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**MODELING TECHNOLOGY AND KNOWLEDGE IMPACTS ON  
UNCERTAINTY OF INVESTMENTS DECISIONS**

Master's Thesis in  
Industrial Management

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**Pages: 72****ABSTRACT:**

This thesis aims at modeling the impacts of technology and knowledge on uncertainty in the investment decision making of a case company operating as a part of the Finnish energy industry. The uncertainty is modeled with the help of three methods: The Analytic Hierarchy Process, the sand cone model and the knowledge and technology (K/T) rankings. AHP was used to weight the investment criteria, K/T rankings to calculate variability coefficients depicting the uncertainty and sand cone model to illustrate the weighted criteria and collapse risks caused by the uncertainty.

The used methods detected some uncertainty in the investment decision making of the case company. This uncertainty could be seen in the sand cone layers as collapses which question the decision making and the comparison of the departments. From the K/T questionnaire results could be analyzed that spearhead technology was the main source of uncertainty. Therefore, interviews were organized in order to find the reasons behind the uncertainties and also to validate the results with the weak and semi-strong market tests of the market-based validation.

The interviewees accepted the uncertainty showed by the models and thus the weak market test was passed. Also the analysis of few past projects confirmed the uncertainty related to spearhead technology. This led to accepting the semi-strong market test as well. Interpretation of spearhead technologies, state authority decisions and the real costs of backup power were seen as reasons for uncertainty in spearhead projects. To the high uncertainty an internal strategy round, TOM training and a more democratic decision making were proposed as solutions.

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**TIIVISTELMÄ:**

Tämän tutkielman tavoitteena on mallintaa teknologian ja siihen liittyvän osaamisen aiheuttamaa epävarmuutta investointien päätöksenteossa energiateollisuudessa toimivan case-yrityksen avulla. Tutkimuksessa epävarmuutta on mallinnettu käyttämällä kolmea menetelmää: Analyyttistä hierarkiaprosessia, sand cone mallia sekä Osaaminen ja teknologialuokittelua. AHP:a käytettiin painottamaan valittuja investointien valintakriteerejä, O/T luokittelua laskemaan epävarmuutta kuvaavia hajontakertoimia ja sand conea mallintamaan kriteerejä sekä epävarmuuden aiheuttamia sortumariskejä.

Menetelmät osoittivat yrityksen investointipäätöksenteon sisältäneen epävarmuutta. Tämä epävarmuus on kuvattu sand conen eri kerroksissa ns. sortumariskeinä, jotka kyseenalaistavat päätöksentekoa sekä yrityksen eri osastojen vertaamista toisiinsa. O/T -kyselylomakkeen vastauksista voitiin päätellä kärkeknologian olleen suurin epävarmuuden lähde. Epävarmuuden syiden selvittämiseksi ja kyselyn tulosten validoimiseksi järjestettiin haastattelut, joissa tulosten validiteetti varmistettiin ns. markkinaperusteisen validoinnin heikolla ja puolivahvalla markkinatestillä.

Haastateltavat hyväksyivät mallien osoittaman epävarmuuden, minkä perusteella heikko markkinatesti katsottiin suoritetuksi. Lisäksi muutamat läpikäytyt hankkeet todistivat oikeaksi epävarmuuden kärkeknologian suhteen, mikä johti puolivahvan markkinatestin hyväksymiseen. Muun muassa kärkeknologioiden tulkinnanvaraisuus, viranomaispäätökset ja varavoiman todelliset kustannukset nähtiin syinä kärkihankkeissa esiintyneeseen epävarmuuteen. Ratkaisuksi tarjottiin yrityksen sisäistä strategiakerrosta, TOM koulutusta sekä demokraattisempaa päätöksentekoa.

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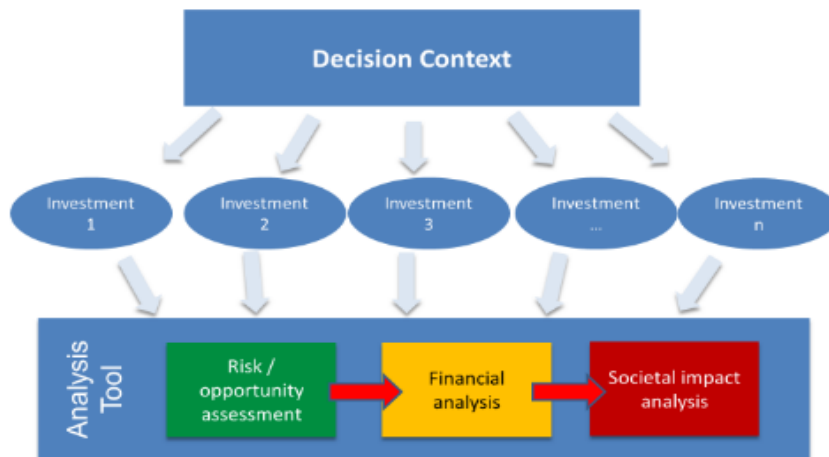
**AVAINSANAT:** Päätöksenteko, epävarmuuden mallintaminen, teknologia ja osaaminen

## 1. Introduction

Takala and Uusitalo declare that the movement towards service-oriented business model brings new risks that can be divided to internal and external risks (2012). Internal risks can be connected to capabilities needed to create new services for high-intensity customer relationships whereas external risks are related for example to the customers' willingness to share information for the creation of new services (Takala & Uusitalo 2012). The case company of this study is not a very traditional service business but operates as a local electricity, water and district heat provider. With its subsidiary companies this Finnish energy group owned by the local municipality produces, sells and distributes the electricity, water and district heat to its customers. The group employs directly 259 people and through cooperation many others such as transport and machine entrepreneurs corresponding 1000 person-years per year in total. In Finland electricity is transmitted always through the distribution network of a local distribution company. The turnover of the subsidiary transmission company achieved 17, 7 million Euros in year 2015. This study concentrated solely to the distribution organization and to its evaluation of infrastructure rehabilitation investments.

As a part of the Finnish energy industry the case company has faced a lot of changes in the market. Before the traditional energy industry in Finland was restricted under the national legislation but has now encountered a wave of denationalization of operations and an entrance to a more market economy-like environment. This is particularly true with many municipality-owned companies such as our case company and especially relevant in the field of electricity markets. However, the objectives of investments decisions remain similar among the industry. All the companies want to invest in energy production units which are profitable. Moreover, to get maximum profits in the long term the whole life cycle of these investments must be handled. On the other hand, the aforementioned great change in the industry has brought a grown uncertainty over the capital intensive and long term energy production. For this reason, more research is truly needed in order support the decision makers. (Mäkipelto & Takala 2009: 282,285)

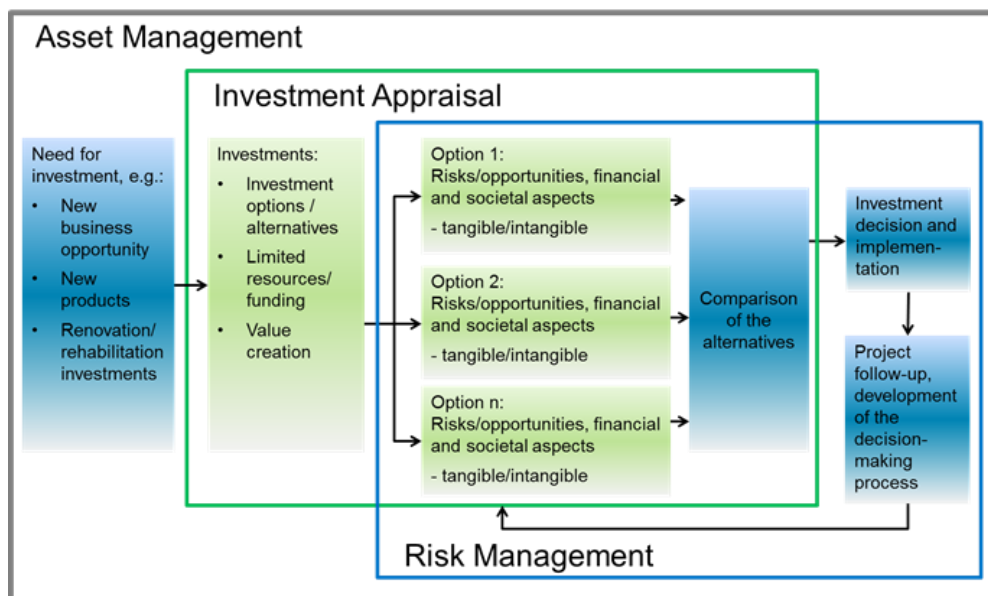
This thesis was conducted as a part of MittaMerkki research project consisting of the University of Vaasa and VTT Technical Research Centre of Finland as research partners and a local Finnish energy provider as a case company. The main focus areas of the MittaMerkki research project include decision-making and investment evaluation in value network. The aim is to give support to decision makers in their difficult task to make optimal trade-offs between monetary and non-monetary factors such as sustainability, safety, quality and social acceptability for instance. The research of this thesis can be connected especially to the aim of evaluating investments and assessing the uncertainty and risk related to the investment decision making (see figure 1 below). Whereas the research project involves case companies from different industries and hence can be considered as not industry specific, the study of this thesis can be more strongly related to the energy industry in which the company of the case study operates. All in all, the MittaMerkki research project was carried out between 1.1.2015 and 31.12.2016. (MittaMerkki 2016)



**Figure 1.** MittaMerkki - Risk-conscious investment decision making (MittaMerkki 2016).

The study of this thesis is based on a framework developed from the preliminary results of the MittaMerkki project. This conceptual investment evaluation framework (figure 2

below) indicates the main inputs, outputs and linkages of the research project. The starting point of the framework is the “need for investments”. For example in the case company of this study it would mean the replacement and maintenance investments needed for the aforementioned distribution capacity. In this framework the assessing of investments is a continuing process and the decision making is considered as a multidimensional problem in which all relevant elements should be considered. The risk assessment forms one essential part of this integrated assessment. All in all, “the framework consists of structuring the decision situation and the investment in question, setting the boundaries and framing conditions for the assessment”. (Räikkönen, Välisalo, Shylina & Tilabi 2015)



**Figure 2.** The conceptual investment assessment framework for MM project (Räikkönen et al. 2015).

This study was designed to connect the investment decision making to risk management from the strategic point of view. Moreover as Takala and Uusitalo declare, the emphasis has shifted significantly from the traditional risk management, which can be defined as various modes of “protecting the system and its users from the failures in the system”, towards uncertainty management since uncertainty can provide both opportunities as

well as dangers to the performance of the system (2012). Thus, the research problem can be defined as following: How to measure and manage the knowledge and technology based uncertainty in the investment decision making. From the research problem two more precise research questions were developed. The first research question asks how the technology and knowledge requirements affect investment decision making in the form of uncertainty. The second question then follows by asking what are the source and reasons behind these uncertainties. In chapter two the concepts of decision making and uncertainty are analyzed thoroughly. To the first research question is answered especially in the chapter 7.1. Before that the used models are presented from the literary point of view in chapters 3, 4 and 5. Chapter six then explains further the methods used in answering the question 1. Moreover, chapter 7.2 focuses solely to the second research question and chapters 8 and 9 then wrap up the whole study and its main implications.

The data collection was started with a proper literature review (chapters 2-5). The main part of the empirical data collection was done with the help of two questionnaires. The AHP questionnaire was used to weight the selected criteria of investment decision making and the K/T questionnaire to analyze the technology levels and to see how the answerers' perspectives differ related to the technology levels. The last major part of the data collection was the interviews conducted in order to address the second research question and to make validations for the results acquired with the two questionnaires. The collected data was analyzed through three different methods: first the already mentioned AHP (chapter 3.) was used to prioritize the investment decision criteria, then the sand cone model (chapter 4.) to make the hierarchy of criteria and possible collapse risks visible, and finally the knowledge and technology (K/T) rankings (chapter. 5.2.) in order to calculate the variability coefficients needed to measure the uncertainty. Moreover, the Implementation index (IMPL) was used to analyze the reliability of the results and the market-based validation of Kasanen, Lukka & Siitonen (1993) to validate the results.



## 2. The decision-making and uncertainty

It is important to be able to make decisions. However, there are many things that might hinder effective decision making such as shortcomings in the strategy or in preparing and traceability of decisions, missing decision making criteria for systematic decisions, insufficiently defined forums and responsibilities etc. There can also be many potential options but only few can be realized since the resources are usually limited. Conflicts or significant differences in opinions between functions and stakeholders can cause problems as well. In these cases, the one with the loudest voice most likely wins. In order to outpace then aforementioned issues some of the following methods can be used. Worth mentioning are for example R.G. Cooper's state-gate model, and portfolio management from the same author and his colleagues. Likewise, technology roadmaps can be found useful. Whereas portfolio management is all about doing the right projects, an effective project management of cross-functional teams and knowing customer needs are required as well to do projects right. (Takala, Hirvelä, Talonen & Vuolteenaho 2005)

Investment decisions are usually in the core of company decision-making. In order to avoid under- or over-investments the factors affecting on the decision making process should be properly understood. Furthermore, it is not anymore enough to evaluate investments solely in terms of money since also other intangible factors such as sustainability, safety, quality and social acceptability should be taken into account when selecting and prioritizing investments. These requirements result from an increasing need to integrate a wider value perspective on asset management decision-making. However, the progress has been hindered by the fact that the aforementioned factors are difficult to measure because of their nature but also by the lack of suitable models and methods which show the importance of indirect and intangible effects. In addition, short-term effects are usually preferred compared to the whole investment's life cycle. This might constrain the investments on sub-systems such as machinery or electricity and water supply networks, which have a very indirect impact on profitability and sustainability but may have a big impact on overall benefits and profits. Therefore, these

kinds of investments should be taken into account and integrated in investment assessments as well. Due to the resulting “transition in value formation” companies are forced to seek new methods in order to support their business and the related investments. (Räikkönen, et al. 2015)

