LAPPEENRANTA UNIVERSITY OF TECHNOLOGY
School of Business and Management
Business Administration
Strategic Finance and Business Analytics

Master's Thesis

Evaluation of financial strength and performance of Finnish mechanical power transmission companies.

Lauri Kumpulainen
2018

Abstract

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Evaluation of financial strength and performance of Finnish mechanical power transmission companies.

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98 pages, 24 figures, 24 tables

Examiner: Professor, D.Sc. (Econ. & BA), Mikael Collan, Professor, Pasi Luukka
Keywords: Fuzzy AHP, TOPSIS, Multiple Expert Multiple Criteria Decision Making, Finnish Mechanical Power Transmission, Decision-making, Financial Performance

In this study the financial performance of Finnish mechanical power transmission industry is studied over period of 2007 to 2016. Financial criteria are weighed by interviewing three experts from different backgrounds and their insights are used to give proper weighing for the criteria. Fuzzy AHP method is used to combine the experts three different weighing to the final crisp values. The companies are then compared against each other based on the financial criteria and performance ranks are derived. TOPSIS method is used to rank the companies and the difference in financial performance is identified to see that some companies have been able to consistently perform better than others.

Tiivistelmä

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Pro Gradu tutkielma
2018

98 sivua, 24 kuvaa, 24 taulukkoa

Ohjaajat: Professori Mikael Collan, Professori Pasi Luukka
Avainsanat: Fuzzy AHP, TOPSIS, Multiple Expert Multiple Criteria Decision Making, Finnish Mechanical Power Transmission, Decision-making, Financial Performance

Tämä tutkimus tutkii suomalaisten mekaanisen voimansiirron yritysten taloudellista toimeliaisuutta vuosina 2007 – 2016. Tutkimuksen menetelmänä on käytetty moniekspertti monikriteeri päätöksentekomallia, jonka yhteydessä kolme asiantuntijaa ovat antaneet arvionsa taloudellisista tunnusluvuista. Asiantuntijoiden haastattelujen perusteella eri tunnusluvut saavat tutkimusta varten puolueettomat painot. Sumeaa logiikkaa hyödynnetään kolmen asiantuntijalausunnon yhdistämiseksi yhdeksi arvoksi, jota voidaan käyttää tulosten painottamisessa. Tutkimuksen kohteena olevia yhtiöitä verrataan niiden tilinpäätöstietojen pohjalta saatujen tunnuslukujen avulla toisiinsa ja yhtiöt on järjestetty paremmuusjärjestykseen niiden taloudellisen kyvykkyyden perusteella. Yhtiöiden järjestämisessä käytetään TOPSIS -menetelmää ja menetelmän avulla pyritään havaitsemaan eroja yhtiöiden suoriutumisessa. Tulosten pohjalta havaitaan, että eräät yhtiöt pärjäävät jatkuvasti paremmin kuin kilpailijansa.

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List of Abbreviations

AHP	Analytic Hierarchy Process
EBITDA	Earnings before interest taxes deductions and amortizations
FAHP	Fuzzy Analytic Hierarchy Process
MCDM	Multi Criteria Decision Making
MEMCDM	Multi Expert Multi Criteria Decision Making
TOPSIS	Technique for Order of Preference by Similarity to Ideal Solution

1. Introduction

1.1. Background and motivation of the study

This thesis uses multiple expert multiple criteria decision-making method to study Finnish mechanical power transmission industry by using selected financial ratios over nine years' time. Its objective is to rank the companies against each other's to see which one of them has the best performance year by year. Three industry experts from different standpoints gave their opinion on relative weights for the criteria's thus providing more objective weights for the evaluation criteria.

