dimensions for the value were *public support* in the other end of the axis and *strong added value* in the other. In *public support* the governments and public instances e.g. universities, are driving the development, because the corporations have not achieved clearly more value or gains from the Grid computing to be provided directly to consumers. The public sector is willing to invest in these technologies and services in order to improve research capabilities and build better services to enhance the information society development. This creates opportunities as well in the business communities. In the *Strong value added* dimension in the other hand, companies have succeeded in getting the real benefits out of these technologies. This drives strongly the diffusion of Grid solutions in the market.

Another issue being debated was *cooperation*, especially with the standardization process because there can be major problems ahead if the vendors break the current standard “consensus”. Although the current open standard development is now supported by many large vendors, different business strategies and objectives can lead to a situation where all vendors do not want to use the same standards. Eventually this factor was not seen to be equally uncertain than value creation and trust, so it was counted out.

After this phase the four following scenarios were sketched out (see Figure 21). Each group were asked to come up with strikingly memorable names (see e.g. Coyle 2004, p. 61) which would capture the essence of every scenario. Few groups used animal names to describe the scenarios. Also one of the leading scenario consultant firms Global Business Network emphasizes this style; see e.g. famous Mont Fleur scenarios (Kleiner 1999b, p. 85). Scenarios are illustrated below in Figure 21 with the chosen dimensions as the dividing axes.

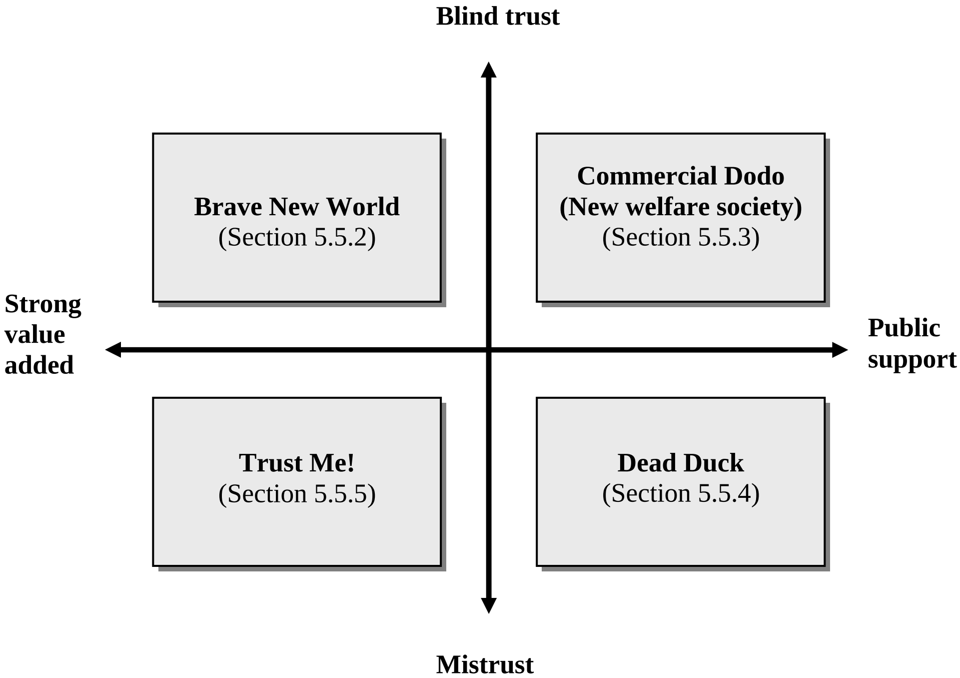

Figure 21. Scenarios for Grid computing.

5.4.7 Writing the scenarios

The final task in scenario development was to turn this list of descriptions and outcomes into short "histories of the future". To achieve this, the teams were told to project themselves to the end year of our scenarios, 2010, and develop the story of how they came to be in the situation they find themselves in. Teams were also looking for some actions or events – *milestones*[18]- which could show the path or direction of the development in the near future. Milestones are important because they are the *early warning signs* that tell which scenarios are beginning to unfold. Sometimes, the leading indicators for a given scenario are obvious, but often they are subtle. It may be some legislation, or technical breakthrough, or gradual social trend (Wilkinson 1999).

The development of scenario outlines was undertaken in sub-groups, so the attendees were divided into three groups, with each group having about an hour to work up their storyline. Sub-groups had two or three members each. One scenario was decided to be

[18] Meristö (1991) uses the concept of *buoys*, Wilkinson (1999) *early warning signs* and Schwartz (1996, p. 246) *leading indicators* or *signposts*.

for later writing because our time restriction and number of participants (with eight members we got two groups of three and only one group of two instead of four groups of two). The scenario called “Dead Duck” was decided to be written later in TBRC based on the notes and ideas from the session.

After sketching the storylines, groups presented their scenarios to each other, with the larger group acting as devil’s advocates. Some questions and adjustments were made, but major discontinuities were not found. Preliminary scenarios were rewritten and finished in TBRC based on sketched outlines in the workshop.

5.5 Scenarios

The following section presents the scenarios with a written story and by showing a table with gathered

- *preconditions* (how the environment develops in order to enable this scenario)
- *characteristics* (key points of each scenario)
- *motivation factors* (why actors want this scenario to happen) and
- *milestones* (events that show this scenario is emerging) of every scenario are presented before the actual scenarios.

Every scenario is presented also as a figure. These figures are intended to capture the essential parts and ideas of each scenario, and illustrate the main points of the operational environment as a figure. The definition of value network was taken as the starting point in these figures. It was used only for guideline and as a framework, not so much as strict rule how the figures should be created. The definition of value network can be simplified and shortly described as “*A group of actors that add value to the final product/service provided to customers”* (Sainio 2003). It is derived and expanded from concept of value chain thinking[19] where value adding elements are seen as consecutive activities from supplier to end users. A value network is usually more or less complex arrangement of reciprocal, cooperative rather than competitive relationships between legally independent but economically interdependent firms (Pfohl & Buse 2000, p.

[19] The concept of value chain was introduced by Porter (1985).

391). In addition the roles of research community and public sector were also considered in these figures.

In creating these scenarios the actors were first identified. Second, the actors who would take the leading role (network centre/hub) in each scenario were found. Scenario groups also looked for positions of other players in the network, their dependencies, powers and customer contacts. Product and service examples as well as earnings logic possibilities were also encouraged to be considered.

The definition of value network as a basis, the emphasis of this phase was to find interrelationships and connections of actors in created scenarios and bringing forth the most important ones. Two of the figures ("Commercial Dodo (New welfare society)" and "Trust Me!") were already made ready during the workshop while the other two were created later based on the notes from the participants. The main points of the figures are explained briefly.

5.5.1 Scenario outlines

This chapter presents the created scenarios with a few sentences. After these short outlines the full-length scenarios are presented with the illustrations of their operational environments. Scenario themes can also be found in Appendix 4, where the key themes of each scenario are summarized.

Scenario 1: *Brave New World* – Grid computing has definitely got the momentum and the Inter-grid development is in horizon. Grid computing is considered widely as one of the most important developments in the history of computing.

Scenario 2: *Commercial Dodo (New welfare society)* – The business environment has not accepted Grid solutions, but governments are pushing the development further. Trust issues have been largely overcome.

Scenario 3: *Dead Duck* – Grid computing is still relatively small size business and companies offering "traditional" computing services are winning the game. Many USP-outsourcing contracts and deals have been called off.

Scenario 4: ***Trust Me!*** **–** The emergence of the *trust boundaries* is characteristic for this scenario. It means that companies lacking the trust make deals and contracts only with their trusted suppliers and partners.

5.5.2 Scenario 1 – "Brave New World"

Limits of possibility: Strong added value, blind trust

Table 13. The key issues in "Brave New World" scenario.