Investment decisions are usually made in a complex and turbulent business environment combining multiple needs, requirements and values. In this environment the investment alternatives should be assessed so that maximum profit is achieved and the requirements and expectations of all parties are taken into consideration. This requires the comprising of risks and uncertainties as well as both quantitative and qualitative factors. As mentioned above the financial methods such as discounted cash flow (DCF), net present value (NPV), internal rate of return (IRR) and return on investment (ROI) are the most common tools of investments appraisals. Although it is relatively easy to find cost data the financial assessment tends to focus too often on direct costs. Especially in capital intensive industries such as energy which have long life cycles and requires many rebuilds, replacement and expansion investments, also the indirect effects on profitability and sustainability should be taken into account. For these reason new solutions such as Life cycle cost (LCC) analysis, which considers also the costs of usage, maintenance, disposal and lifetime profits, have been developed. Also earned value analysis, the productivity index, expected commercial value, real options, Monte Carlo simulations and stochastic programming have been introduced as recent examples of analysis methods. All in all, many empirical findings show that companies, which use financial methods as primary decision-making criteria, can end up in lower outcome levels and performance. Therefore, the financial methods should be used rather as directional methods than the only way of approving and rejecting investment alternatives. (Räikkönen et al. 2015)

There are naturally also other methods for impacts assessment than financial. For example, the societal methods focus on criteria inexpressible in monetary, physical, logical or in other quantitative ways. These criteria include for example social, environmental, ethical, political, law and regulative factors. The aim of the societal

impact assessment is to create value to a wider group of investment stakeholders and thus increase the amount of invested capital. Also better transparency and accountability of the investment impacts belong to the few benefits of taking the societal criteria into the investment decision making. There are many different kinds of methods for the societal assessments: some methods such as The Value Creation Index are based on quantifying intangible value, others such as the Global Impact Investing Rating System (GRIIRS) can be described as rating systems. Also the Analytical Hierarchy Process can be used in the societal context. (Räikkönen et al. 2015)

Finally, risk and opportunity management form the last major part of the impact assessment. If risk is defined as “uncertainty with negative effects”, opportunity can be described as upside risk or “uncertainty with positive effects”. In this category there is less methods available but it can be stated that the risk and opportunity management should always be based on a defined framework which includes an identification process of possible events. The risk management requires also a risk analysis in which different scenarios describe the effects of possible alternatives. In order to make the aforementioned possible, the investment should be systematically described. One potential qualitative method for the estimation of risks and opportunities is the Double Probability-Impact Matrix for opportunities and threats. However, it is very recommendable to assess risk and opportunity separately since they have clear opposite nature. This means that some opportunities might have huge potential but also really serious consequences if failed. (Räikkönen et al. 2015)

Uncertainty and risk form understandable a central part to the concept of decision making and both can be described as the main obstacle for the effective decision making. Although being an important part, Lipshitz and Strauss have determined that there are very few studies assessing the relationship of uncertainty and decision making. Nonetheless, these few studies have shown that there are many different concepts of uncertainty and risk. The concepts also show a clear difference between uncertainty and risk. Furthermore, the differences in the conceptualizing indicate that the term “uncertainty” is even too commonly used in the decision making. This leads to

confusion when distinguishing closely related terms to uncertainty such as risk, ambiguity, turbulence, equivocality and even conflict. Therefore, Lipshitz and Strauss have made three different propositions in their attempt to define the concept of uncertainty. The first proposition describes uncertainty as “a sense of doubt that blocks or delays action”. The second addresses that coping with uncertainty depends on the decision-making model used. (Lipshitz & Strauss 1997: 149-150)

In the final proposition the authors provide a classification in which they divide uncertainty based on the issue and source. According to the issue, meaning the aspects the decision maker is uncertain about, the uncertainty can be divided to alternatives, outcomes and situation. This means that the decision making is hindered either by the uncertainty over different alternatives, outcomes of these alternatives or the nature of the situation. Moreover, the source of uncertainty can be divided to incomplete information, inadequate understanding and undifferentiated alternatives. Incomplete information is defined as the most probable source of uncertainty. On the other hand, decision makers can also be overwhelmed by the information as the inadequate understanding suggests. Finally, the decision can be harmed by equally attractive or unattractive alternatives. There have also been suggestions that the whole decision making can be described as differentiation of alternatives sufficiently from each other. In addition, based on their empirical study the two authors state that incomplete information can be further divided to partial and complete lack of information as well as to unreliable information. Also inadequate understanding can result either from equivocal information, novelty of the situation or from unstable/fast-changing situations. Lastly the equally attractive and unattractive alternatives are put under the topic of conflicts together with incompatible role requirements. (Lipshitz & Strauss 1997: 151, 155)

There are also many ways to battle uncertainty and these methods can be connected to the aforementioned classifications. Based on the empirical study of Lipshitz and Strauss, for example lack of information can be prevented by using a method called Assumption-based reasoning in which a certain “belief-based mental model of the

situation” is created. Likewise, the inadequate understanding can be decreased with the use of different “tactics of reduction” which include methods such as collecting additional information, seeking backing or advice as well as relying on doctrines and SOPs (Standard Operating Procedures). The conflict of undifferentiated alternatives is best solved by simply weighting of pros and cons. Furthermore, the different methods of forestalling such as improving readiness, preempting and avoiding irreversible action can be used to cope with all the sources of uncertainties. The same is the situation with different tactics of suppression. In these tactics are included the ignoring of uncertainty, the use of intuition and even taking a gamble. Although the results show a clear pattern the authors want to remind of some small sample sizes which challenge the universality of the results. (Lipshitz & Strauss 1997: 156-157)

In their article about the resource planning and decision making of electricity utilities Eric Hirst and Martin Schweitzer argue that five elements are needed to treat uncertainty. At first data and assumptions are needed in order to define resource alternatives and external factors. Next an analytical method is required to simulate operations. Then the data, assumptions and analytical methods must be combined with proper techniques. This makes possible to analyze uncertainties and “to select suitable resource portfolios”. Furthermore, it is important to have functioning communications within the utility for example between the analysts and executives. Finally, the last element of treating uncertainty is naturally feedback which is acquired e.g. from utility actions and its external environment for the necessary modifications of plans and actions. The two authors also provide some means to battle uncertainty. The first and simplest way is to ignore the uncertainty. This can be done in two ways: either by following a so called base-case plan presenting the most likely scenario of events or by making only short-term strategies (“next few years”) and leaving long-term issues aside. (1990: 137, 142)

The other end of the extreme is to make a lot of alternative plans with many contingencies and in such way “predetermine” decisions. The authors do keep neither this solution nor the first one as very feasible. Already some long term commitments

may preclude alternative plans. However, delaying decisions is kept as a completely possible method for few reasons. First of all, delaying can be used to get some time for additional information. For example, an investment can be held in order to get more cost information. This option is of course possible only if the investment can wait and is not imminent. Sometimes this kind of additional information can even be purchased. The next method introduced is the selling of risks which is especially recommendable if another party is better in managing the risk in question. The selling can be done in practice by arranging auctions for the suppliers and by negotiating long-term contracts including penalties for delays or unreliability. In these ways mainly financial risks of building own utilities etc. can be avoided and shifted to suppliers. The last method of battling uncertainty according to authors is flexibility which can be increased for example by obtaining shorter lead times, lower capital costs and smaller unit sizes. With flexibility changes can be made easily and at low cost when risk scenarios materialize. On the other hand, the increasing flexibility can also bring extra costs and lead for example to rising long-term lifecycle costs. (Hirst & Schweitzer 1990: 142-143)

### 3. The Analytical Hierarchy Process

The Analytical Hierarchy Process by Thomas Saaty was developed to answer complex situations and to “include and measure all important tangible and intangible, quantitatively measurable, and qualitative factors”. This means avoiding simplifying assumptions that leave out significant factors and taking all the controlling factors into the consideration. Since many models and theories depend on measurable factors such as units, weight, monetary value and probabilities, and exclude human behavior, there is a clear demand for a model that takes into consideration differences in opinion and the real world conflicts. All in all, the idea of the AHP method is to give a method of scaling that evaluates tradeoffs between different criteria such as cost, quality and so on. Moreover, this means creating measures for the aforementioned entities such as happiness, for which there are normally no measures, and then using these entities in the decision making. (Saaty 1980: 1, 4)

The AHP method was first created for contingency planning in 1972 (Saaty 1980: 4). Then the method was used in designing of alternative futures for Sudan in 1977 and resulted in a set of priorities and an investment plan for the country used in the late 1980's (Saaty 1980: 4). After that AHP has been used in multiple applications such as energy allocation, technology investments under uncertainty and even dealing with terrorism as well as with many different participants alternating from lawyers, engineers, and scientists to children (Saaty 1980: 4). In other examples the use of AHP has been suggested for marketing purposes due to its rather simple way of making paired comparisons (Takala et al. 2005). Takala et al. have also used the method in a case study in which five potential project options were pairwise compared based on five main market and technology factors (Takala et al. 2005). The method was described as time efficient, analytical and traceable decision making solution but not so favorable for screening a lot of ideas and every project (Takala et al. 2005).

The first principle of AHP is to decompose the studied problem into a hierarchy. This means dividing the problems in levels that always form the criteria for the lower levels.

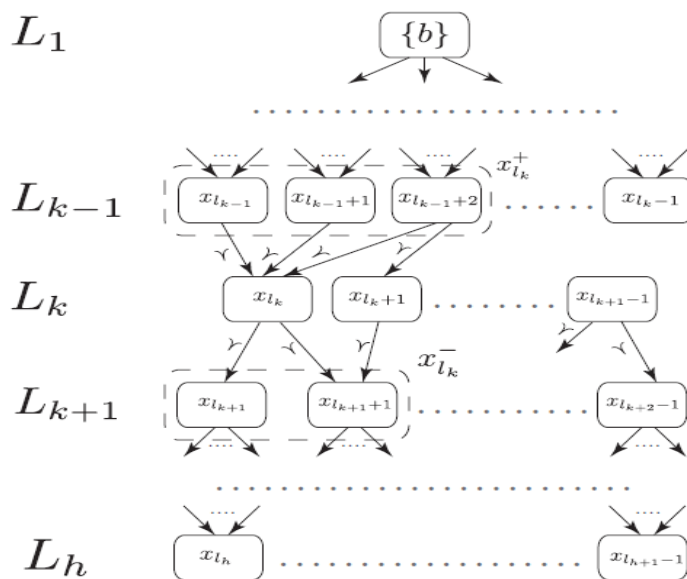
Every level should contain few understandable elements which are easy to manage. Then every element in a level consists of a group of lower level elements. This process is continued until the lowest levels of basic elements are defined. These basic elements are typically something such as “actions”. AHP seems to be a very flexible method of decision making since there is no one right way to form the hierarchy. The decision maker can decide itself how to create a hierarchy that fulfils every need and viewpoint. Moreover, AHP can be used to decompose every problem efficiently and to find every basic elements of the problem. In a typical hierarchy the element of the highest level is the general goal of the organization or system. The next level might include something such as the criteria for the allocation. The next lower level can then further explain these criteria by presenting more accurate targets and tasks. The lower the hierarchy goes the levels can contain elements such as operational principles, projects, subprojects and furthermore actions. However, this categorization can be seen as an example and every element in the lower level does not even have to affect every upper level element. (Niskanen 1986: 5-6)

In his book *The Analytic Hierarchy Process* (1980) Saaty states many advantages to the use of hierarchies. First of all, a hierarchical presentation of a system is practical in showing how the upper level priority changes affect to the priority of elements in the lower level. Furthermore, this kind of presentation includes a lot of information about the structure and function of the system all the way down to the lower levels containing also the actors. Purposes of the actors are best presented in the higher levels and the constraints of the elements always in the next higher level in order to ensure being satisfied. Saaty also claims that the natural systems are more efficiently evolved through hierarchies than as a whole. The last benefit is the combination of flexibility and stability. The stability means that small changes have only small effects and the flexibility for example that additions in a well-structured hierarchy are possible without disrupting the performance of the method. (Saaty 1980: 14)

The concept of AHP hierarchy is illustrated in the figure 3 below. As can be seen the hierarchy is “a decision scheme” in which the goal is achieved by comparison of



alternatives in pairs according to different criteria. The small elements are contained with the larger elements/levels. In other words, the small elements belong to the larger ones from which they depend on. In order to make the comparison between the elements possible the elements in one level must be related according to the next higher level. This means that the outer dependence of the lower level elements to the higher ones is indicated. This process is then repeated upwards in the hierarchy towards the top element of focus/goal. Furthermore, the elements in one level depend on each other based on a property in the next level. Moreover, homogeneity is important in comparing similar things due to errors which occur when widely disparate elements are compared. This great disparity promotes the use of levels and decomposition. (Saaty & Kulakowski 2016: 6-8)



**Figure 3.** The AHP hierarchy (Saaty & Kulakowski 2016: 7)

So as already briefly introduced in the previous chapter the next principle of AHP is the comparative judgments, which give also some demands for the decomposition. For the lower level elements, it should be possible to make pairwise comparisons based on the

upper level elements. Actually the whole hierarchy is based on pairwise comparison matrices that illustrate the next lower level elements' effect to the upper level element. In practice every lower level elements' importance is compared pairwise and a numerical value is given based on which element is more important and how much. As can be noticed from the previous sentence, two questions are presented for each comparison. The first question asks for example which one of the two lower level elements A and B is more important for the upper level element in question. The second question then requests to specify more in detail how much important the element A is than B or vice versa. (Niskanen 1986: 7, 9)

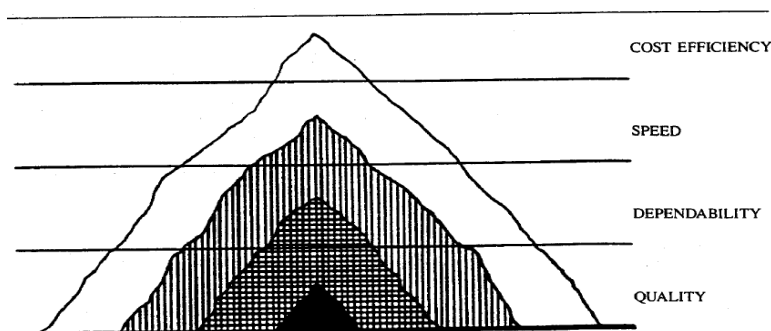
In order to answer to the aforementioned second question with a numerical value Saaty has decided to use a scale of 1-9. In this scaling number one means an equal importance between the compared elements. Furthermore, the value 3 hands a weak importance to one element over another or in other words a slightly favoring judgment. Next the number 5 favors strongly the selected activity and the number 7 very strongly. Finally, value 9 is given when an absolute importance or favor is decided for one of the two elements. Values 2, 4, 6 and 8 work as intermediate values. The use of the scale with upper limit of 9 is explained by various reasons. First of all, an infinite range was excluded due to the fact that human ability to discriminate is highly limited to a range and without it answers tend to be too arbitrary and far from the actual. For this reason, also the bounds should be quite close in a region to make the comparisons reflect our real capacity. This is especially the case with qualitative distinctions in which the categorization of "equal, weak, strong, very strong and absolute" is applicable. In the need of greater precision, a possibility of making compromises between adjacent attributes leads to the scale of nine values. Also the often used evaluation method of "classification of stimuli into trichotomy of regions" leads to nine values with the three regions of rejection, indifference and acceptance and all of these three having a subdivision into low, medium and high. All in all, this scale of 1-9 seems to have to strongest human affinity to form a connection between shades of feeling and the numbers in the scale. This limit of  $7 \pm 2$  is also presented in the psychology as an amount that the brain can simultaneously process. (Saaty 1980: 53-57)