The research is done to cover Finnish companies among the industry. To the knowledge of the author there has not been any previous research on this topic. This provides fresh information and analysis of the operators within the Finnish market to anyone who is interested in this industry. Similarly, as there are no previous researches on this area of industry with the methods presented in this thesis this allows filling the research gap. Also, managers of companies studied might use this information to analyze the reasons for their ranking and what could they do better to increase their competitiveness. Any private equity investor who might be interested in this industry will get quick insight on what players there are on the field and how they are performing compared to each other's. Ultimately, as stated in the beginning this thesis uses multiple expert multiple criteria decision-making method, owners of these companies can use this information to make more informed decisions. Should one sell their stake to someone who might be interested in to consolidate the Finnish industry and is someone interested in investing more money to their company. This thesis does not provide answers to those questions, but it can give a stepping stone to figuring out the answers. The period for this research is from 2007 to 2016. As of writing the 2016 financials were the most recent publicly available figures. The period also covers the financial crisis which had substantial impact on the industry and the companies, in some cases wiping half of the turnover away. The industry has then recovered from the financial crisis but recently some companies have faced similar declines in their turnovers as in the last crisis. Could this be a forecast of upcoming crash?

Multiple criteria decision-making methods have become increasingly popular way of solving complex problems involving many aspects to the problem. There are vast amount of different methods and variations under the multiple criteria decision-making umbrella. With the increase of computing power increasingly complex problems can be solved with the aid of computers. Thus, more criteria and alternatives can be compared in one analysis. This has also allowed for development of more complicated decision-making methods. (Velasquez & Hester, 2013). To capture as objective as possible weights for the financial criteria three experts are interviewed on financial criteria. They provide imprecise information based on their own subjective backgrounds. However, when the three inexplicit pieces of information from different sources is combined much more definite view is obtained. The information gathered from the experts is thus fuzzy in it's nature and a model which can cope with such information is needed. Fuzzy models can process vague and imprecise information to more usable and understandable form. The weights are most comprehensibly presented as crisp values and therefor model that can convert fuzzy numbers to crisp numbers is needed.

This thesis presents the resent literature over multiple criteria decision-making methods and their applications. Based on the literature review, combination of two methods is identified to be suitable for ranking companies within the same industry. Selected methods are Fuzzy Analytic hierarchy process and TOPSIS. These methods allow combination of different information such as pure quantitative figures, qualitative aspects converted to numbers and information from interviews. There is virtually no limit on how many targets can be analyzed over different evaluation criteria. For the evaluation of the companies, first the common financial criteria were identified, and then those criteria were evaluated by experts who gave objective weights for these criteria. Then each criterion was weighed accordingly in analysis of target companies.

1.2. Research questions

Research questions idea is to structure the research and find answers to these questions. Also, with the help of the questions, new information of the studied subject can be brought forward. The main research question for this thesis is as follows:

“How AHP and TOPSIS combination can be used to compare companies based on their financial statements?”
The secondary questions support this main question. Secondary questions are:

“What different multiple expert multiple criteria methods there are?”,
“Which criteria weights are relevant for analysis purposes?” and
“What are the main reasons for better performance when compared to competitors?”.

Main hypothesis is that there are companies which consistently perform better over time compared to their peers, this is to say that we should see some companies getting better rankings throughout the research period. The reasons for this can be then analyzed in the results part of this thesis.