Preconditions	Motivation
- Actions against cyber terrorism work - Positive economic development - Open source dominates - Strong diffusion of broadband networks - Increasing interest in outsourcing	- Customers want to enhance their productivity and competitiveness - Companies need to concentrate on their core competencies and outsource IT activities - Vendors want to create markets, push new business models and make profits before other vendors (fear of losing the business)
Characteristics	**Milestones**
- The emergence of open, virtual organizations - Benefits and concrete applications of Grid computing can be seen in the early phase of emergence - Effective cooperation both in research and business sides and between them - Successful standardization process - Profitable business with variety of vendors in the market	- First Extra-grids appear in enterprises - Small Grid computing vendors' stock prices outperform the markets - Building of nationwide high speed networks - The service business of large vendors becomes more important for them (more turnover comes from services)

Some years ago researchers and Grid vendors had great visions of Grid computing and how it would change the way of computing. Who would have guessed, that they would be mostly right. Companies like IBM, HP, CASun (formed in a merger of Computer Associates and Sun) and of course GridVendor Ltd., one of the most promising Grid computing company in the market whose stock exchange price rocketed in the Nasdaq last year, were certain that Grid computing will be a great commercial success as well in just a few years. GridVendor is the first small niche-player with great success in the Grid computing market. It provides comprehensive Grid-software solutions and services for Fortune500-companies around the world.

Strong added value for the customers and users

Vendors have really succeeded in planning, building, running and managing Grids that link ICT to companies' core business objectives, and helped their customers to improve service levels, reduce costs and enhance business performance (almost everything what they promised to do in the future over five years ago). With industry-wide partnerships and a strong commitment to standards of Grid software development, vendors have created real, tangible business value. In other words, the change of computing paradigm is here, at least in some areas of computing.

It was very important that these new Grid computing services could show their effects in cutting the total costs of their ICT and increasing the efficiency of the existing computing resources. Over time, Grid environments have enabled the creation of virtual organizations and advanced Web services as the partnerships and collaborations have become more critical in strengthening each link in the value chain.

We all want to make it work

Nowadays there is high level of co-operation between organizations and common consensus of how to access Grid and how to build on a homogenous platform. Technical issues and standardization have been mostly agreed upon and this has allowed the competition to fuel innovation and market development. Tight cooperation in the development and standardization process between researchers and many major active ICT vendors generated robust platforms and standards for building new services. The most important standard in the success of commercial Grid computing has definitely been OGSA.

All in all, cooperation in the development process has been very successful and large international research and education projects have been conducted (e.g. international data grid project, AllNet, where China, USA and EU set up large grid of computers). In addition many global vendors have build or are building Inter-grids in their own organizations, where different locations and offices are globally connected.

Customers are trusting more and more in Grid computing solutions

Worries about the security issues were taken very seriously because it was obvious that the success in security and trust issues would be essential for the commercial success of Grid computing (and for the other ICT services and solutions as well!). As a result, Grid computing vendors have invested largely in building secure and trustworthy services. At the same time both the vendors and the authorities have taken strong and visible actions against the cyber terrorism, e.g. suing several "hackers", who had coded the viruses which paralyzed millions of computers in the internet. This seems to work: the malicious activity has reduced five years in the row in the ICT industry.

More important issue to be won was customers' trust, because some companies did not want to locate their computing resources offsite and sacrifice their autonomy on them. Fortunately majority of the users did not share this view. Many thought that this was just one evolutionary step to take greater advantage of outsourcing the IT department.

Enterprise Grid solutions are now quite robust technology and this indirectly helps attitudes toward Inter-grid usage. It is this familiarity and opportunity for direct evaluation of the security available that is turning out to be the necessary first step towards acceptance of commercial distributed computing on the public network.

Game is on!

Outsourcing has been major trend in ICT industry for many years already and this has made it easier to adopt these new solutions as well. All major customer segments are adopting this new Grid approach and there is a keen interest especially on changing the fixed ICT costs to variable costs and of course lowering overall ICT costs. Until now, life science industries (especially pharmaceutical industry) have experienced the biggest success in using Grid computing approach. The need for larger computing resources in developing new medicines was the needed "push" and today all major pharmaceuticals companies are exploiting Grid computing in their R&D. Further, vendors have entered to market with very aggressive pricing strategies, which have driven customers to use these utility services and solutions. Enterprise adoption was driven by those who used clusters in 2004.

But the B2B-market is not all what is happening, because B2C- and B2G-markets are also emerging. Many governmental organizations are willing to use Grid computing in producing data-intensive services and cutting their costs. Consumers have been clearly more interested in online-gaming and data storage services than anything else.

The fast growing market and profits have attracted many other ICT-companies as well (Microsoft, Nokia etc.) and nowadays there are smaller niche-players as well (e.g. GridVendor Ltd.) offering their knowledge in more specific areas of Grid computing. The current Grid computing market is estimated to be worth of 10 billion€ in 2010.

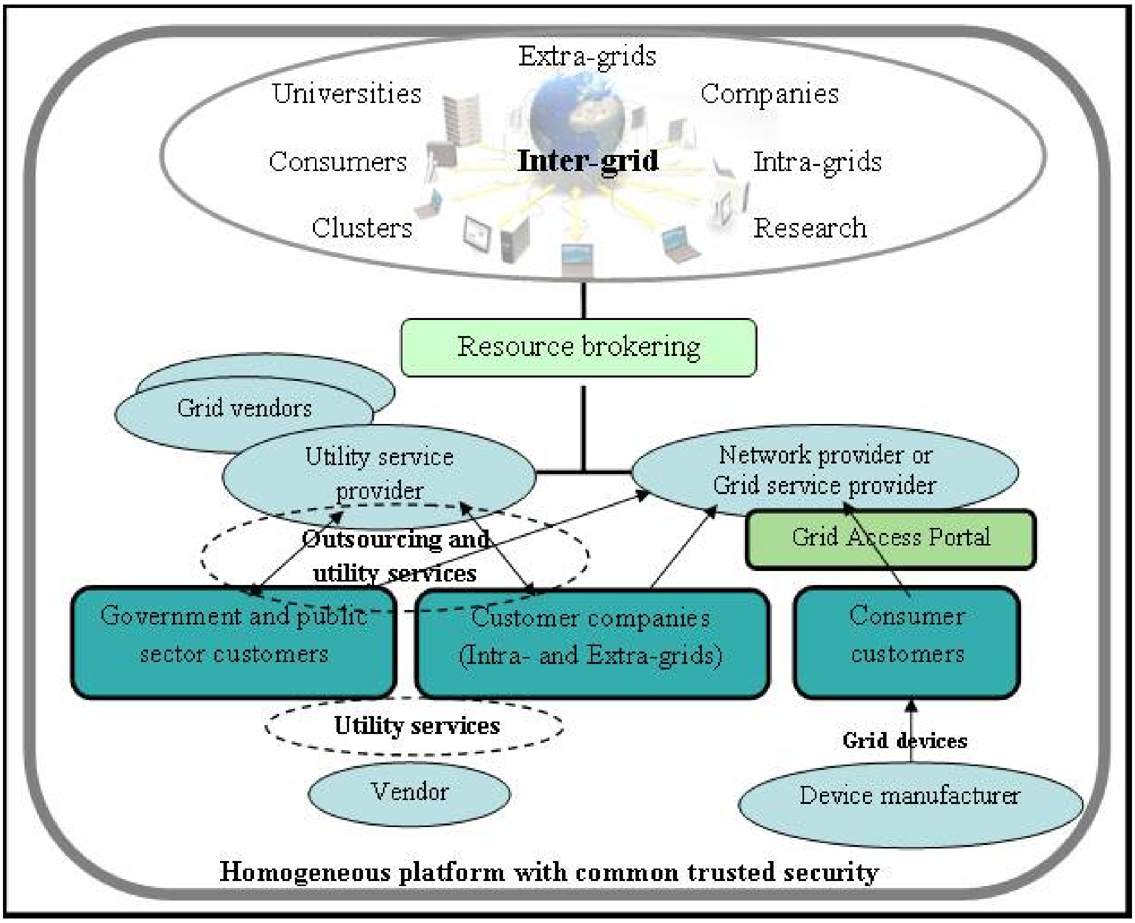

Figure 22. Scenario 1 – “Brave New World”.