The last principle and aim for the Analytic hierarchy process is through the decomposition and comparative judgments to create priorities for the lowest level elements. This phase is called the synthesis of priorities and it should lead to a description of the lowest level elements' relative effect on the top level of the hierarchy by taking all the middle level elements into consideration. In practice these priorities are developed from the pair wise comparisons and Niskanen recommends the use of a computer algorithm that calculates the priorities from the matrices. There are also some readymade programs for the calculation such as Expert Choise developed by IBM just for the AHP. Also programs such as Matlab are usable. One more important factor of the AHP is the consistency of the hierarchy, which is measured from the consistency index. This value should not exceed 0, 1 in the case of the whole hierarchy as well as in the case of a single comparison matrix. (Niskanen 1986: 5, 9, 12)

#### 4. The sand cone model

The sand cone model illustrates the studied object by showing its hierarchies as well as the relative importance and relationships of the sub-objects. The structure is the key in understanding sand cone. The factors placed in the bottom of the structure can be stated as internally crucial for the organization and they function as a base for the value creation to the external stakeholders such as customers. The rest of the factors are then placed on this base. The top of the model shows the customer-oriented factors that result from the internal factors. (Takala, Leskinen, Sivusuo, Hirvelä & Kekäle 2006: 338.)

To clarify the aforementioned a figure of the original sand cone model by Ferdows and De Meyer is presented in the figure 4. This model was created to enhance organizations' manufacturing strategies by analyzing four different and important capabilities: quality, dependability, speed and cost efficiency. As can be seen from the figure, quality was placed in the bottom serving as a foundation supporting dependability, speed "resting" on dependability and finally cost efficiency "resting" on speed. Based on this model the cost efficiency can be declared as the ultimate goal, which means it is the most visible and external factor but has not much influence in the stability of the structure. In practice this would mean that "saving money everywhere" is not the central internal method towards cost efficiency. On the contrary the cost efficiency can be seen rather as a result of the quality, dependability and speed factors. (Takala et al. 2006: 338-339.)



**Figure 4.** The original sand cone by Ferdows and De Meyer (1990: 175)

The sand cone model emphasizes how the development should always start from the bottom of the model. Only in this way the best total performance can be achieved. In the Ferdows and De Meyer case it would mean that the development has to start from the quality, proceed to dependability, then to speed and finally to cost efficiency in order to achieve a better performance. All in all the development based on sand cone must have a positive effect to the top of the model (e.g. in cost efficiency). Otherwise the model is not working properly according to its principles. (Niemistö & Takala (2003: 102)

To show how the process would work in practise Ferdows and De Meyer give the following example. In order to improve cost efficiency for 10% a larger percentage is needed for speed. If this value for speed would be for example 15 %, even larger share of the improvement effort is required for dependability (e.g. 25%) as well as to quality (e.g. 40%). Ferdows and De Meyer underline that their model is of course not the only way to improve cost efficiency but with sand cone it could be done without the expense of the other factors. Actually on the contrary, reaching better cost efficiency would be accomplished by enhancing these other capabilities. Improvements done by this manner would also lead to more stable and long lasting improvements. What these improvements might be in practise are left to the companies. Actually the metaphor of “sand” used in building the “sand cone” simply refers to management effort and resources. Since the concepts of quality, dependability, speed and cost efficiency are all very broad there is a wide range of possibilities for the companies. This makes also differentiation from competitors possible for the individual company. Moreover, Ferdows and De Meyer continue that also the amount of performance indicators should follow the sand cone sequence and improvements programs. (Ferdows & De Meyer 1990: 174-176.)

The central questions of the sand cone model seems to be “whether firms improve manufacturing performance in a cumulate manner” as the sand cone theory suggest or “trade one measure against another”. There are of course supporters for both ends and therefore it is no surprise that the sand cone model has also received some criticism. For example Schroeder, Shah and Peng have analyzed cross sectional data from 189

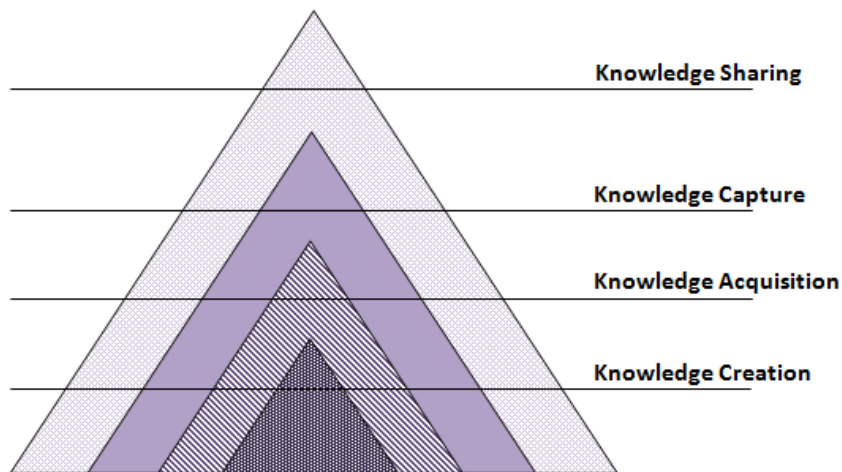
manufacturing plants with path analysis, structural equation modeling and sequence tests. They declare that in order to prove that the sand cone works the direct effect of any two non-adjacent competitive performance measures should be less than the indirect effect. Based on this neither path analysis nor structural equation modeling support the sand cone model. Furthermore the sequence test implies that one third of the analysed plants or even more do not follow the sand cone model raising doubts over its nature as an universal phenomenon. (Shroeder, Shah & Peng 2010: 1-2,18-20)

Also Wang and Masini from the London Business School state that there are some tradeoffs between the factors in the sand cone model. The main reason for this is the resource slack which moderates the relationship between the factors. Also the moderating effect might be different for each factor. Due to the differences in the resource slack some companies can follow the sand cone sequence better than others. These are usually the companies that have a great amount of resource slack since they can develop new capabilities without taking resources from the existing ones. Companies with moderate amount of resource slack are not able to do this while their resources are simply insufficient and effective companies with no resource slack are forced to take resources even from the capabilities considered in the bottom of the sand cone such as quality. Based on the study it seems indeed that companies facing the tradeoffs tend to preserve capabilities located in the bottom of the pyramid. More significantly the sand cone can be used in the reverse order to find the capabilities that must be sacrificed first. This is an interesting result since in the earlier studies sand cone has been seen mainly as model for creating new competitive strengths. (Wang & Masini 2009: 8, 13, 20-21, 24-25)

However, in achieving the competitive strengths the use of reverse order of the sand cone seems not to work. In the original study of Ferdows and De Meyer was detected that quality improvement programs tend to increase also cost efficiency. However, focusing to increase cost efficiency did not seem to have the same effect on quality. The same pattern seemed to work between dependability and flexibility. More reliable production systems enabled higher flexibility. Once again the reverse order had no

equal implications. What comes to the slacks in the system, Ferdows and De Meyer ensure that the cost can be reduced without weakening the other resources. On the contrary these capabilities should be enhanced by “deeper penetration of good manufacturing management practises in the organization”. The enhancement may only take some time. This is the interpretation of Ferdows and De Meyer from the data of improvement programs performed by large European manufacturing companies included in the European Manufacturing Futures Project. For example one program tent to improve quality and dependability but not much the cost efficiency. Based on the interpretation this is possible since cost efficiency is located in the top of the cone and for that reason the cost will come down only in the long run. (Ferdows & De Meyer 1990: 169, 170, 174)

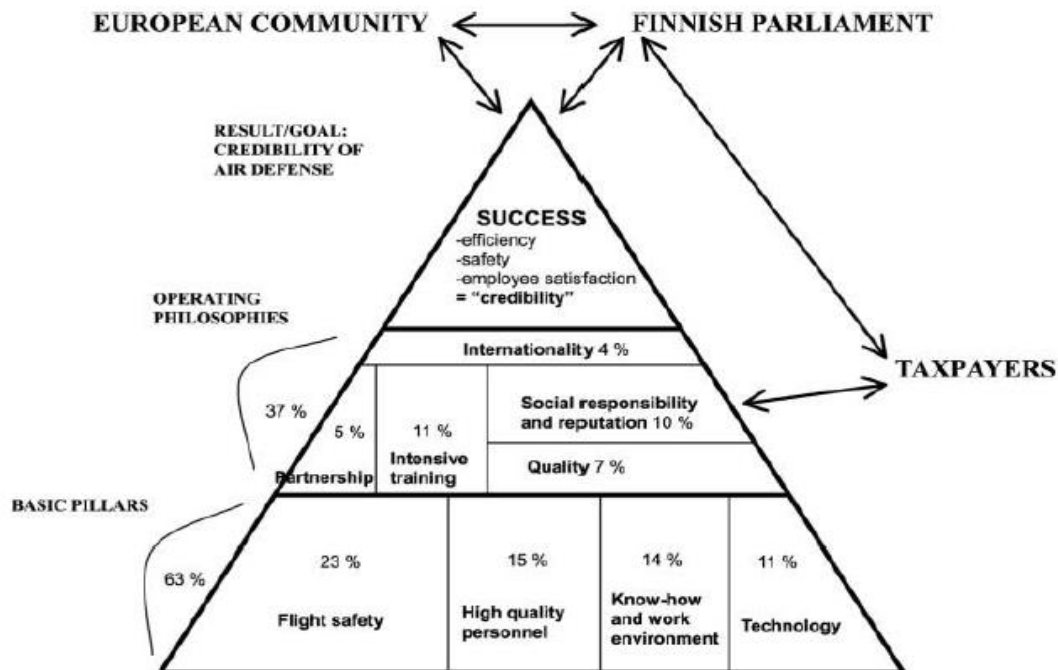
One strength of the sand cone is that it can be used for many purposes and with many different attributes. It does not necessarily have to be manufacturing companies measuring their performance with the four aforementioned factors. In the following example by Saufi, Rusuli, Tasmin and Takala the sand cone model has been used to study Knowledge management (KM) in the Malaysian university libraries. The results can be seen from the figure 5 below with four KM related factors inserted into the sand cone. In the model the “sand” poured into the sand cone portrays the effort and resources needed by the knowledge management. The foundation is built on Knowledge creation. In order to continue building the sand cone more effort and resources are needed for the Knowledge acquisition layer which functions as a base for the Knowledge capture. Finally by reinforcing all the three previous layers a stable top of the cone can be formed for the Knowledge sharing improvement programs. Saufi et al. believe that this kind of sand cone model helps to understand library resources, identify the different categories of KM, support the library’s organizational strategy and spot the challenges related to KM. (2012: 1,6)



**Figure 5.** The sand cone model of the Malaysian library KM (Saufi et al. 2012: 6)

Since the original model sand cone has been developed and used successfully for example with the Finnish Air Force. In this developed model of Takala from 2002 the AHP method was used to derive the relative importance percentages determining the levels of the sand cone model. Due to this developed model two different levels of importance could be determined. The first level was formed by basic pillars with high level of importance covering two-thirds of the whole strategy. The second level were described as operating philosophies with lower level of relative importance and covering the remaining one-third of the strategy. The complete sand cone model for FAF is illustrated in the figure 6 below. From the figure can also be noticed how, in addition to the basic pillars and operating philosophies, the original conical layers of the Ferdows and De Meyer model were changed to “flat” layers. This way of illustration was discovered to be in this case more realistic since it revealed also the bottom layer and as can be imagined factors such as flight safety and technology are a very visible part of the FAF’s strategy to its stakeholders. (Takala et al. 2006: 339-341.)





**Figure 6.** The sand cone model for the FAF strategies (Takala et al. 2006: 341)

In the FAF sand cone model the top level (result/goal) is dedicated to the mission that the rest of the model should fulfill. The middle level of philosophies, described also as “the facilitating layer”, give practical guidelines for the operations from the stakeholders’ point of view and as mentioned before are not as crucial to the strategy as basic pillars but yet important since externally very visible and lead to faster results than the basic elements. Lastly the basic pillars are described as the factors that FAF builds its credibility on. These elements are a crucial part of the organizational culture, first in priority and their level should always be guaranteed. Furthermore, as can be noticed this FAF sand cone model contains also the role of external interest groups that can be seen for example in the link between the “Social responsibility and reputation” factor and the taxpayers. (Takala et al. 2006: 341.)