In this scenario (Figure 22) the development of Grid computing has really got underway. There is a homogeneous platform with common trusted security solutions. Markets are large especially in the enterprise market but also public sector and consumer markets have started to emerge. Vendors offer ‘utility’ and outsourcing services to public and private sectors. These services include Intra- and Extra-grids as well as Inter-grid solutions. Public sector and enterprise customers can also have access to Grids through Grid service providers. Consumers have access through access portals with their own computers or e.g. smart phones.

5.5.3 Scenario 2 – “Commercial Dodo (New welfare society)”

Limits of possibility: Public support, blind trust

Table 14. The key issues in "Commercial Dodo (New welfare society)" scenario.

Preconditions	Motivation
- Failure of private security - Governments want secure computing - Clear decrease in cyber terrorism - Open source dominates - Digitalization of civic services	- Need to cut costs in healthcare care of elderly - To enhance equality between citizens by providing Grid computing to everyone - To get better research results - Need to provide secure digital services for citizens in building the new kind of welfare state

Characteristics	Milestones
- Governments are active in the Grid development and invest in these technologies - National Grid strategies with e.g. partly publicly supported broadband networks - Public sector has an important role in delivering data security - Tight price competition between the vendors - Emphasis on basic research (computing and storage-intensive research, current development continues) and civic services - Users have strong trust in Grid-based services	- Governments announce clear information society and/or Grid computing strategies - Launch of first civic Grid services

Grid computing was first the promise in the field of research and was supposed to be a major commercial success as well. Unfortunately this “new wave” of computing has not yet fulfilled all the expectations.

Quite surprisingly, the public sector has been the biggest force behind the development of Grid computing. When the Grid approach got attention of the general public, many governments began to be interested in exploiting Grid technologies in order to deliver a wider set of services for the people. This meant also that these governments which had already invested in “Grid-projects” wanted to participate even more actively in the development project. In Scandinavia the progress has been the most rapid.

Two main drivers in this development are the civil rights and the emphasis to offer digital services for the citizens. And although the national Grids are yet to be developed in their full scale, the direction of this development is quite clear.

Governmental cooperation and activity

After year 2005 EU restructured their strategy to achieve the goals set in the so called ‘Lissabon Act’. Major members of EU were worried that the Union would not be the most competitive economic zone in the world now in 2010. Grid technology was seen to be a strategically important technology in order to achieve competitiveness and Grid research got large funding in the Europe as well as in the USA. This broadened up the scope of the Grid in research projects, although commercially it has not redeemed its promises.

In the emerging phase of Grid computing we experienced undisputable success of open source development and cooperation. It seems that everyone understood the benefits of this kind of development, where standards are widely approved and security issues are handled openly.

Governments have been very active in this process through different actions. For example Scandinavian countries made national development programs for the Grid technology, which included e.g. partly publicly supported broadband networks as well as financing large well-known international collaboration project, NorduGridTwo, where Scandinavian countries combined their powers and built the Grid between all the major universities and computing centres. Especially Denmark is among the leading countries offering public services in digital environment.

Trust regained

The failure of private security has been the main driver in the security issues. Governments were forced to take straight actions in order to create the needed trust in Grid approach. Continual problems with the cyber terrorism and uncertainty in using different services are something that no one wants to experience. That is why governments have supported strongly the creation of new *de facto* security solution, where governments have taken the active role of guaranteeing the network identity. One key component of this restricted, but effective security approach is one official, public identity (anonymity difficult) where access rights depend on “good network behaviour”. This approach and major public investments have created strong trust in these offered services.

In addition, many countries have adapted so called national perspective, where national “portals” are offered centrally, and international connections are regulated. It is not necessarily the best possible option but it is definitely working.

Some people are even talking about the emergence of “below-the-line”, underground Grids, which can provide anonymity, sensitive services and of course, more free international access. All the qualities which are not offered in the present approach. Linux-society was quite similar phenomenon some time ago although it is still too early to say if there is even going to be any “underground” Grids.

Globus has emerged as the *de facto* standard to handle lower level Grid operations including authentication, file transfer, resource allocation, and process management. Thanks to public sector, the security issues have been solved in a very large scale. This is important because otherwise it would be almost impossible to offer anything with these technologies.

Research going strong – business still in the starting blocks

There is clear emphasis on basic research: Computing and storage-intensive research for example healthcare simulations. As we know it, this has been mainstream quite many years already. The biggest success Grid computing has had in the research where it is widely adopted. For example DataGrid project (large amounts of data produced by the LHC-accelerator in CERN is been analyzed across widely distributed scientific communities) which is funded by EU, has been a great success. Also the Grid portals which allow home users to participate voluntarily in research projects (i.e. giving their computer's idle time for the use of research) have millions of users as well.

Although the emphasis has been on basic research, there are also other government instances using the Grid approach. A good example is that today's tax administrations are actively exploiting this collective computing power with very encouraging results. This public sector push has stimulated the Grid computing markets and business-to-government business has become the main source of Grid computing revenues to many vendors, which are in tight cooperation with the public sector in several countries.

Market development is driven by the need to cut costs in healthcare system and the opportunities for Grid approach in telemedicine (to keep elderly people at home longer). Grid computing is seen now as a one possible tool for reducing these costs, increasing productivity and delivering a new set of services. This development is not going to stop just in healthcare sector. The emphasis is to provide other public services as well. Free services e.g. library services will be maybe offered to people (free e-books for a limited time) as well as other educational services.

Free wireless Grid access, W-Grid, has received a wide interest, although business is still quite limited. With W-Grid one can wirelessly connect itself to variety of Grid services, ranging from basic computational services to above mentioned social services.

In practice all the technological building blocks exist, people are trusting in these utility services and there are some commercial solutions too, but the momentum seems to be over. Cooperation between different developing parties has been working and different technical solutions have been developed to support uniform platform, but commercially something is missing and Grid computing is still relatively very small business. So, it is quite easy to see the analogy with a bird, dodo, which was extinct in the end of 17^{th} century. It does not fly either.