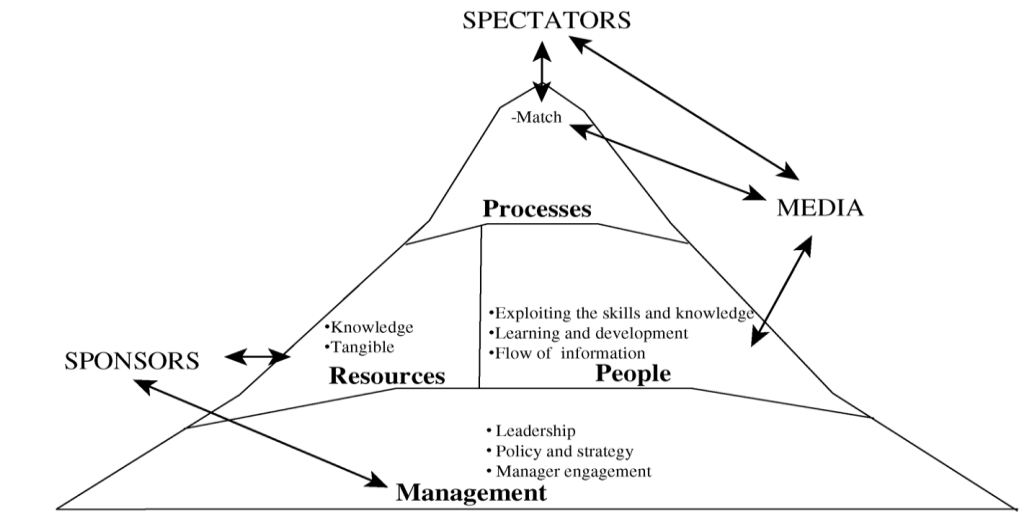
In this sand cone model a so called implementation index (IMPL) is used to evaluate the usability of the AHP assessment results and is calculated by dividing the standard deviation of the attribute assessment results with the corresponding average value

(Mäkipelto 2010: 29). The IMPL illustrates the homogeneity of the results which means that the higher IMPL the higher is the deviation related to the priority in question (Leskinen & Takala 2005: 42). Therefore, the IMPL can be considered as an indicator of quality to the decisions made by AHP and “a measure for the operative reliability of the evaluations” (Takala et al. 2006: 339). Mäkipelto and Takala argued in their research concerning the dynamic decision making of energy industry that the aforementioned reliability was established when all the IMPL values were under one (2009: 292). Takala et al. also discovered in the FAF case that when the priority of a sub-strategy increased the IMPL decreased which means that those sub-strategies receiving a high importance received high homogeneity of results as well compared to the sub-strategies given a low importance (2006: 339-340).

All in all, this developed model of sand cone takes the factors and places them based on AHP values to the three layers that are the bottom layer of basic factors, middle layer of facilitating factors and the top layer of resulting factors. It describes the structure of sub-strategies and their strategic role in a visual, systematic and simple way. However, a military organization usually has a strong culture, long traditions and a unanimous way of decision making. This means that more research is needed with different type of organizations which follow multi-focused strategies, operate under high uncertainty or even confront disagreements. Also the question about the extra parameters needed in order to use this model more generally remains to be answered. (Takala et al. 2006: 342.)

One further example of the sand cone model is illustrated in figure 7 below. This model shows the prioritization of the factors concerning professional Finnish ice hockey clubs and their business environment. Based on the study management was placed in the bottom of the cone serving as a basic pillar for the other factors and being externally visible only to the sponsors. People and resources were inserted in the middle layer since both of them depend on management and support processes. People are seen as internal element for the clubs but also some visibility can be seen in terms of media affairs. Lastly the processes were set to the top of the cone because including the match

they truly are the mostly visible part for the clubs, partners and especially to the customers. However, this layer does not have any supportive role in the cone. (Leskinen & Takala 2005: 43.)



**Figure 7.** The sand cone model for the ice hockey clubs (Leskinen & Takala 2005: 43)

MittaMerkki project has provided a great possibility to further develop the sand cone model and to answer the aforementioned questions. Combining risk assessment and investment decision making in an energy sector case where AHP method is already used to weight the investment criteria gives an excellent new environment to test the sand cone model in a different type of organization and with different challenges compared to the FAF organization example. As new parameters K/T (Knowledge and Technology) rankings were introduced to the sand cone model in order to see how technology and knowledge affect to the decision making and hence to the factors collected in the sand cone. These new parameters are introduced in the model as a form of uncertainty which can cause so called “collapses” in the sand cone layers. These collapses stem from the different K/T requirements in different departments of the case company.

## 5. Knowledge and Technology

### 5.1. Knowledge and technology in general

Technology should not be defined too narrowly only as machines and tools. On the other hand, a too wide definition such as "a method for producing material wealth" makes it impossible to differentiate technology from other activities such as commerce or accounting. Therefore, in his book "Technology in Context" Ernest Braun defines technology as "the ways and means by which humans produce purposeful material artefacts and effects" or alternatively as "the material artefacts used to achieve some practical human purpose and the knowledge needed to produce and operate such artefacts". No matter which of these two definitions is preferred or even a completely other one, one special characterization needs to be acknowledged. There is always two parts in technology: the first one is hardware such as material artefacts and the second is software such as knowledge which is necessary and immediately associated with the hardware. (Braun 1998: 8-9)

The growing role of technology brings many opportunities as well as threats to the companies (Takala, Koskinen, Liu, Tas & Muhos 2013: 45; Mäntynen 2009: 9). Technology can be seen as a source of business development, growth, profit and competitiveness to the companies. On the other hand, it demands a lot from the companies. They must be able to continually adapt to the technical requirements of the market. Since technology has also been linked to a possibility of achieving competitive advantage the recommendation for the decision maker has been to integrate this opportunity to the strategy. The idea of competitive advantage or more precisely the sustainable competitive advantage (SCA) has been connected to Porter's work in the 1980's and in 1991 Barney determined it as an implementation of a value creating strategy that is not implemented nor successfully duplicated by competitors. (Takala, et al. 2013: 45-46, 48)

Following technical breakthroughs as well as new business opportunities is very important for both new and mature industries. This is especially crucial during the bad economical situations in which only the strongest will survive healthy. Achieving the sustainable competitive advantage can be seen as a result of four factors which are Core competence, Time compression, Continuous improvement and Relationships. With a core competence it is possible to differentiate itself from the competitors. In practice this means having a distinct service or product and most likely to also deliver this service/product with more added value than others. This is especially important for the small and medium sized enterprises. The next factor called time compression means cutting production and delivery times in order to achieve the customers' expectations on fast delivery. This can be achieved for example by reducing lead times but of course not with the cost of lower quality or service. Therefore, continuous improvement is needed "to maintain a position in the market" or to make it even better. Continuous improvement requires a mentality where the company is never too satisfied about its products and services because there is always someone trying to do things better. Finally, the fourth factor relationship means simply networking due to the synergy benefits as well as in order to create even better services and products. (Mäntynen 2009: 9-12)

The sustainable competitive advantage also requires knowledge and intellectual capital as the primary bases of core competencies especially when special access to markets and resources are given. In order to achieve sustainable competitive advantage knowledge must be spread within the firm since without it remains a property of few and will therefore have a limited impact on value creation. Obviously there is always a risk that the knowledge spread within a firm spreads also to other firms and becomes the industry best practice instead of a competitive advantage. As examples of this kind of knowledge Lubit mentions the total quality management and just-in time inventory management. Therefore, in order to achieve sustainable competitive advantage knowledge, skills and resources should be relative easy to share inside the firm but difficult for other firms to copy. (Lubit 2001: 164-166)

This kind of tacit knowledge is information that is “difficult to express, formalize or share” and it can be related to intuition. It is as an opposite for explicit knowledge which can be expressed easily with words. It is clear that tacit knowledge has a lot to do with experience and is related to the work of experts. Lubit divides tacit knowledge into four different categories: skills, mental models, ways of approaching problems and organizational routines. Skills also described as “know-how” is an obvious part of tacit knowledge. Skills need to be practiced, feedback is essential and a “feel” how to do things is needed. In addition, a “hard to pin down” skill cannot be explained in words. Mental models then show the construction of world, its central elements and parts related. Cause-effect connections are a vital part of this tacit knowledge category which helps to sort masses of data, extract relevant parts, formulate problems and find solutions. At the center of the third category is the decision trees people use to solve problems. Finally, organizational routines are all about the firm’s standardized operating procedures and roles. One major part of these procedures is also decision-making. In this category the tacit knowledge becomes a part of routines based on the judgments of the company’s managers on how things should be done. (Lubit 2001: 166-167)

The key with tacit knowledge is how to spread it within the company in order to develop it to a core competence and furthermore all the way to sustainable competitive advantage. One central way is to use coaches and observe experts. Coaching or in other words mentoring works best when skills leading to a superior performance are first detected. Also experts do not always know what makes them successful. This can be solved with a group of experts defining a list of key tasks and skills needed for these tasks. This leads to another central way of distributing tacit knowledge: through networking and work groups although these groups may end up discussing about explicit knowledge and not so much about its tacit counterpart. This happens if the discussion becomes too theoretical where no proper case examples are included. All in all, working groups and networking are seen as road to new insights and innovations. Tacit knowledge can also be recorded as “learning histories”. (Lubit 2001: 167-169)

The managing of technology driven organizations is challenging. The opinion how to do it varies even between the experts in the field. According to Gehani the management of technology driven organizations and their operations can be successful with the help of “six major technology related value adding competencies”, which can lead to sustainable competitive advantage. The three primary technology related competencies are production automation and engineering, R&D based proprietary know-how and intellectual property, and new product development in targeted market segments. Moreover, the supporting competencies would be the promise of quality, processing of information and communication, and management of people resources and human capital. All these competencies have to be integrated together and carefully guided. This can be achieved through project management and cross-functional integration. Project management means coordinating the competencies with one-time initiatives which should have clearly determined starting and finishing points. Cross-functional integration then ensures the continuity of the process. Of course, vision and leadership are needed as well. A value based vision is needed for the dynamic guidance system. Furthermore, the leadership can be either transactional or transformational. (Gehani 1998)

## 5.2. The knowledge and technology rankings

In order to implement SCA the critical attributes in resource allocation must be detected. This can be done through the sense and respond methodology (S&R). After determining the critical attributes improvements and dynamic adjustments can be done to enhance the company's strategy. The idea of sense and respond thinking is to detect changes in the turbulent business environment (“sensing”) and then react to them (“responding”). In practice this is done with the help of the critical factor index (CFI) or in the more developed models BCFI (Balanced critical factor index) and SCFI (Scaled critical factor index). The knowledge and technology factors are inserted to the S&R in the form of a requirement section in which the respondents have to evaluate each S&R questionnaire attribute according to basic, core and spearhead technologies. In other

words, each attribute is divided based on these three technologies so that the sum of the technologies equals 100%. Basic technology refers to commonly used technologies that can be purchased or outsourced. Core technology is current competitive technology in a company and the term spearhead is related to future technologies. The importance of these three different technology levels is the knowledge they require. This affects a lot in the strategy implementation and furthermore to the success of the technology-based businesses. (Takala & al. 2013: 46–48)

Actually the relations of the technology levels can be best illustrated by familiarizing with Professor Noriaki Kano's model known also as the Kano model (figure 8 below). With the help of the Kano model it is possible to understand the relationship between the product or service attributes and the customer satisfaction (Kammonen 2012: 52). Based on the Kano model there are three different possible ways to determine product or service quality (Kammonen 2012: 52). The first ones are so called "must be attributes", which customers take for granted but without feel very dissatisfied. (Shen, Tan & Xie 2000: 92). An example could be a car engine, which the customers expect to start in minus degrees but feel very unhappy if it does not (Määttänen & Öhrnberg 1984: 9). This kind of basic quality is not usually mentioned by the customer because of its self-evident nature (Kammonen 2012: 52). If the aforementioned quality aspects are paralleled to the knowledge and technology rankings, this kind of quality can be clearly connected to basic technologies.





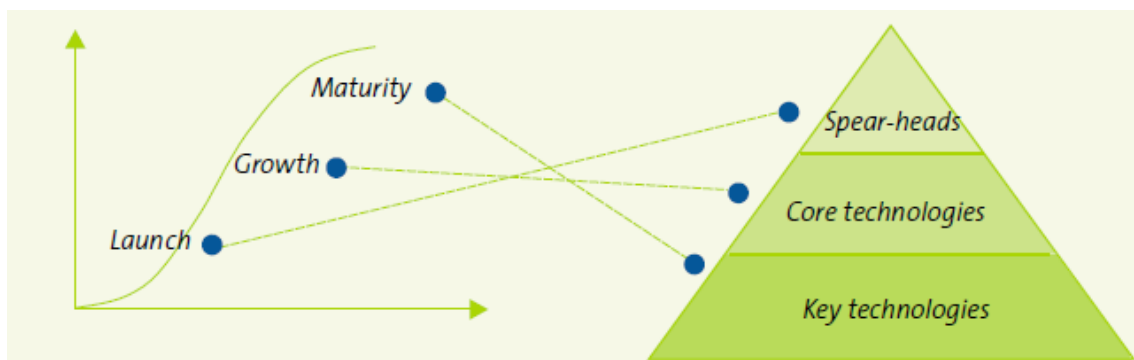
**Figure 8.** The Kano model (Shen, Tan & Xie 2000: 92)

The second part of the Kano model are the one-dimensional attributes which the better fulfilled increase customer satisfaction and vice versa (Shen et al. 2000: 92). A good example of one-dimensional attributes is “low fuel consumption” since the less the car uses fuel the happier is the driver (Shen et al. 2000: 92). These quality aspects can be discovered for example by making a market research (Kammonen 2012: 52). Likewise, these attributes depict also very well the core technologies. Supposedly the last part of the Kano model called attractive attributes can be illustrated also as spearhead technologies. The customer is not dissatisfied without these attributes since they are not expected qualities (Shen et al. 2000: 92; Määttänen & Öhrnberg 1984: 10). However, including attractive attributes in the product will increase customer satisfaction which will lead to better sales in due course (Määttänen & Öhrnberg 1984: 10). A competitive strategy should take into account all three categories as well as the fact that attributes change category over time: above all from attractive attributes to one-dimensional and eventually to must-be basic attributes (Shen et al. 2000: 92). Therefore, these product attributes can be stated rather dynamic than static (Shen et al. 2000: 93). The same characteristics are also true with the technology levels of the knowledge and technology rankings.