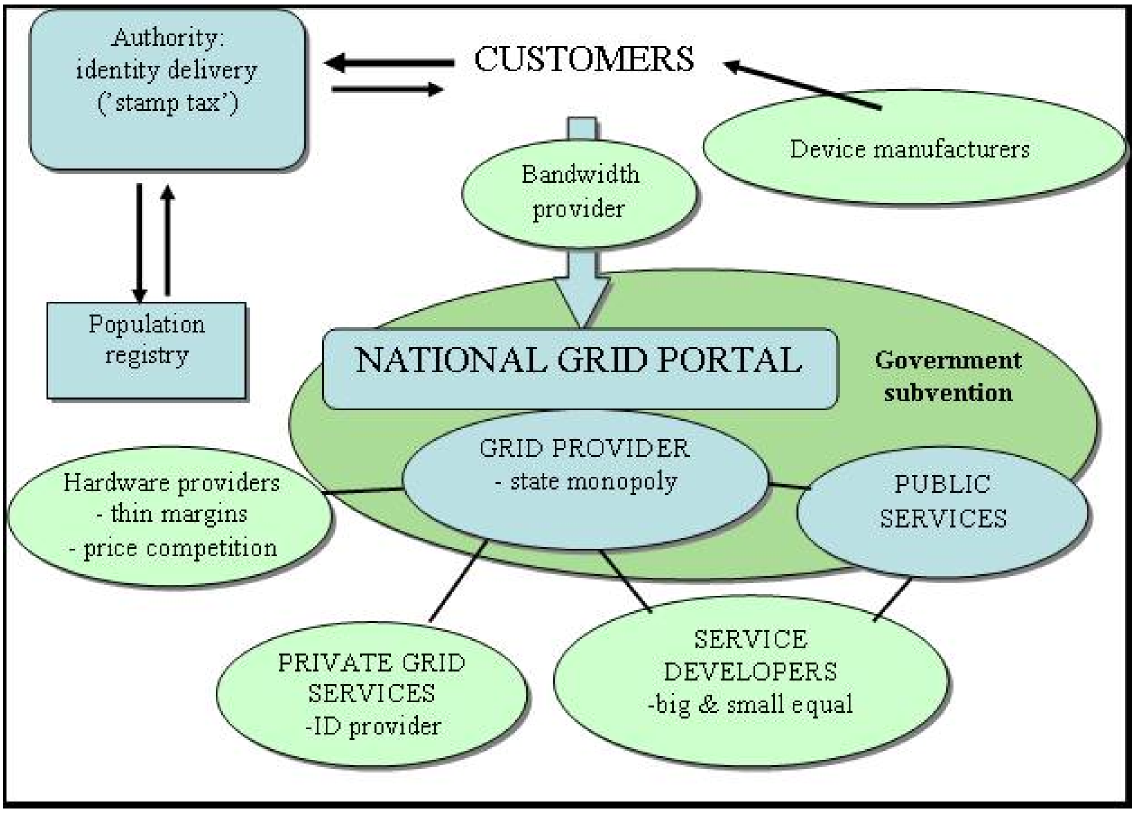

Figure 23. Scenario 2 – "Commercial Dodo (New welfare society)".

In this scenario (Figure 23) the public sector is a major actor as they support the emergence of the Grid computing environment. In this scenario business is created around the modern information society services, which are pursued by the governments and the public sector. Governments invest greatly to create infrastructure which could deliver digital civic services to citizens. This creates business possibilities to hardware providers and service developers. Authorities provide network identities to users and collect payment for it.

5.5.4 Scenario 3 – “Dead Duck”

Limits of possibility: Public support, mistrust

Table 15. The key issues in "Dead Duck" scenario.

Preconditions	Motivation
- Major problems with cyber terrorism - Poor global economic development - Public sector interested in exploiting the advances of Grid computing	- To get better research results - To enhance national competitiveness and advancement (e.g. China) - High computing-intensive users can experience major benefits
Characteristics	**Milestones**
- Customers cannot afford to invest in Grid computing and keep using more robust technologies - Collaboration between vendors breaking up and large Grid projects launched by governments fail - Strong mistrust in Grid computing services leads to many different security solutions - Added value is not realized and major vendors deliver managed or private utility computing solutions that are more readily accepted by the enterprises	- Utility computing vendors do not push and invest in Grid computing technologies - Cooperation organs fail to build robust technology - Bankruptcy or mergers of the small “pure” utility computing vendors

After all the hype and fine marketing slogans, the substance of commercial Grid computing seems to be still quite scarce. In research Grid computing is widely adopted and it has proven to be an effective tool in many research projects but commercially only clients’ business needs will drive the adoption of the various technologies and services along this journey and this seems to be forgotten. Already in the middle of this decade it was seen that although the hype and the great expectations, real value of these solutions and services remains unexposed still many years ahead (some say forever). Consumers and companies have needs for more secure and trusted solutions than what grid based services can offer. Same needs can be fulfilled much more efficiently with the other solutions and still continuing dispute of the techniques and standards e.g. in the resource brokering are definitely not helping the commercial development.

Problematic cooperation

In research, cooperation is the only way to really exploit the advances of this technology, and 'the front line' has lasted. But among the commercial vendors collaboration has ended. Few years ago, consensus between companies and researchers started to scatter because of different opinions how the Grid computing should be developed. As a result, standardization process was too slow to satisfy all parties. This has led to many company-specific solutions and interoperability problems e.g. in security, which has been devastating for the Grid computing market. End-users have strong mistrust towards many of these solutions and this has tightened the dependency between the companies and their former trusted IT-suppliers.

Security issues have not been overcome

Cyber terrorism has become a bigger problem than ever before. Almost every week you hear news about new viruses or other malicious activities and the professional ICT security companies seem to be always one step behind. Taken actions against the cyber terrorism have not been enough. Quite opposite, there are some opinions and fears that the terrorists could easily exploit the benefits of Grid. But still, it is more problematic that technical security issues have not been overcome. For example there is no agreement on authentication etc. It is obvious that without creating robust technology, there will be no trust and surely no users at all.

Not fulfilling the promises

Grid computing showed its capability when different cooperative research projects were successful and the benefits of the Grid computing could be exploited in research. Governments (EU, USA, China) have invested heavily in these projects because no one wants their research lagging behind from others. Probably the best example has been China's large program to build an Inter-grid between every university in the country.

But commercial users do not want to get confused by numerous slogans, they want practical solutions. Now it seems like companies have just come up with a new proprietary mechanism to lock the customer in. In fact, what we are seeing now in the field of utility computing is that many companies, who had outsourced their IT-departments among the first ones, do not want to renew those contracts because they want to take care of their IT in-house style. The main reason is that they really have not seen expected benefits to become reality. Quite opposite, different security failures and lack of common authentication methods have been devastating for the popularity of utility computing. Some companies are also afraid of losing an important part of their competitive advantage with the large outsourcing projects. This has lead to situation where major vendors deliver managed or private utility computing solutions that are more readily accepted by the enterprises.

The adoption has been slow

At least until now, it seems that it is just too hard to change the ways people behave. Going from static to dynamic infrastructure requires greater organizational fitness than we have seen. The real goal, after all, is not having an efficient and agile data centre. The real goal is having an efficient and agile company. So the question is more about the cultural change than about technology and until we are ready to exploit these new innovations, their real value is not realized. Dynamic, adaptive, on-demand IT is a fabulous goal, but just saying that you are going to put orders of magnitude more intelligence, flexibility and harmoniousness into an IT structure is not the same thing as doing it. Sometimes you have to put the flexibility and intelligence elsewhere first.

That demands strong motivation as it will also take time and effort. As a result, not many enterprises have had the energy and enthusiasm to make the transition. They have not only wasted a lot of time and money, but they have ended up being in position of competitive disadvantage. This has been the main reason why Grid computing business has not fulfilled its promises.

Further, many companies have found it useless to invest in Grid systems and solutions, because the present development of the IT infrastructure has been so rapid that the need for more computing power and storage has been fulfilled with more simple and robust computing technologies. Companies are very satisfied with clusters and virtualization as well as SAN (Storage Area Network) -techniques, which all has developed rapidly in the last years and they do not see any strong need for a change. The companies have not seen much of added value in connecting their computing clusters or network attached storages with each other. This has been one of the main reasons in the underachievement of commercial Grid computing.

One major problem is the lack of killer applications. Commercially driving forces for these current services and use of technologies are the same as earlier: companies want to reduce their cost or increase their productivity, simply as that. But we have not really seen any of those, despite few success stories in quite specific sectors like the bio-medical or financial modelling industry. One must understand that not all applications can be transformed to run in parallel on a Grid and achieve scalability. In fact nowadays, although the big marketing hype some years ago, only small portion of applications make really use of Grid computing.

Grid computing is still small scale business

Only industries which can achieve clear competitive advantage (high computing-intensive industries e.g. finance) with the grid approach, have really adopted it, but even in those industries there are built no Inter-grids yet. Even though the Grid computing has not been able to meet its commercial expectations, governments have invested largely on this technology, hoping that it would become a new key to success in research sector.

Major vendors have not succeeded with their utility strategies and although the term ‘utility’ is still widely used in their offerings, it does not mean necessarily that they are using Grid technologies, but other more viable technologies and solutions. Other ICT suppliers with more ‘traditional’ offerings have gained more market share.

It is obvious that the industry has not opted for the right, profitable business models and this has lead to restructuring of the business. Most recent example is the merger between Platform and Avaki some time ago, both promising Grid computing companies few years ago, before their financial problems). Also few players have completely withdrawn from the market. One of the biggest gainers has been Dell Computer, which strategy was not to invest in these Grid-services and technologies at all. Today Grid computing is still estimated to be a small scale market.

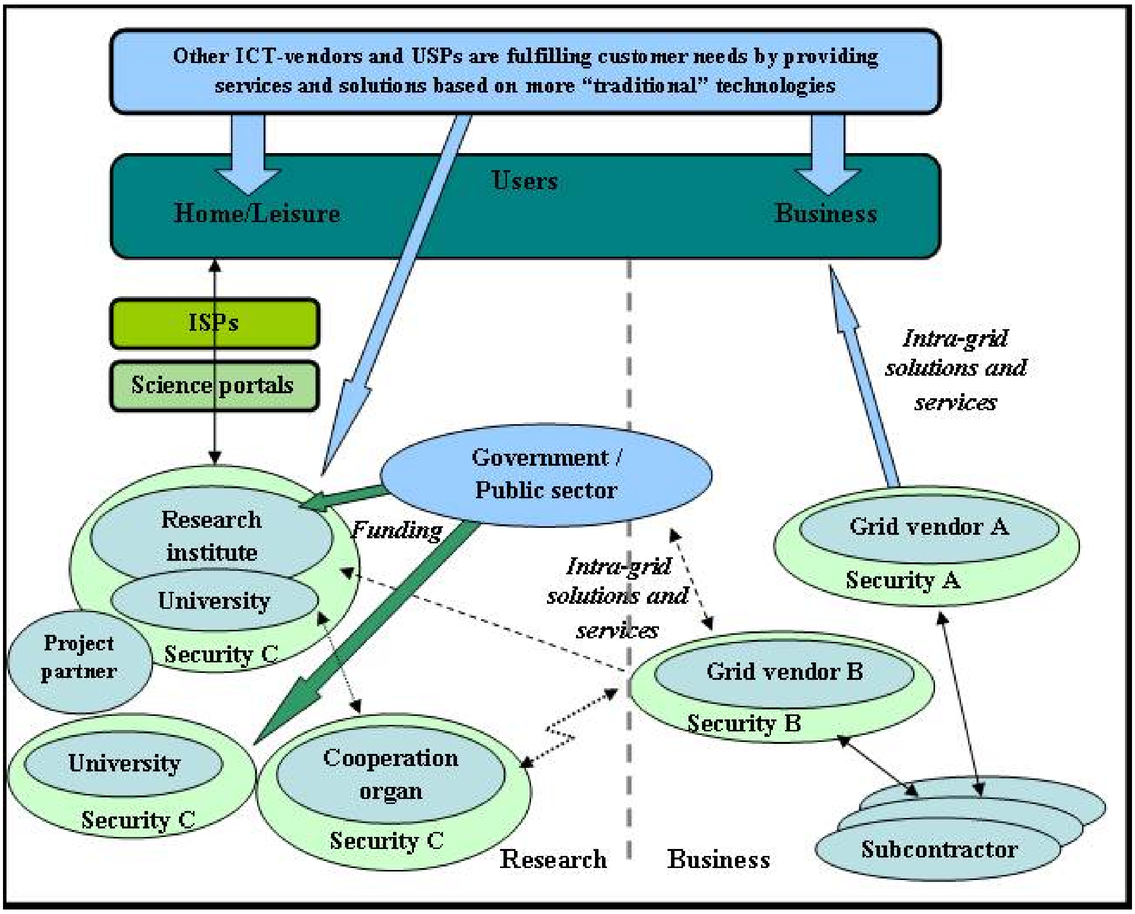

Figure 24. Scenario 3 – "Dead Duck".

In this scenario (Figure 24) research and business communities are quite separated and the cooperation has broken down. This has lead among others to many different incompatible security solutions. Vendors sell some solutions and services to universities and research institutes either direct or via project partners and subcontractors. Different research Grid-projects are mainly funded by governments.

Users can participate in different research projects through their Internet service provider and eScience-portals, but large-scale use is not reality. Pure Grid vendors are in tough position and losing the competition to other ICT-vendors with their offers because the utility service providers deliver their services with more accepted and trusted technologies.

5.5.5 Scenario 4 – "Trust Me!"

Limits of possibility: Strong added value, mistrust

Table 16. The key issues in "Trust Me!" scenario.

Preconditions	Motivation
- Major increase in cyber terrorism - Low trust in IT solutions and services - Positive economic development - Improvements for the security requested	- Vendors want to lock-in customers - Customers want to exploit the possibilities of Grid computing inside their 'trust boundaries' - Companies outsource their IT departments (to trusted vendors)

Characteristics	Milestones
- Big players invest in own secure Grid techniques - Cooperation in standardization process does not work - Many different security solutions with interoperability problems - Grid technology itself develops strongly and creates strong added value compared to 'traditional' technologies - Companies purchase IT inside their 'trust boundaries'	- Failure of basic Grid computing security or short-term collapse of major data system (e.g. Internet) - Launch of vendor-specific security solutions - Applications with clear benefits of Grid computing

The boom in the IT-outsourcing has also opened up the way for the Grid computing. Companies have shown to be quite interested in the Grid computing approach, and there are some commercial success stories. Grid approach has showed strong value for research community where academic trust applies, but there are still strong doubts in business community. The main reason for this is the lack of trust.

The original vision still far away

Cooperation between companies has not worked and this has clearly slowed down the standardization process. Although many different Grid development projects are under way, it seems that commercial solutions are concentrating on company-specific solutions and diverging from the original thoughts of offering common platforms to users in order to be capable to build global Inter-grid networks.

Despite the problems with the standards, the development has been strong. Vendors have created different robust business solutions for the Intra-grid and Extra-grid approach and pushed these services in the market. New data centre applications have been quite successful among the customers although the ‘real’ wide area Grid services are still unavailable.

Cyber terrorism is a threat, trust me!

The reason why Intra-grids or Extra-grids have not been linked between different companies is simple: the lack of trust. Companies do not want to take needless risks with their ICT. In the last few years there have been some major issues which have cast the shadow over the industry. Cyber terrorism is increasing massively and there are strong doubts not only against the Grid computing business, but against the whole ICT industry. Furthermore, in the war against terrorism USA gave wider rights for the authorities to check suspicious telecommunication activity in the country and now some people say that with the global Grids the “big brother” is truly everywhere.

Users are critical and require more from the Grid because of their mistrust. The perceived risks of putting responsibility for mission-critical data and applications into the hands of other companies are high. Companies want to be sure that they will always have access to their data and applications in every moment, and that there are no risk of other companies accessing their data. Although there are many cases of positive experiences in using these services, generally the data Grid solutions are still kept in-house.

Closed user groups gain benefits

Corporations in different industries have gained clear reductions in their IT-costs with the new utility services, but the mistrust has been an obstacle for the true commercial breakthrough. Today all the commercial Grids are Intra-grids and services are mostly offered by the major players of the industry (e.g. HP, IBM) with their comprehensive (but complex) approach and formerly gained trust. Many of these services have been a part of larger IT outsourcing contracts, which have been quite long, many of them up to 10 years.

As a matter of fact, some experts are strongly arguing that the term ‘Grid’ should not be used when talking about these services, although they are based on the Grid technologies because the services are mostly offered in Intra-grids or Extra-grids at best. The vision of commercial Inter-grids seems still to be somewhere far away in the future.

The idea of true virtual organizations is still basically in square one. Companies would want to get the benefits from Grid computing, but risks seem to be too high because the common trust is missing. User groups are closed and normally these utility computing services are delivered into one company at a time. Best examples of Grid computing with value added are the interdepartmental Intra-grids which have been used in computing intensive tasks. E.g. DrugCompany Ltd. has connected all its 50 000 computers (lap tops, PCs, servers etc.) with each other and uses this one large computing resource in their R&D activities. This exploitation of the company’s whole computing capacity has been one of the most important Grid computing services although it is quite evolutionary development after cluster computing.