In an earlier study such as the one by Takala, Koskinen, Liu, Tas and Muhos the S&R methodology has been used to study one multinational Finnish company. In this study the answerers from the company were divided to three different groups. The first group consisted of the company's management team, the second included global directors and the third group was mixed from the results of groups one and two. Furthermore, the S&R and BCFI were used to figure out the resource allocation of attributes in which the attributes were divided to over resourced, under resourced and balanced attributes. After this the dominating technology was determined for each attribute with the K/T rankings. The dominating technology refers to the technology level which reaches more than 43% of the given values and if none of the levels reaches that much then the one with the highest values is referred as dominating. Also the company's strategy type can be detected based on the so called manufacturing strategy index (MSI). All strategy types or more precisely the manufacturing strategies are divided to three possible groups: prospector, analyzer and defender. (Takala & al. 2013: 45, 48, 50)

In the first group a weight between 25% and 50% were given for basic technologies depending on the attribute, for core technology around 35% on each attribute and for spearhead roughly 20%. From these values could be concluded that the company is more or less competitive. Only the proportionally low share of spearhead technologies aroused some concerns about the future of the company. With the second group the weights were pretty much the same. Basic technologies were valued more than spearhead and the core technology reached the same value as with the first answer group. All in all, the mixed results from both groups showed the following results. Basic technologies were in a range of 25% to 60, core technology roughly around 35% and spearhead around 20%. Based on the principles introduced in the previous chapter the basic technologies can be determined as dominating technology for most of the attributes. This questions the competitiveness of the company from the technology point of view although the 35% share of core technology is not seen as totally bad. Furthermore, the company's strategy type seems to follow the defender group. (Takala & al. 2013: 51-52)

It is also possible to connect the technology levels to technology pyramid and even further to technology life cycles as presented in the figure 9 (Tuominen et al 2004: 10). In this figure the basic technology is replaced with Key technologies which are described as “essential know-how, in which the products and the business are based” (Tuominen & al 2004: 10). However, it is mentioned that also a fourth layer could be added under the name of “additional technologies” which presents the outsourced functions (Mäntynen 2009: 14). In any case the figure illustrates brilliantly the linkage between the two models and the technology levels. It is essential for the management to understand the phases of the life cycles and the impact of technologies since being late in adaption gives the advantage to the competitor (Tuominen et al. 2004: 11). Obviously some technologies can be left for others to develop and therefore it is important to identify the very technologies meaningful for the business. (Tuominen et al. 2004: 11).



**Figure 9.** The linkage between the technology levels, technology pyramid and technology life cycles (Tuominen et al. 2004: 10)

## 6. Methodology

According to Olkkonen the two most significant philosophical research approaches are positivism and hermeneutics. In positivism the research should be independent of the researcher and also repeatable. The latter means that other researchers should be able to get the same results when using the same methods and research material. Moreover, positivism is based on so called “hard facts” and external observations. This means that the research material is mainly quantitative and includes a lot of measurements. Alternatively, hermeneutics can’t guarantee autonomous results since it is usually based on the understanding of the researchers. Researchers and the users of the results can understand the information and its significance differently. They might also have different backgrounds compared to each other. Therefore, it is essential that the researcher’s view on the matter is clearly understood. Furthermore, the material in hermeneutics is naturally mainly qualitative and “soft”. Usually the natural sciences are based on positivism whereas the humanities use more hermeneutics. In business economics both approaches can be found. (Olkkonen 1993: 26, 28, 35-36)

Positivism and hermeneutics can be both further divided to computational science, theoretical science and observational science. Computational science enabled by the development of data processing focuses on modeling phenomena and studies them by using methods such as simulation. Moreover, theoretical science develops theories by the means of deductive reasoning which means that already achieved theories are tested, expanded further and applied to new or existing areas. In other words, conclusions about the problems are based on the already existing theories. Lastly observational science gathers observations and processes them by using inductive methods. Inductive reasoning is mainly empirical research in which conclusions such as causalities or correlations from the whole population are made statistically based on samples. In this way the deductive and inductive reasoning can be seen as opposite methods to each other. All the aforementioned ways of making science can be called as the paradigms of science or alternatively as research strategies. (Olkkonen 1993: 28-30)

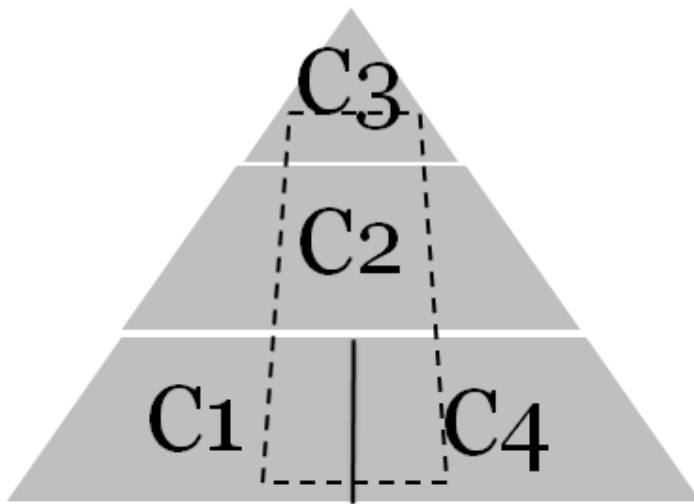
The research of this thesis can be considered belonging to the hermeneutics as its philosophical background. Therefore, the produced data can be seen mainly as qualitative although one important goal of the whole MittaMerkki project has been turning intangible criteria to quantitative data. This is partly the case also in this thesis since for example uncertainty is depicted as variability coefficients i.e. as percentage figures. However, as a research the study of this thesis can be defined as qualitative consisting largely of a case study. Furthermore, the research is based on deductive reasoning since the theories regarding AHP, the sand cone model or knowledge and technology (K/T) rankings have already existed and been developed before as is explained thoroughly in the literature review. However, in this study these methods have been applied into a new model of investment uncertainty assessment which has been tested in the field of energy distribution.

In this study the Analytical Hierarchy Process was used to weight the selected criteria of investment decision-making. The investment criteria signified the aspects that the company wanted to take into consideration when selecting and comparing possible investment options to its distribution infrastructure. Naturally the investment budget is limited and not every potential investment could be realized, at least not during the same budget season. In the workshops arranged between the case company and the research partners, four criteria were selected and weighted with the following AHP questionnaire (Figure 10).

1 Criterion 1	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	Criterion 2
2 Criterion 1	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	Criterion 3
3 Criterion 1	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	Criterion 4
4 Criterion 2	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	Criterion 3
5 Criterion 2	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	Criterion 4
6 Criterion 3	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	Criterion 4

**Figure 10.** The AHP questionnaire

Next the selected and weighted criteria were inserted to the sand cone model. Based on the AHP prioritizing, the criteria 1 and 4 were located in the ground layer of the cone since these two criteria had been given 2/3 of the total weight as introduced for a requirement by Takala et al. (2006: 340) when analyzing the features of items considered as the first level basic pillars. The sand cone is presented in the figure 11 below. However, in this sand cone the desired effects of the technology and knowledge factors (K/T) remain invisible. In the figure this lack of transparency is illustrated with the black dotted line rectangle.



**Figure 11.** The sand cone with the illustration of K/T invisibility

In order to make the knowledge and technology factors and their effects visible the aforementioned Knowledge and Technology requirement section of the Sense and Respond method was utilized. There were two possible ways to proceed. Either to connect the basic, core and spearhead technology weights directly to the sand cone model or to calculate so called variability coefficients from the technology levels. The latter was evaluated to be better in measuring the uncertainty related to decision making and also more potential considering the calculations. Before the calculations at least one example of the technologies used in each level (basic, core and spearhead) were determined as well as the time perspective utilized. This procedure was conducted by

the case company experts for each department separately. However, as an example the next table (table 1) illustrates some possible technologies from the field of electricity and as can be noticed this procedure makes the case more practical at once.

**Table 1.** K/T technology levels example: Electricity networks

<b>Basic:</b>	cables, transformers, substations, overhead lines, energy meters, information systems
<b>Core:</b>	automation systems, protection systems, telecommunications, fault indicators, automatic fault locations
<b>Spearhead:</b>	LVDC, 1000-V systems, smart grids, self-healing network, HVDC nodes

After naming the technologies, the Knowledge and Technology rankings were gathered with a questionnaire presented in the figure 12. As can be observed the technology levels are illustrated in the first row and below them each department per technology level in the second row. In this questionnaire each criterion (from the first column) is divided according to the three technology categories so that the sum equals 100% in both the department and the criterion in question. For example, C1 is divided in the department A as 60 percent for basic, 40 percent for core and zero percent for spearhead technology ( $60\% + 40\% + 0\% = 100\%$ ). This means that 60 percent of the company's current infrastructure related to the first criterion is basic technology. If this criterion

would be for example dependability this answer would mean that the company has no spearhead technology affecting on dependability. Furthermore, can be seen that the sum of the last row marked with the red color does not equal 100% (15%+65%+30% = 110%). Hence, the answerer is required to take care of this requirement.

	Basic			Core			Spearhead		
	Dept. A	Dept. B	Dept. C	Dept. A	Dept. B	Dept. C	Dept. A	Dept. B	Dept. C
<b>C1</b>	60 %	-	-	40 %	-	-	0 %	-	-
<b>C2</b>	-	60 %	-	-	30 %	-	-	10 %	-
<b>C3</b>	-	-	70 %	-	-	30 %	-	-	0 %
<b>C4</b>	15 %	-	-	65 %	-	-	30 %	-	-

**Figure 12.** The K/T questionnaire

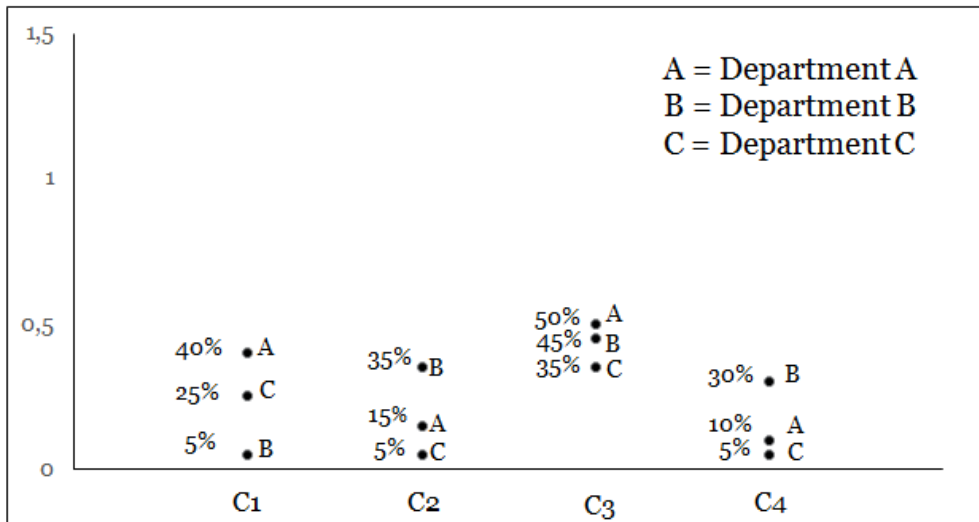
The aim was to collect the answers from the distribution company's board and a minimum of three experts from each department. In the answering procedure the board members would answer for every department and the experts on behalf of their own department. From the data the variability coefficients were calculated by using the following formula,

$$Var C_{C1,C2,C3,C4} = \sqrt{\sum_{i=B,C,SH} C_{C1,(C2,C3,C4)} \left(\frac{std_i}{mean_i}\right)^2} \quad (1)$$

In this formula a variability coefficient (VarC) depicting the uncertainty is calculated for each criterion from the answered basic, core and spearhead technology levels. This procedure is then performed for every department. The aforementioned implementation index (IMPL) introduced in chapter 4 is also part of the formula. This makes the analysis of the answers possible from the reliability point of view as well. All in all, the end results should look as illustrated in the next figure below (figure 13). From this figure can be detected which department has the highest uncertainty in which criterion.

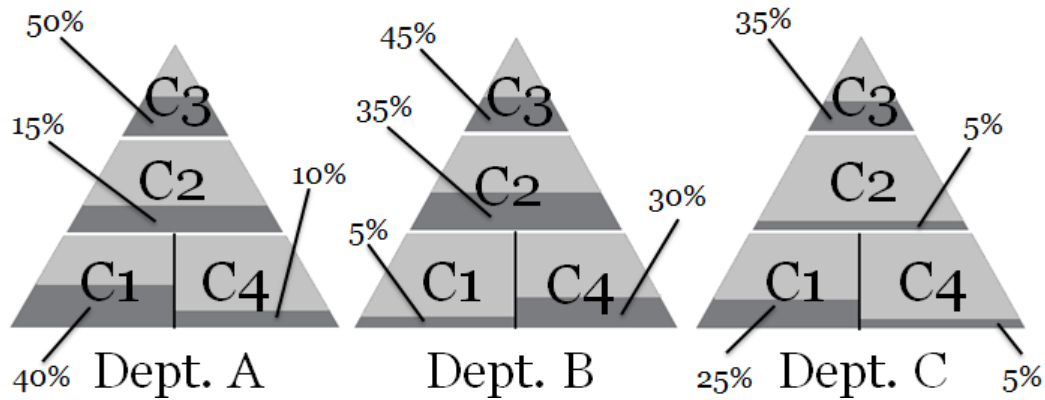


Furthermore, some observations can be made such as in this example that criterion 3 causes the highest uncertainty in each department.



**Figure 13.** The variability coefficients (VarC)

Next the variability coefficients are inserted to the sand cone in the form of risk that can cause collapses in the sand cone layers (see figure 14). These risks are pictured with the darker shade of grey in the sand cone layers and the accurate percentage values are illustrated always next to the criterion in question. A separate sand cone is created for each department in order to see their differences. The reasons for the possible collapses are the different technology and knowledge requirements of the different departments competing from the shared investment budget.



**Figure 14.** The sand cone model with K/T collapse risks

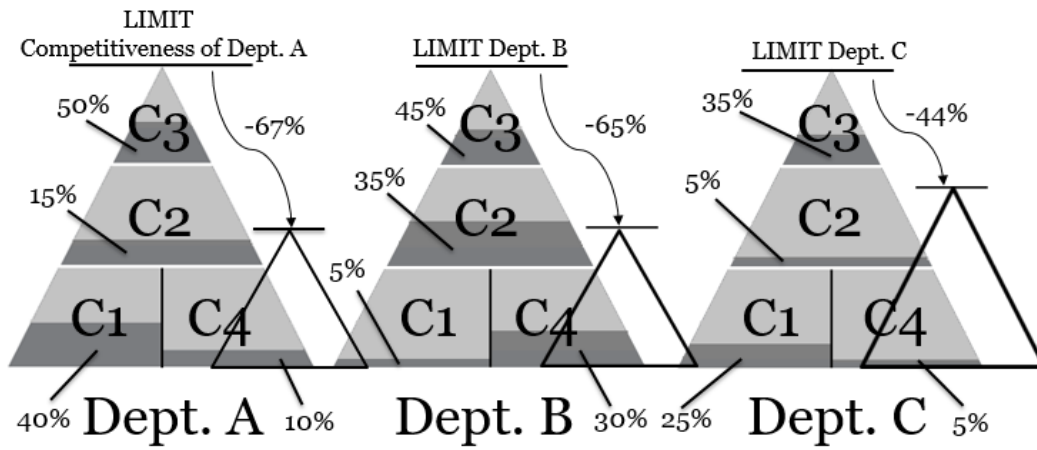
The previous figure makes the comparison of different sand cone layers possible but the overall picture of the department's situation regarding to the uncertainty remains unclear. Also the comparison of different departments is challenging when based on individual criteria. Therefore, a single figure is needed to show the amount of T&K affected risk in each department. This figure is called the T&K -uncertainty and it describes how much in generally the department "falls" under its competitive range when the T&K risk estimate materializes. The T&K –uncertainty figure is calculated for each department from the variability coefficients as can be noticed from the equation below,

$$\text{T\&K -uncertainty} = \sqrt{\sum_{i = C_1, C_2, C_3, C_4} \text{Var}C_i^2}$$

Dept. A, B and C

(2)

All in all, the end result would look as in the figure 15. Right to the cones are presented the T&K –uncertainty figures as well as the graphical illustration of the possible collapse of the department's sand cone. Now, the comparison of departments is much manageable and the overall status regarding uncertainty clearly visible.