Public Grids have not existed in larger scale, because the integrity of information is not guaranteed. However, the anonymous cooperation is quite popular (SETI@home - project was a pioneer in this field) and after some successful voluntary projects (e.g. genetic mapping) the really effective way to get people involved in this kind of projects has been surprisingly lotteries with money prizes.

The emergence of trust boundaries

Academics have stated in several utility computing studies that every user group has their own so called *trust boundary*, which refers to the psychological limit that separates companies’ trusted parties from the mistrusted ones. It seems that it is very difficult to get inside of these trust boundaries and this has led to closed user groups.

However, the companies inside these trust boundaries have very good positions because the customer lock-in is very strong (i.e. high “switching costs”). Using these services and products can tie a company down to one or few vendors. This development has helped "traditional" IT companies, because they have been trusted vendors already for years.

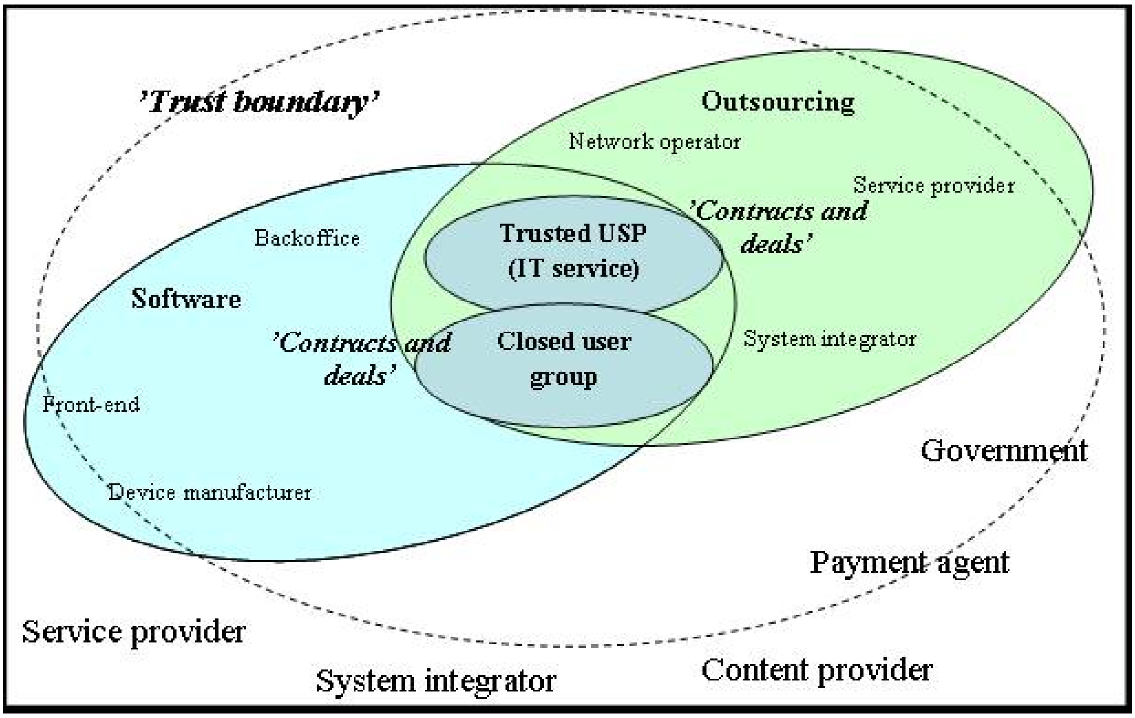

Figure 25. Scenario 4 – "Trust Me!"

In this scenario the picture is quite clear. Trust boundaries have emerged because of the lack of security and trust. Grid vendors are either inside the trust boundary and get the contracts, or they are outside without possibility to get any deals from the customers. In Figure 25 actors inside the boundary are trusted ones and do Grid computing business with customers. The barriers of entry are high and gaining new customers is difficult, because the customers want to do business with the vendors they trust. Established and trusted vendors and utility service providers have strong positions compared to smaller newcomers. Long outsourcing contracts (5 to 10 years) are favoured.

5.6 *Reviewing*

Reviewing is also important element of the scenario analysis. The iteration cycles help to improve scenarios. The created scenarios were sent to a number of Grid computing experts (see the list in Appendix 1). Although there eventually was a scarce participation, several comments and annotations were catered. On the basis of these remarks, created scenarios were refined and the implications were pointed out. Here, only the largest issues are presented.

One of the reviewers criticized the “Value creation” axis. He posed a question of whether there can be public support on technology which is not being value adding. In importance the value creation was raised above other forces, although as few reviewers pointed out it is hardest to define and process because it is relatively abstract term. Without being capable of creating added value to its users, it is obvious that Grid computing will not be a commercial success.

From the four different futures the scenarios called “Brave New World” and “Dead Duck” were seen as the most believable and helpful. In the “Commercial Dodo (New welfare society)” scenario it was criticized that there might be no civic services that could be delivered via Grid. Instead all these solutions can be done without it with Internet services.

5.7 Implications

The four different scenarios searched the edges of the Grid computing development in the near future with the emphasis on the business activities. After writing the scenarios, they were reviewed and analyzed with the emphasis on business and following issues were identified.

Business implications. The breakthrough of commercial Grid computing was questioned and although potentially fast growing, Grid computing market is estimated to be still relatively small in the end of this decade. The majority of the opportunity of Grid computing will be in research and specific industries in the short term. The major business implication is the emergence of utility computing services which are made possible with the Grid technologies. The Grid vendors have to overcome a considerable range of customer concerns by educating customers on utility computing and its benefits, least of which are proving that utility computing services work. Outsourcing trend of enterprises’ IT departments is strong both in situation of positive (search of competitiveness through new paradigm of ICT) and negative economic development (search of cost reductions) and it drives the adoption of utility services ahead.

It is important to focus on early adoption points and provide a compelling, robust value proposition to gain customer trust as a result of these early enterprise datacentre[20] and/or Grid initiatives. If pieces of these Grid technologies are deployed within the deals of next-generation datacentre initiatives, Grids will have a momentum to grow organically.

Totally new kinds of business possibilities will rise as well if the Grid computing really has a breakthrough (resource brokers, identity providers etc.). These possibilities attract also new players. But the newcomers who enter the market have to quickly realize the market potential and be profitable, because this time the major ICT-vendors are in the leading edge (e.g. compared to the development of the Internet). In addition they are in the strong position with established customer base and wide range of services. Established vendors are pushing the development strongly forward in afraid of losing in the competition if they keep offering more traditional ICT-services and products.

Technological and other implications. From the technological point of view Grid computing is clearly an evolution, which means that the needed technologies to create robust services already exist. However security and trust as well as value creation play a critical role in the development of the commercial Grid computing. Cyber terrorism in its all occurrences was identified as a major threat of deploying Grids.

The emergence of underground Grids (in scenario “Commercial Dodo (New welfare society)” was also seen possible. These Grids would lean strongly on current open source development, where developers globally participate in the decentralized development of needed software. Governments may take an important role in the development when launching ICT-based civic services and building next-generation information welfare societies.

[20] The department that houses the computer systems and related equipment, including the data library (TechWeb 2004).

5.8 *Recommendations for possible strategic actions*

Although scenarios were written from the objective point of view, some different possible strategic options and actions were identified. On this basis few strategic recommendations are suggested. The development of Grid computing opens up new opportunities as well as challenges for the vendor organizations operating in the Grid computing environment. All the recommendations are general thus they do not take any company-specific point of view. Recommendations were made by the researcher and they are presented in Table 17.

Every scenario has its own distinctive features and that is why every scenario has different recommendations for the vendors. In “Brave New World” scenario it is recommended to invest strongly on Grid computing and especially for service business. In “Commercial Dodo (New welfare society)” vendors have to be in close cooperation with authorities if they want deals. In “Dead Duck” it is obvious that the market is not ready for Grid computing and that is why the vendors should not concentrate solely on Grid market. Customer lock-in and secure outsourcing services are the key issues in “Trust Me!” scenario.

Table 17. Strategic recommendations for Grid vendors.

Scenario 1: Brave New World	**Scenario 2: Commercial Dodo**	**Scenario 3: Dead Duck**	**Scenario 4: Trust Me!**
Invest strongly on Grid technologies and offer robust services	Cooperate with the authorities and public sector	Do not actively invest in Grid technologies	Create robust, closed solutions, and position yourself as a secure vendor
Participate in standardization alliances in order to create better standards and enhance your power	Develop niche-strategy and focus on e.g. to identity providing business	Withdraw from Grid markets and initiatives	Develop Grid computing-based outsourcing services
Develop outsourcing services into more utility way	Develop and provide civic services	Keep still the eye on the Grid market and be prepared to act if needed	Make long outsourcing contracts and try to lock-in users
Be active in research cooperation of Grid technologies	Support and exploit the open source development	Develop services which are focused to make cost reductions	

6 DISCUSSION AND CONCLUSIONS

This section discusses the limitations and conclusions of the study and suggestions for its extensions and further research.

6.1 Scenario analysis and emerging technologies

Why to choose scenario analysis to study Grid computing? First of all, the great deal of uncertainty and novelty related to Grid computing supported strongly the selection of scenario method. At the present time, as a technology Grid computing is still developing and it has shown its power only in research communities and although commercial activity is emerging, it is too early to say anything certain about the markets. Especially it was experienced that scenario methodology is useful in the case of potentially disruptive technologies, when their future development is impossible to study leaning on the past or current understanding and knowledge. Then new insightful approaches and visions are needed and this can be done with the help of scenario analysis.

The results of this study strongly support the hypothesis that the scenario method is a good tool for studying emerging technologies. It gives you help especially when you do not have enough information to use more systematic tools. With scenarios you can combine existing explicit as well as tacit expert knowledge in narrative way and create something new as well. As Courtney et al. (1997, pp. 69-71) point out, the scenario analysis works best when used in situations where there is a wide *range* of possible outcomes or futures, with no true theoretical, or evidential basis for making a clear choice of which is the more likely, or which factors will have a particular effect. Current scenario literature (e.g. Heijden et al 2002; Schoemaker et al. 2002; Schwartz 1996) advices organizations to accelerate organizational learning by using scenarios in comprehensive style and enhancing strategic conversation. The idea is that with the scenario approach organizations could know a little more about the future than the competitors and eventually this would lead to better results and winning in global competition.

During the scenario process four different pictures of the future were created. The process consisted of problem definition, initial analysis (literature study and pre-questioning) of Grid computing, expert group session, where actual scenarios were sketched, and the reviewing of the scenarios. Since the beginning it was obvious that these scenarios would have to lean strongly on knowledge of technological and industrial experts. The power and impressiveness of created scenarios is in the exploitation of expert knowledge. Without the technological strong background and knowledge it is simply impossible to create plausible visions about the future of such technology. This view is supported in literature by Levary and Han (1995, p. 15) as well.

In this thesis, the main reasons to choose the intuitive logic approach as a scenario methodology were the need to *exploit expert knowledge, time restriction* and *the ease of use*. There was only one possibility to gather the scenario group together in the same place, which limited the number of potential methods. It can be argued that the scenarios would have been enhanced if more sessions had been possible to organize. Scenario analysis was very flexible and major problems did not occur during the session or process.

As scenarios try to influence in decisions made today, the actual use of created scenarios is naturally important. Thus it should be ensured that scenarios really are used in strategy making. It was also noticed that the process itself was highly useful to many experts involved, since the scenario analysis helped to structure the large number of uncertainties and complex issues.

Because created scenarios are intuitive, there lie a few risks in the process. If the process is too intuitive, the scenarios can inherent too much subjectivity and be quite easily criticized as well as implausibility. Whether scenarios are developed to guide R&D plans or to inform other strategic decisions, some basic steps should be always followed. Other possible pitfalls are related to the scenario group method. Strong authorities can try to lead the process and scenarios in the preferred direction. Also the dynamics of the group is important, so during the sessions all disturbances should be extracted. Definitions of different terms, issues and especially goals are critical as well.

Every participant should get a good picture about what they are going to do and why. This thesis leaned tightly on the guidelines of the leading scenario literature in order to minimize the risks of intuitiveness. The most important element in order to success in the process is the commitment. Without willingness and interest to create and use the scenarios in strategy making and everyday decisions, the benefits of the methods will not be achieved.

The empirical part of this thesis is based on views of technological experts. Few of them had also strong business expertise from the field. It can be argued whether these scenarios would have been more insightful if experts from other industries or instances would have been involved. Of course this is possible, and some technological emphasis was noticed during the session, even though the group was asked to concentrate more on the business side. Nonetheless, in this case it was assumed that the technological expertise is the *threshold* competence, which all the participants should have in the first place.

The timeframe of the created scenarios was six years, because the rapid development of Grid computing. This was supported in the literature, but still one could argue that chosen timeframe is too short to create clearly different realistic and possible visions of future.

In my opinion, scenario analysis is suitable and applicable in a variety of situations in any organization because it is a very flexible method. Of course, the final structure and method should be chosen according the available resources. The scenario process takes time and effort in order to succeed. Thus it is realistic to assume that large companies can use more complex methods to create scenarios than smaller organizations. It is also good to remember that scenarios are normally made for long-term planning. In short-term planning it is more adequate to use other future research methods.

6.2 Grid computing

Although Grid computing has analogies with extensively used technologies as Internet or power-distribution network, it is still long way from having the same extent of impact on people’s life. But in the long run the potential is truly substantial, although technologically Grid computing is just a part of evolution.

In the research Grid computing is already showed its potential and it is currently being used in many different science and industry-wide collaboration projects all over the world. At the same time a number of ICT vendors are pushing these technologies strongly forward and trying to “cannibalize” their own old business, because they are afraid that otherwise someone else could do it for them. If the Grid computing destroys the competence-base (see chapter 2) which is needed currently in the industry, the first-movers will have a clear advantage. That is why major ICT-vendors are collaborating with their competitors and that is also why these scenarios were created. So it seems that at least now the researchers and businessmen are going to same direction.

But after all the marketing slogans and visions, there are a lot of open questions remaining and a great amount of uncertainty surrounding the possible new paradigm of computing technology and its business. At this point, no one can really say if there is going to be any major Grid business and wide adoption of these technologies at all or will it still be “a great promise of the ICT industry” in the year 2010. The written scenarios tried to expose those different possibilities and tell different possible stories about the future.

Four clearly different scenarios were created. Written scenarios present four different development paths for the Grid computing in the next following seven years. One goal was to find out elements which will have effect and potential to shape the future Grid computing. Tens of factors were identified during the workshop and clustered in eleven different groups. Found uncertainties which will have the strongest influence in development of Grid computing were security and value creation.

Scenario “Trust Me!” was created on the assumptions that Grid computing has a great deal of added value to the companies but the trust towards technology is missing. The role of the governments can be quite surprisingly very important and especially the scenario “Commercial Dodo (New welfare society)” explores the possibilities that countries actively utilize Grid computing in delivering welfare services and sees it as an important tool in building the modern information society. “Brave New World” is clearly the most positive scenario and describes the world where many of the great visions have realized and Grid computing business is flourishing. “Dead Duck” instead showed the future where the Grid business has not taken off almost at all.

Among other things, the role of government and public sector was found highly important and the possible emerge of trust boundaries was noticed. Milestones were identified for each scenario as well. In future they will show which scenario starts to emerge. The large investments on Grid computing will not be paid back in the short run, but as in the case of every technology. As a managerial contribution, different general strategic actions for the vendors were recommended. Similar recommendations could be made to all other players of Grid computing in every scenario as well.