**Figure 15.** The T&K uncertainty and the sand cone model

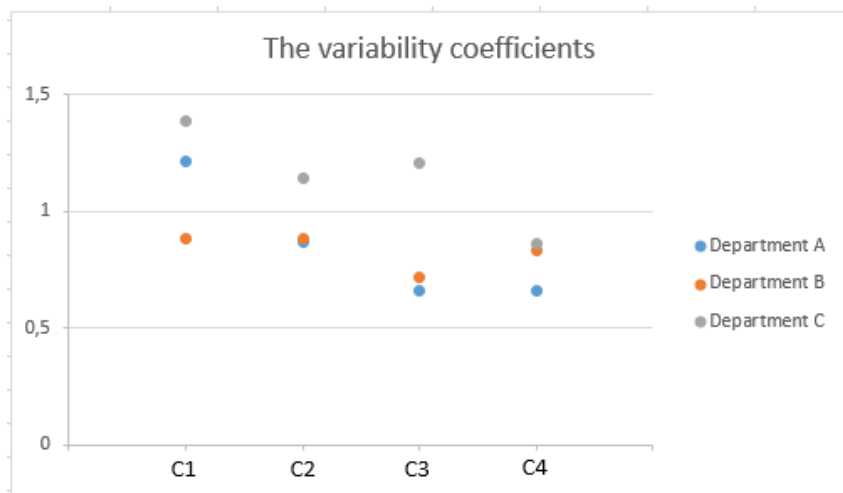
## 7. The case study and data collection

As introduced in the first chapter the case company is the subsidiary distribution company of a Finnish city-owned energy group and thus responsible for the maintenance and rehabilitation of the distribution infrastructure. The research of this case study concerns solely the decision making of the rehabilitation investments planned for the distribution network. The investment proposals are drawn in three departments each responsible for their own specific area. Then the proposals are brought to a steering group, which decides those investments realized from the proposals. All the investments are funded from the same budget. The steering group consists of the distribution company's executive board members and few experts from each department. The aim of the MittaMerkki project was to develop the evaluation process of the steering group by creating a unified comparing method for the investments of the three departments so that the comparing process would be considered fair and supporting to the company's strategy. One responsibility of the University of Vaasa was to connect strategic view to the decision making and this thesis has done so by evaluating the uncertainties in the steering group decision making with the methods presented in the previous chapter.

Altogether the research process consisted of gathering answers to two questionnaires. To the AHP questionnaire six members from the company's executive board contributed their answers. The AHP answers were then used to develop the model and the K/T questionnaire. The answerers to the K/T questionnaire consisted of the executive board and some experts from each department. In the end four members of the board were able to answer to the questionnaire. In addition, two experts from department A, one from department B and again two from department C were able to participate. The amount of experts was then a bit lower than the desired three from each department but in the end found sufficient to complete the study. The board members answered for every department and the experts on behalf of their own department. After analyzing the questionnaire results few group interviews were organized in order to present, validate and further analyze the results.

### 7.1. The modeling of uncertainty

Based on the K/T questionnaire answers the following variability coefficients (figure 16) were determined for the case company. As can be observed from the figure all the coefficients are higher than 0,5 under each criterion. Furthermore, only one criterion (C4) had lower variabilities than 1 in all the departments. This makes the uncertainty rather high for every department. In this case the department C has the highest variability in every criterion. The best situation seems to be in department B since all the coefficients are less than 1. Altogether it can be said that there is a lot of uncertainty in the investment decision making of the case company.



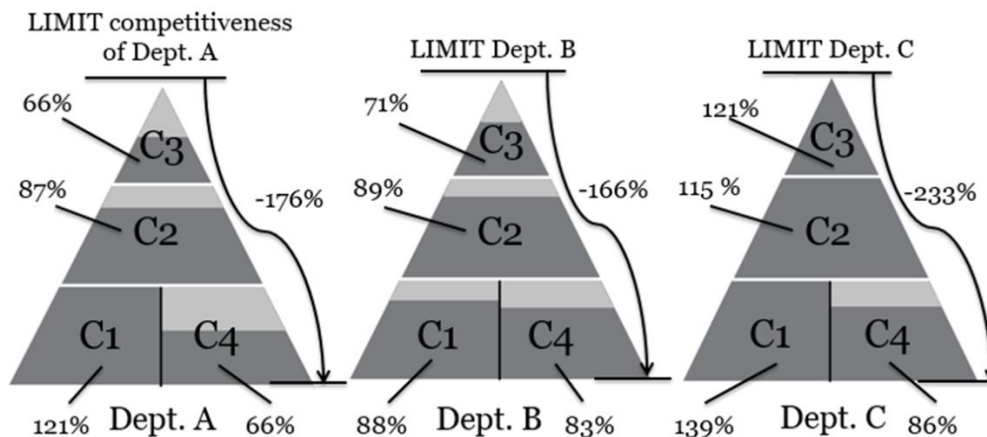
**Figure 16.** The variability coefficients of the case company

The implementation indexes are illustrated in the table 2 below. As can be seen most of the IMPL values are under one ( $<1$ ). This speaks for the reliability of answers and results as is explained in the study of Mäkipelto and Takala (2009: 292). Only four values are higher than one (marked with the red color). For these values more information is needed from the reliability point of view.

**Table 2.** The IMPL index values

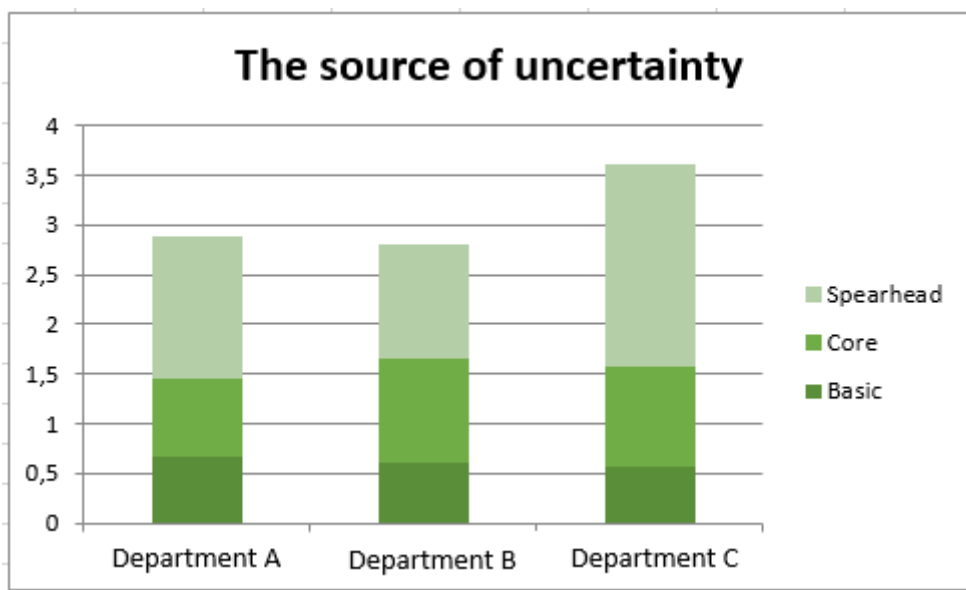
	Department A			Department B			Department C		
	Basic	Core	Spearhead	Basic	Core	Spearhead	Basic	Core	Spearhead
C1	0,480	0,375	1,049	0,330	0,426	0,697	0,340	0,469	1,265
C2	0,251	0,375	0,739	0,251	0,640	0,559	0,252	0,476	1,011
C3	0,281	0,394	0,454	0,147	0,471	0,516	0,315	0,596	1,002
C4	0,251	0,454	0,411	0,426	0,540	0,471	0,194	0,465	0,699

When inserted to the sand cone model the variability coefficients of the case company are illustrated in the form of collapses (darker grey in the figure 17 below). Those criteria with over 100 percent variability question the whole investment evaluation based on that criterion. Although there are small differences among the uncertainties of different criteria between the three departments the big picture can be seen from the T&K-uncertainty figures next to the sand cones. As can be seen the T&K-uncertainty is over 100 percent in each department. This puts the whole investment evaluation under question as well as the comparison of different departments.

**Figure 17.** The T&K -uncertainty and the sand cone collapses of the case company

Some remarks can be done from the sand cones. The collapse risks in department B seem quite manageable but obviously can't be praised. Such is the situation also with

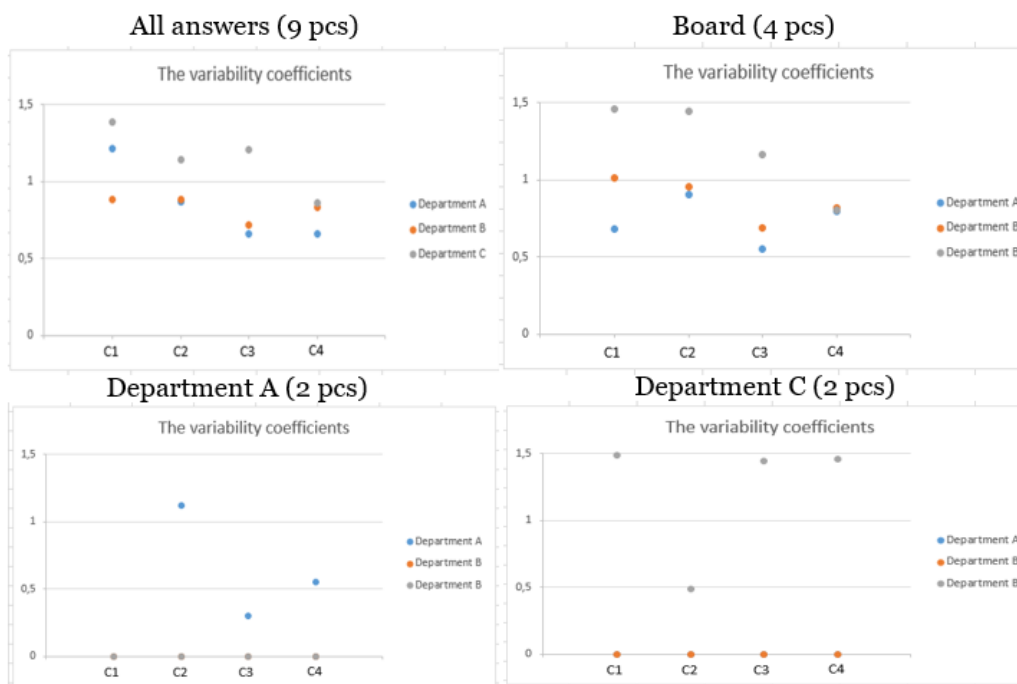
department A except the criterion 1 which is very dominating. With department C the situation is clearly unbearable since such high is the uncertainty in each layer. What is then the source of this high uncertainty? The next step was to study which part of the basic, core and spearhead classification causes the most variability in the answers. The image is very clear as can be seen from the next figure (18). The spearhead technology and –knowledge is the main source of the uncertainty. It can also be pointed out that even the core technology gets too high variabilities in every department but still much smaller than the spearhead. Therefore, a conclusion can be drawn that the company bases its technology and knowledge management mainly on basic technology.



**Figure 18.** The source of uncertainty in the case company

Moreover, the case was cut to pieces in order to figure out the implications of the results. From the next figure (19) can be compared the answers from all interviewees, only board answers and only expert answers from departments A and C. Department B is missing because only one expert from that department was able to answer to the questionnaire. Within the answers given solely by the experts there is a lot of fluctuation

between the criteria meaning that some of the criteria received very high variability coefficients and some even very low. For example, based on the answers given by the two experts from department C can be deduced that the criteria 1, 3 and 4 seem to be very challenging for the experts. With department A, the case is similar with criteria 1 and 2. In criterion one the variability was even so high (1,74) that it could not fit to the scale used and therefore cannot be seen in the figure. At the same time the answers of the board tend to remind more the trend of all answers. Therefore, a conclusion can be made that the board's view seems to be rather dominant in the investment decision-making of the case company.

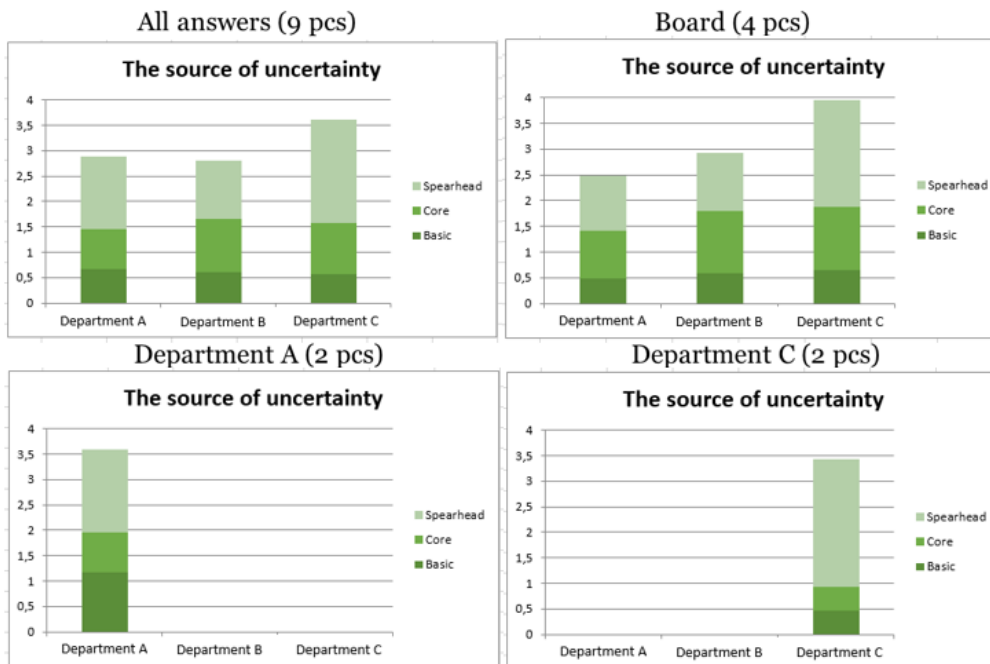


**Figure 19.** The comparison of variability coefficients between different departments

Furthermore, the same review was done with the bar charts portraying the source of uncertainty (figure 20 below). In every answer category the spearhead technology is the biggest source of uncertainty. It seems that especially the experts are no able to perceive



the share of the spearhead technologies. The variability regarding spearheads is big in the answers of department A and even bigger in department C answers. This generates clearly a major part of the uncertainty also in the total answers.



**Figure 20.** The comparison between the sources of uncertainty.

## 7.2. The market-based validation

Although the results seem rather clear feedback from the case company is required especially for defining the reasons behind these uncertainties and in order to validate the methods. In this process the market-based validation of Kasanen, Lukka and Siitonen would be followed (1993). The market-based validation is based on the assumption that in order to test the pragmatic adequacy time and several attempts of the application is needed. There are altogether three different market tests which are based on the concept of innovation diffusion. In this concept the so called managerial constructions “are viewed as products competing in the markets of solution ideas”. The term

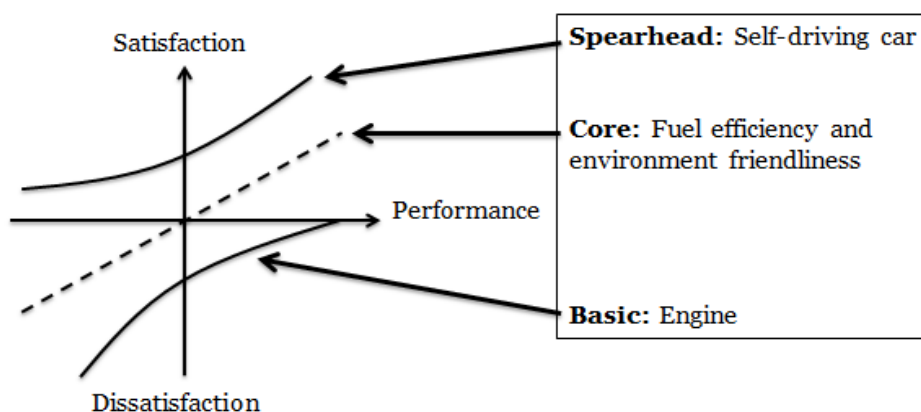
“constructions” refer to something that “produces solutions to explicit problems” and in managerial constructions these problems to be solved are especially related to “running business organization”. (Kasanen et al. 1993: 244, 253)

The first market test of the marked-based validation is the weak market test which requires a manager who wants to apply the construction in the actual decision making. This manager has to be responsible for the financial result of his/her business unit as well. The second test is the semi-strong market test in which the construction has to be put from willingness to use to actual practice widely by the companies. Finally, the last and the most demanding is the strong market test. In addition to be put in practice there have to be also better financial results than without the construction in question. Although there is a clear degree of difficulty between the three market tests, it does not mean that the weak market test would be somehow easy to carry out. Actually Kasanen et al. emphasize that a tentative construction is not often even capable to pass the weak market test. However, for the strong and the semi-strong market tests a lot more time is needed since they demand a significant amount of statistically analyzed implementation data. (Kasanen et al. 1993: 253)

In this study the idea is to use the weak market test and in addition possibly the semi-strong market test for the validation of results and methods. The strong market test was seen as too challenging and also hard to implement because of scheduling reasons. In order to pass the weak market test, the necessary amount of interviews would be organized for the analyzing of the results and the reasons behind the results i.e. the uncertainty. Also the experts' willingness to apply the results in the decision making would be analyzed. As mentioned the semi-strong market test is possible as well. Obtaining it would mean in this case to clarify whether there is any data from projects performed in the departments that would support the results of the study. The aim was to get 1-2 experts from each department to be interviewed and then to make conclusions based on the two aforementioned market tests.

### 7.2.1. The interviews

The starting point of the interviews was to define how clear the basic, core and spearhead technology levels of the knowledge and technology rankings were to the interviewees and how easy it was to name technologies to these categories. These questions could be seen pivotal to the successful fulfilling of the questionnaire and thus to the success of the study. As explained in the chapter six, the company experts named the technologies in every technology level for each department. Previous to the procedure the researchers defined the levels and provided some examples to each category (in the same way as for the example in table 1) in order to facilitate the experts' work. These examples were collected from various experts and professors from fields corresponding the departments of the case company. However, it is quite possible that in the beginning a simpler example (such as the car example in chapter 5.2.) would have been better in explaining the technology levels. In the same manner the technology levels could have been presented together with the Kano model in order to further enlighten the idea of the process. Because of these presumptions, the matter was decided to be taken in the conversations (interviews) together with the presentation of the Kano model and a simple car example regarding the technology levels (figure 21).



**Figure 21.** Connecting the Kano model to the K/T technology levels

The next important step for the interviews and especially considering the weak market test was to determine how credible the interviewees found the results. In practice this was done with the help of the department sand cones including the collapses in the layers as well as the T&K-uncertainties. The credibility had two aspects: credibility regarding the departments and credibility regarding the investment criteria. The third aspect for the interviews was the source of uncertainty (see figure 18). Why it was the spearhead technology which received the biggest uncertainties among the answers? In this point there was a possibility to conduct the semi-strong market test as well by gathering experiences from past spearhead projects and pilot projects. With experiences was meant possible problems and uncertainties in the projects such as overran budgets or delays in the schedules.

When presenting the uncertainty results to the case company for the first time few preliminary conclusions were instantly made by some of the board members. They thought that the results corresponded the strategic planning of the company since a major part of its strategy was to secure the distribution operations by leaning on basic and core technologies. Being a so called “first mover” was not seen as its role in the market nor necessary for the successful distribution operations. The one main surprise for the company was the biggest uncertainty in spearhead technologies received by the department C since this department has had the most spearhead and pilot projects. The results also raised questions about the awareness of the requirements posed by the spearhead technologies on the case company. Based on these preliminary conclusions the researchers wanted to ask from the interviewees once more, did the results correspond the strategic planning of the case company, what does the spearhead technologies demand from the case company and are the conclusions made so far correct. Other conclusions included for example the company’s lean on basic technology, the dominance of the board’s opinion in the decision making process and the decisive role of technology and knowledge in the investment decision making.

Based on the aforementioned conclusions few proposals for actions were made before the interviews. If the interviewees would consider the results credible, then due to the

high uncertainties in each department and in most of the criteria it would be advisable to arrange some training in the field of technology and operations management (TOM) in order to reduce the uncertainty related to technologies. The training could be based for example to the core competencies and managing methods introduced by Gehani (in chapter 5.1.). On the other hand, if the interviewees would not agree with the results nor find any linkage to the strategy, it might be better to enlighten the strategy by organizing an internal strategy round/reflection. Of course also the interviewees would be asked to present ways to decrease or eliminate the technology and knowledge related uncertainty since they indeed are the experts in their field of work.

Furthermore, in the case of board dominated decision making a more democratic way of decision making especially in the department level would be an action worth considering. The importance of this action would of course depend on how direct impact the T&K –uncertainty has on investment risk management and hence to choosing the right investments. In practice this “democratization” could be done by following the method used by Takala et al. (2005) in their case study. In this case the AHP method was used weight five main market and technology factors and then according to these criteria make a pairwise comparison between five “evenly competitive” projects (Takala et al 2005). The answers were taken from two different groups the first one consisting of 7 project managers and the second of 6 R&D managers (Takala et al. 2005). Hence, the amount of criteria and answerers in both groups is more or less similar as in the case company of this study. Only the amount of projects differs significantly since instead of five projects the decision making of the case company comprises dozens of different investments options. However, this AHP process was seen as fast and easy in helping the managers to get acceptable average weights for criteria and project candidates (Takala et al. 2005). Moreover, this solution would bring traceable results to the discussion and show the differences in opinion (Takala et al. 2005). Also technology roadmaps could be added to the process as an assistive tool (Takala et al. 2005).

### 7.2.2. The weak and semi-strong market tests

As mentioned in the chapter 7.2 the aim was to interview 1-2 experts from each department. This requirement was achieved since after having discussions with the case company two experts from each department were named for the interviews. Interestingly one expert from each department had participated to the K/T questionnaire and the other not. Thus also new viewpoints were received about the possible uncertainties. In addition, one member from the executive board and one person responsible for the network services and metering were interviewed as well. The interviewees were divided to four interview groups: three groups consisting of the two experts from each department and the fourth consisting of the two remaining interviewees.

After further explaining the basic, core and spearhead technology levels and connecting them to the Kano model the interviewees stated that they had understood the idea and the levels correctly. Based on the information, the listing of technologies was found successful although some modifications would have been done afterwards such as adding some potentially missing technologies and moving few for example from basic technology to core technology etc. Furthermore, few observations were made about the listing process. It was found important that the content of the levels was defined to include only investments related to the distribution network and especially the rehabilitation investments instead of investments to new infrastructure. Also the listing of technologies was not required to be too in detail. In order to keep the lists as simple as possible it was sufficient to include only the technologies and not necessary every component related to these technologies. After clarifying the aforementioned the technology levels were found clear and it was possible to position technologies based on the levels. This conclusion was important for the successful fulfilling of the questionnaire and completion of the study as mentioned in the previous chapter.

Nonetheless there were some aspects related to the uncertainty of investments that could be noticed when analyzing the technology levels. Although a technology is put in the

right level, it might still be interpreted differently, which increases uncertainty among the answers. One of these technologies in the study was the decentralized production of energy and the related distribution, which has received a lot of attention as a potential and probable way of producing energy in the future. The decentralized energy systems have been connected for example to battling the climate change, production of green energy, energy security etc. (Altmann, Brenninkmeier, Lanoix, Ellison, Crisan, Hugyecz, Koreneff & Hänninen 2010). However, the concept of DG (distributed generation) seems to be all but clear from the perspective of an energy company. Does DG mean the company's own decentralized distribution network instead of big centralized plants, the energy generated by its customers and consumers or both? To each of these possibilities has to be prepared but the amount of investments needed varies a lot depending on the option and this creates uncertainty especially regarding the spearhead technology related to decentralized energy production and distribution.

Next the case company's sand cone model of investment uncertainties including the risk collapses and T&K-uncertainty figures were discussed and analyzed thoroughly (see figure 17 in chapter 7.1.). The opinions about the right number of investment criteria varied between the departments. In department C four criteria were found sufficient, department A would have wanted to add one extra criterion and department B two extra criteria. These differences between the departments came as no surprise and the board had taken it into consideration when selecting the criteria. The board defended its decision with the fact that the criteria had to be large and clear enough to make the investment decision-making and risk evaluation as straightforward as possible in order to be successful. Furthermore, the one and two missing criteria were already partially included to the current four criteria. However, the department experts wanted once more to express their desire of having these aspects as separate criteria in order to ensure their features to be taken better into consideration when making investment decisions for the infrastructures. This raises a question that although each department would be analyzed with the same amount of criteria, should every department has its own AHP prioritizing to make sure that the different premises of the departments are better taken into account?

All the interviewees found the size of the collapses difficult to analyze from the reliability point of view or even a bit too large but everyone believed that a greater sample of answerers would decrease the variabilities especially when combined to the same kind of elimination of extremes as the inconsistency index is in AHP (see chapter 3). The only barrier for a bigger sample was detected in department C in which the amount of experts is rather small and happens to include a lot of new workforce. In department B increasing the amount of expert answers instead of board answers was kept as an imminent way of decreasing the uncertainty since all of the board members able to participate had their background from the fields of the other two departments. All in all, since the interviewees accepted the uncertainty showed by the sand cone models and kept the sequence of the criteria arranged according to the variability coefficients as correct, it could be declared that the models and the study results passed the weak market test.

In addition to the weak market test, few conclusions were drawn from the sand cone collapses. Although the company is in many fields in a monopolistic or dominant market position, the experts felt that the uncertainty can't reach zero in any circumstances. On the other hand, the different requirements posed by the law on the three departments were seen as a cause of uncertainty because it contradicted the idea of having the joint investment budget and the unified investments decision-making of the departments. Moreover, especially carefully were discussed the very high variabilities received by the department C. The experts of the department did not see their high uncertainties as particularly worrying, because despite the possibly varying opinions of the experts every investment proposal is thoroughly discussed inside the department and for significantly larger projects the approval of the board is always ensured. In this sense the decision-making of the department resembles slightly the Delphi method in which "the most reliable consensus of opinion" is obtained in a group of experts by exploration of the subject through discussion, reaching an understanding between the views, finding the underlying reasons of disagreement and making a final evaluation of the matter in question (Linstone & Turoff 2002: 5-6, 10).



Besides to the openness of interpretations, also other factors were found that explained the high uncertainty of spearhead technologies (see figure 18 in chapter 7.1.). For example, with department A the main cause for high uncertainty was seen to be the state authorities who don't appreciate the future technologies in their evaluation of reasonable compensation statutory for this industry. The focus was seen to be too much in the presence and not in the future although the investments in this field are very long lasting up to 40-60 years. A couple of practical examples were discussed to further enlighten the situation also regarding the overall uncertainty. The first one involved a power plant project in which distribution equipment had been in the beginning of the project accepted by the authorities but afterwards a part of the revenue was demanded to be returned to the customers within the reasonable compensation scheme. Obviously the predictability of the authority decisions is very important to the investment decision making.