6.3 Further research

Now scenarios were used to study the environment of Grid computing from the objective perspective and only few general strategic recommendations were given. As an extension, scenarios could be used more closely for strategic planning in organizations. The viability of existing or chosen strategies in different organizations could be tested in these scenarios as well. Secondly, the scenarios should be used to create new strategic options. In order to do this, members of the stakeholder team should try to “live” in each scenario and determine what strategies or actions might lead to success. Then the options for each scenario should be tested for robustness. This is important because making strategy development proactive rather than reactive and dynamic instead of static is among the most valuable dimensions of scenario analysis (see e.g. Heijden et al. 2002; Schwartz 1996).

Different possible future research areas and/or business possibilities in different scenarios could also be studied e.g. with the help of group decision support system (GDSS) methods. With GDSS different possibilities could be evaluated and prioritized for the basis of strategy (see e.g. Bergman et al. 2004).

The idea of *open innovation* (e.g. Chesbrough 2003, pp. 1-24) poses an interesting perspective to Grid computing as well. Open innovation refers to an innovation process where organizations share their knowledge and let the knowledge spillovers to happen in order to innovate something new. Compared to many other technologies there is an exceptionally strong consensus both in the business and research communities on how the Grid technology should be developed, at least for now (e.g. standardization process is well underway). Some suggestions for further research questions can be formulated from the open innovation perspective:

- Why the leading ICT service vendors are willing to share openly their knowledge about Grid computing and what are the incentives behind this behaviour?
- Is the development in Grid computing a true example of open innovation?

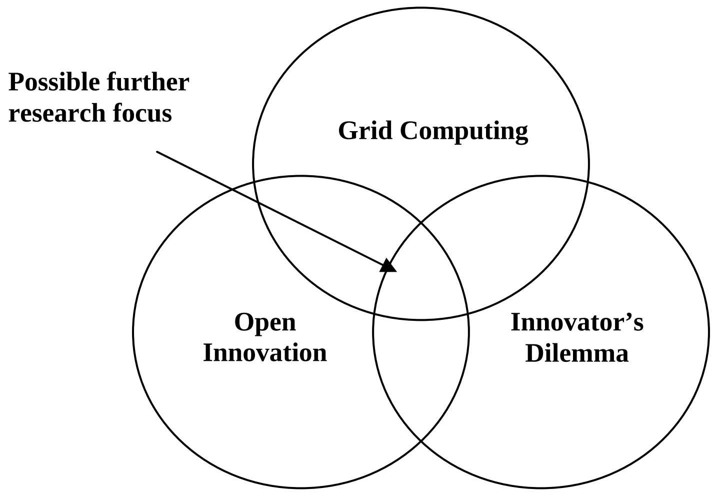

Figure 26. Possible further research focus.

7 SUMMARY

All the future thinking embodies uncertainty. Because it never can be excised, one has to cope with it. That can be done a little bit more easily by understanding the fundamentals of futures research and taking a deeper look into the future with scenario analysis.

This study focused on applicability of scenario analysis in studying emerging technology. Theoretical part strongly emphasized theories about the characteristics and the use of scenarios as well as technological change. The case section concentrated on a new, potentially disruptive technology called Grid computing.

On the basis of the theoretical analysis scenario analysis was seen highly applicable to study emerging technologies. This hypothesis was tested in the empirical part of the thesis which shed light on the edges of the different futures of Grid computing. Emphasis was on the commercial development and on the drivers of this emerging technology. In this study plausible and useful scenarios were created embodying a number of uncertain elements. The main purpose of the scenarios is to encourage people to conversation about the future of Grid computing.

The future will always be unpredictable, but it has been shown that by adopting the right approach and by using appropriate techniques it can be imagined, planned for and managed. Scenario building, in all its forms, has proved to be a powerful and effective component in the futures researcher’s tool-kit.

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Appendix 1. Interviewees and respondents

Brian Carpenter, IBM Distinguished Engineer, Internet Technology team, IBM

Christian Gasser, Head of Technology Innovation, ELCA

Michael Gindonis, Scientist, Helsinki Institute of Physics

Ari-Pekka Hameri, Professor, HEC University of Lausanne

Matti Heikkurinen, Scientist, Helsinki Institute of Physics

Juha Herrala, Scientist, Helsinki Institute of Physics

Jari Järvinen, Scientific Director, CSC

Marko Niinimäki, Scientist, Helsinki Institute of Physics

Jukka K. Nurminen, Principal Scientist, Nokia Research Center, Nokia

Jari Porras, Professor, Laboratory of Telecommunications, LUT

Liisa-Maija Sainio, Researcher, Telecom Business Research Center, LUT

Oxana Smirnova, Researcher, Lund University

Miika Tuisku, Project Leader and Scientist, Helsinki Institute of Physics

Appendix 2. The format of the scenario workshop.

Workshop on Scenarios for Grid Computing Business in 2010	
Aim:	Develop outlines to four different scenarios for Grid computing business in 2010 • Brainstorm the changes and driving forces • Envisage the different futures • Think value networks in the different scenarios
Attendees:	Dr. Brian E. Carpenter, Dr. Christian Gasser, Prof. Ari-Pekka Hameri, Matti Heikkurinen, Jari Herrala, Mika Lankila, Prof. Jari Porras, Liisa-Maija Sainio, Miika Tuisku
Duration:	One day
Agenda	
Morning:	Starting the day in CERN Introduction to scenario thinking and –process and the goals of the day Finding the driving forces Clustering the driving forces Dealing with impact and uncertainty Scoping the scenarios
Afternoon:	Building the scenarios Reviewing the scenarios What will the Grid business environment look like in terms of value network? Closure of the day

Appendix 3. The pre-questionnaire for the scenario session.

<u>Questions:</u>

1. Which environmental (political, economical, social, technological and ecological) factors have impact on the development of Grid computing? Name some of these drivers and also inhibitors.

2. What kind of uncertainties can create threats or opportunities for the development of Grid computing?

3. What kind of motivations do the players behind the key drivers have? Name those players.

4. How Grid computing fits with the overall development of the ICT-industry?

5. What kind of competences and knowledge is still needed to make the "Grid-vision" become reality in the future?

6. Why Grid computing has so much potential, or has it? Think both technological characteristics and needs of different players.

Appendix 4. Scenario themes.

	"Brave New World"	"Commercial Dodo"	"Dead Duck"	"Trust Me!"
End user markets	Consumers have multiple options to access Grids	Public sector buys Grid services	Some success in small computing-intensive industries	Users buy only from trusted partners
	Business users pay for new services	Users have strong trust on Grid services	Users have strong mistrust towards Grid computing services	Consumers are willing to pay for trustworthy services
Technology	Most technological challenges resolved	Public sector funds the development of Grid technologies	Interoperability problems, large Grid computing projects fail	Major increase of cyber terrorism
	Strong diffusion of broadband networks, Inter-grid are being deployed	Open source development dominates	Grid technologies are not deployed widely	Grid computing develop rapidly
Industry players	Emergence of many new players	Niche strategy is an opportunity	First-movers have financial troubles	Vendors position themselves as secure outsourcing partners
	Large vendors like IBM, Microsoft and HP invest strongly in Grid computing	Tight price competition	Large vendors disinvest their Grid-focused SBUs	Many vendors with company-specific security solutions
Business models	New business models, such as resource brokering, emerge	Launch of civic services based on Grid technologies	Offering the highly specialized services	Deals and contracts are made inside the trust boundaries
	Business users in certain vertical markets enhance their competitiveness and efficiency	Differentiated service to public sector	Private utility computing services	Customer lock-in
Legal issues	Privacy and security concerns have been overcome	Authorities distribute and control Grid identities	Fierce fighting over patents and technologies	Few patent wars and lawsuits
		Governments have Grid computing strategies	Cyber terrorists are being sued with no real effect	