In another example some spearhead technology offered by a supplier could not be invested in since it was not included in the compensation scheme by the officials. Lastly, there had been a dispute over a property, which the company had defined as a safe area. However, the officials did not accept the size of the safe area and instructed to reduce the area. The company's found this as a very contradictory practice that was hard to understand from the perspective of their safety expertise. There were also similar examples in the other departments related to spearhead technology. For example, in department C a pilot project aiming at even out the peaks of production had resulted in stalemate because of the uncertainty over the real costs of using backup power plants. After analyzing these practical examples about the uncertainty, a conclusion can be drawn that the models do give a reliable illustration from the situation and hence the study passed the semi-strong market test.

Based on the interviews the following can be said about the departments. Department A faces a strict official supervision. Moreover, the experts felt that the strategy of the department follows to good effect the investment strategy of the company and the technology supports the operations. Just the resources are often not sufficient to further

research of spearhead technologies. Department B has in general bigger and more expensive investments than the other departments and also a larger territory of operations. The department experts felt that is enough to assess the AHP weights on demand when something in the strategy changes. Hence there is no need to a regular assessment. Department C is the less regulated of the departments and interestingly faces the biggest uncertainties. However, the experts felt that more instructions would have been needed for the study. Altogether, one particular thing, which was seen to decrease uncertainty, was the cooperation between the company and the industry of technology suppliers. The possible associations related to the field of operations were seen as a potential environment of collaboration as well. An interesting aspect was also given to the possible changes in future products. This means that in future energy facilities might be selling “light” instead of electricity or that the customers might buy cooling and let the company decide how this cool air is produced. This change in productizing can cause uncertainty especially related to spearhead investments but gives also many possibilities to new business opportunities especially in services.

The premade suggestions for actions were taken interested by the experts. Although the models of this thesis seem to give a precise picture of the reality and reflect the company’s strategy, the experts undersigned the need to enlighten the strategy. The strategy was found a bit loose and in order to avoid it being labeled mainly as “marketing material” a clarification would be advisable. Especially important would be to clarify the “dismounting” and practical implementation of the strategy. This means answering to questions such as what the strategy means in practice and how it should appear in the everyday work of the employee. Nothing groundbreaking in this sense and as suggested in the previous chapter an internal strategy round/reflection could be the answer to this problem. The interviewees were also very interested about the training of technology and operations management (TOM). With the TOM training would be aimed at improving the management of technology and knowledge but it could be connected to the development of the aforementioned new service business possibilities as well.

The third suggestion raised the most discussion in the interviews. A more democratic way of decision making between the departments was seen as the main goal of the MittaMerkki research project. The message from the experts was, that in addition to the difficulty of comparing the risks between the departments, the departments are not equal anyway for example because of the different requirements posed by the law to the different fields in which these departments operate. The department experts hoped to get more elasticity in the investment decisions. This is especially related to the larger investments and means that each department could have in turn their bigger investments trough and others would be flexible when needed. Also more flexibility was desired to the whole investment budget since the amount of investments needed varies a lot and depends on how much infrastructure has been built in the past centuries for instance. Actually, based on the interviews the whole shared budget of the departments could be questioned since such substantial are the differences between the departments. In addition, the synergies between the departments supporting the joint budget have turned out smaller as expected. Lastly was pointed out that the current investment decision making emphasizes too much the initial cost of investments in the expense of their life cycle costs.

## 8. Discussions

Compared to the previous studies combining the decision making with uncertainty this case study has two very distinctive features. First of all, it measures uncertainty from the technology and knowledge point of view and secondly focuses to the investment decision making in the energy industry. As introduced by Rääkkönen et al., most of the investment decision impact assessments are based on financial methods and to some others which also take for example societal factors into consideration (2015). However, the risk and opportunity category is more underserved, what comes to the methods (2015). Moreover, only few studies consider the relationship between decision making and uncertainty (Lipshitz and Strauss 1997). The solutions provided in those studies might also be in a too general level compared to this very specific energy industry investment decision making case. Furthermore, those few studies focusing on energy industry might have different perspectives such as the article of Hirst and Schweitzer which concentrates solely to the resource planning and decision making of electricity utilities (1997).

If we consider for example the Lipshitz and Strauss categorization of uncertainty (presented in chapter 2), it could be argued that the issue of uncertainty in this case is “alternatives” – which alternatives to choose to be invested in from the limited budget. Furthermore, the source of uncertainty can be argued to be either the incomplete information, since it can never be known beforehand which investments should have been selected (which pipe breaks first etc.), or undifferentiated alternatives since all the proposed investment are necessary and therefore equally attractive. The tools offered to battle these sources of uncertainty are the Assumption-based reasoning and the weighting of pros and cons. However, it remains hard to see how these methods could replace or even supplement the expert work already done in the company. The same is the situation with the different methods of forestalling not to mention the tactics of suppression. However, with the knowledge and technology rankings it is possible to see which part of the basic, core and spearhead technology levels creates the uncertainty and is the situation in line with the strategy or is some TOM training needed. This

process can give the decision makers practical information how technology is perceived in the company and how it causes uncertainty. This is especially important in the technology intensive industries such as energy. Of course other industries might benefit from different kind of solutions.

As concluded in the chapter 7.1 the case company seems to lean on basic technology in securing its distribution operations. In other words, basic technology has the position of dominating technology in the company as Takala et al. suggested in their study (2013). This can be also observed from the weights given to basic technology ranging roughly from 45% to 60%. Similarly, the core technology reaches weights between 26%-42% and the spearhead 7%-22%. From the technology point of view, the low amount of spearhead technologies can be seen as worrying. Especially when added to the high uncertainties related to them. However, the company mostly saw this as a reasonable outcome based on the strategy. As introduced the company is a very traditional Finnish energy company owned by the local municipality (which is not a very uncommon form of ownership in the Finnish energy markets). By “playing safe” it ensures the distribution of energy to its customers and as a very local operator it does not have to be first in adapting future technologies in order to survive the international competition. Based on this feedback and the more or less fine share of core technologies, it can be assumed that the company is rather competitive at the moment especially when considered its monopolistic or dominant market position in the business environment. Moreover, the company’s strategy seems to follow the defender group in the manufacturing strategy categorization.

The concern of overemphasizing short-term effects and the present costs instead of whole life cycle costs seems not to be a particularly new aspect especially in the energy industry. For example, David G. Woodward stated the same problem in his article already in 1997 saying that many organizations in both public and private sector seem to rely mainly on initial purchase costs (1997: 335)). Based on his view only sectors such as military, building constructions and use, and maybe some public sector applications could be considered as exceptions (1997: 335). Based on the interview of

this thesis the problem might still exist. Also Rääkkönen et al. have reached the same conclusion and recommend the use of solutions such as the Life cycle cost (LCC) analysis which considers also the costs of usage, maintenance, disposal and lifetime profits for instance (2015). The life cycle cost evaluation becomes also very important if uncertainty is managed with measures such as increasing flexibility as the Hirst & Schweitzer study suggests (1990: 142-143).

Also one aspect worth discussing is the almost fierce criticism received by the state authorities. In many projects the decision made or changed by authorities were seen as the major reason for uncertainty. Also Moilanen states in his dissertation that “public policies, legislation and regulation have a crucial impact on industry structure, an individual firm business model and firm survival in the electric power industry” (2009: 188). Moilanen continues that the relation between public policy and electric power industry is not one way but rather twofold from its effects (2009: 189). Therefore, the future public policies and following measures should be prepared in cooperation between the government, related authorities and the electric power industry (Moilanen 2009: 189). This mutual co-operation should be conducted in the form of industry associations as well as with individual firms (Moilanen 2009: 189). This need for further co-operation was noticed also in the interviews as a mean of decreasing uncertainty. Only that the co-operation concerned mainly the relations between the company and the related industry or associations. This indicates that co-operation should be increased also with officials if possible. Furthermore, Moilanen makes a one more important notice based on his research: “public policies and regulation restrict the use of technology” (Moilanen 2009: 189). This observation can be undersigned also based on the results of this study.

## 9. Conclusions

From the variability coefficients can be concluded that there is uncertainty in the investment decision making of the case company. Thus, the collapse risks in the sand cone layers and the T&K -uncertainty figures question the investment evaluation and the comparison of departments. The uncertainty is caused by the spearhead technologies as observed from the figure 18. The high level of variability coefficients, the uncertainty that they depict and the source determined for the variability paint a quite clear picture. The case company seems to rely a lot on basic technology in securing its distribution operations. This is actually a rather reasonable result as discussed in the previous chapter. Moreover, it can be argued based on the same principles as in the Takala et al study (2013) that the company follows a defender type of strategy. Also the case company felt that the results depicted its strategic planning. All in all, it seems that the technology and knowledge are essential in the investment decision making since such notable is the uncertainty related to these two factors.

From the interviews can be concluded that the listing of technologies based on the technology levels where found explicit and helpful for the process and for the successful filling of the K&T questionnaire. However, one interesting conclusion from the listing process was that although listed properly the technologies (such as the distributed generation in this study) can still be interpreted differently. This is clearly one reason for possible uncertainties. Therefore, the key is to identify these technologies and use methods such as the Delphi method to decrease uncertainty related to these mainly spearhead technologies. The next main conclusion was that it is hard to assess investments with the same criteria when the departments operate in such different fields of energy. However, the same criteria are necessary if any comparisons between the departments are to be done. Therefore, it might be a good idea to make separate AHP prioritizing for each department in order to take better into consideration their characteristics.

The interviewees admitted that the uncertainty depicted by the sand cones exist and the criteria uncertainty is sequenced in the right order. Only the amount of uncertainty was analyzed to be a bit too high also in the case of the T&K-uncertainty figures. From this a conclusion can be drawn that the uncertainty might not have as direct effect to the decision making as the models indicate. However, the high uncertainties over spearhead technologies seemed to be reality as the many problems in different projects suggested during the semi-strong market test. In addition to the interpretation of spearhead technologies factors such as state authority valuation and the costs of backup power were named as factors which increased uncertainty over spearhead technologies. Also changes in the products such as the example of “selling light instead of electricity” can cause confusion in the future but may lead to new business possibilities as well. What comes to the departments an interesting observation was that the less regulated and supervised of the departments faced the biggest uncertainties. The natural conclusion might be that regulation decreases uncertainty. However, in the most regulated department the current regulation was seen more as a reason of uncertainty than the factor decreasing it. Since the co-operation between the company and the industry of technology suppliers as well as related association was seen as way of decreasing energy, increasing mutual co-operation with authorities could be recommendable as well.

The managerial implications of this study included three suggestions. The first one concerned strategy and as probably in many other cases too was linked to the clarification of the company’s strategy. Especially should be acknowledged its practical implementation. Therefore, organizing an internal strategy round would be advisable. Also the possibility of Technology and Operations Management (TOM) training was found interesting and one intriguing idea could be to connect the possible training to the development of new business models especially in services. The last suggestions for a more democratic decision making in the department level caused a lot of discussion. The final conclusion was that even the comparison of these very different departments is challenging. This conclusion questions the whole shared investment budget. In addition, more flexible budgeting was hoped especially in the case of larger



investments. Also the whole investment budget should follow more the need but this might be of course very challenging and depends on the economic situation as well as on the financial situation of the company. Lastly, in the investment decision making the actual life cycle costs should be emphasized more than the initial investment costs. This seems to be a problem recognized in many publications but still existing in the field as noticed in the Discussions chapter.

Finally, can be concluded that the evaluation of uncertainty based on knowledge and technology evaluation brings a functioning new method to the underserved category of risk and opportunity assessment and thus can be a good supplement to the more traditional financial methods and the emerging societal methods. It also adds data from an energy industry case to the important subjects of investment decisions, technology and knowledge management and uncertainty in decision making. To the latter an uncertainty measurement model based on knowledge and technology is something new and very different compared to the traditional categorization methods. This method can also bring new solutions such as TOM training or AHP based decision making to the managing of uncertainty in addition to other more traditional solutions such as the Assumption-based reasoning. These new solutions might be recommendable especially to the technology intensive industries in which the energy industry truly belongs as well.

### 9.1. Validity and reliability of the study

Independent answer from the informants in both AHP and K/T rankings questionnaires improved the objectivity. Although both groups were small (six board members for AHP answers and nine informants for K/T questionnaire) and since not very statistically representative, both consisted of qualified department experts and executive board members. Therefore, the results could be considered as reliable for the case company. Moreover, the IMPL values of the variability coefficients (from K/T questionnaire) were almost all less than one ( $<1$ ) which is a strong indication of reliability as

Mäkipelto and Takala suggested (2009: 292). Three of the four IMPL values being greater than one came from the department C in which also the strongest need for more starting instructions were expressed. This might explain the unreliability related to the four values in question.

The validity of the study was ensured by conducting the weak and the semi strong market tests of the market-based validation. The weak market test was passed when the interviewees accepted the uncertainties showed by the sand cones and also agreed upon the uncertainty based sequence of the criteria. Only the direct effects of the depicted uncertainty might be a bit smaller than the figures present. Furthermore, some projects where discussed through and as the models suggested (see figure 18) there were clearly some uncertainties and especially regarding the spearhead technology. Therefore, as aimed before the interviews, the study passed the semi-strong market test, which was a very forceful indicator of validity as well.

## 9.2. Limitations and future research

All of the interviewees agreed that increasing the sample size added with the elimination of extreme values would decrease the sand cone collapses. However, in one department this was seen difficult to realize because of the department's small size added with the great amount of new employee. This was clearly one true limitation for this study and made the increasing of the sample difficult at least regarding the department in question. Therefore, for the future research the sample size could be increased for example in other case companies operating in the same field of business. It would be vital also to further analyze the calculations behind the uncertainties since in this case the size of the variability coefficients was questioned. This could be done by performing this study in other similar energy provider companies. In the same time a more in-depth analysis could be made about the industry and uncertainties related to its investment decision making. This could enable also some kind of a benchmarking study

gathering the best practices in the industry for making efficient and effective investment decisions.

The study of this thesis comprised also “only” the rehabilitation investments of the distribution infrastructure. Therefore, one logical step would be to expand the study also to the new investments and further to the investments of production and service infrastructures. The reasons for the uncertainty discovered in the interviews could also be further analyzed. Questions were raised for example about the future of distributed generation, lack of life cycle cost analysis and the decisions of governing officials. Especially interesting would be to hear the respond of the officials to the projects presented in this study. This would also be rather useful in order to make further analyses about the regulation practices and the required improvements to them.

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