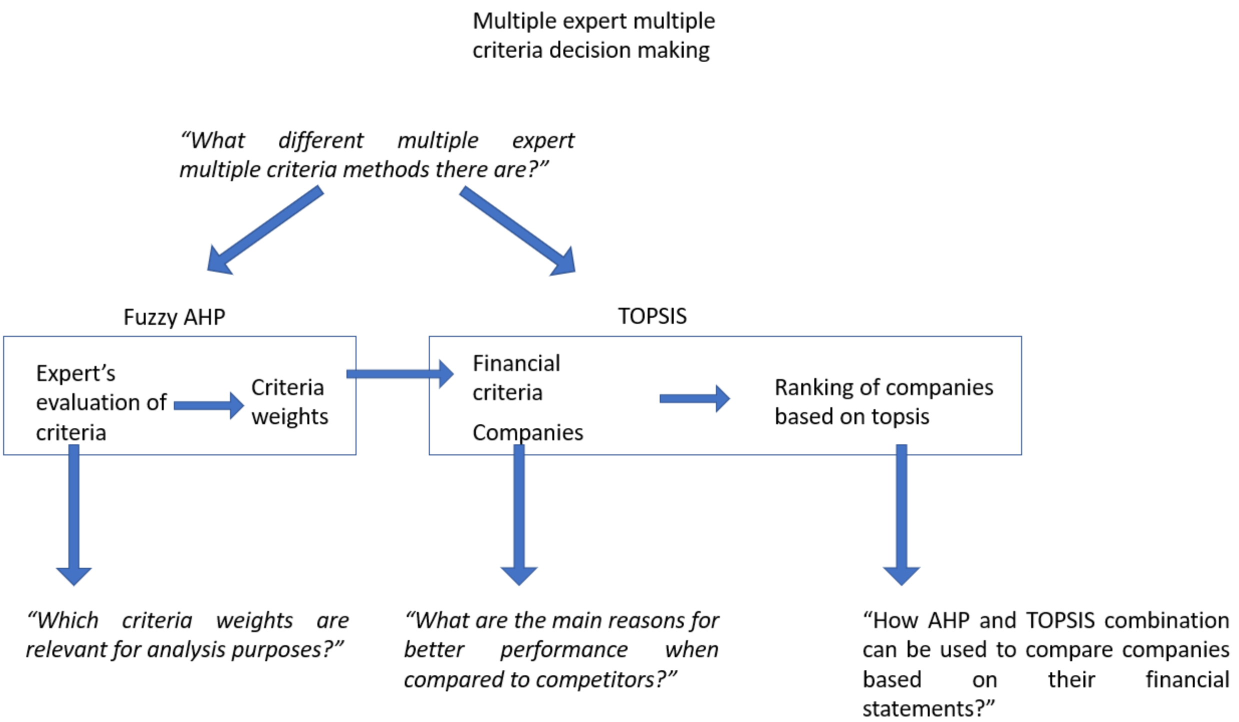

Figure 1. Research structure and research questions

Figure 1 above show the structure of this research and how research questions are connected to each other and from which part of this research answer to each question is derived from. The figure also shows how Fuzzy AHP and TOPSIS are used to different objects, the experts’ evaluation of criteria and Financial criteria and Companies to compose results. The utilization of Fuzzy AHP provides us with weights for the criteria which then can be used in TOPSIS to weigh the Financial Criteria that are used to rank the companies. The TOPSIS method then allows easy way to rank the companies based on the given data, thus it will result in a ranking list of the companies.

The research question “What different multiple expert multiple criteria methods there are?” is found from the literature research and that research justifies the usage of TOPSIS and Fuzzy AHP combination for decision making problem at hand. From the experts’ evaluation of criteria, the weights are derived and the criterion which gets greatest weight is the most important one. Thus, the research question “Which criteria weights are relevant for analysis purposes?” is answered by analyzing the experts’ evaluations. The main research question, “How AHP and TOPSIS combination can be used to compare companies based on their financial statements?” is answered by the case outcome, which ranks the companies year by year. The final question of “What are the main reasons for better performance when compared to competitors?” arises after the performance of the companies is assessed. The question is answered by analyzing the financial figures of the companies and it tries to identify some key characteristic which the better ranked companies have.

1.3. Research methodology

This research is conducted using mainly quantitative methods combined with qualitative assessment of interviewed experts. Research will include both theoretical and empirical parts. In the theoretical part of this thesis previous literature is analyzed from the view point of this research and it will consist of methods and applications of multiple criteria decision making with focus on Fuzzy analytic hierarchy process and TOPSIS methods. Quantitative data is gathered from databases which provide access to financial statements of selected companies. Companies are selected based on their industry classification and data availability. Literature for this research is gathered from scientific articles, books and internet sources.

Qualitative data is gathered by interviewing experts who gave their subjective opinions on evaluation criteria. During the interviews each expert worked together with the researcher in a way where the researcher captured and converted the verbal information from the expert to numerical scale. After each set of questions, the researcher asked the expert to affirm the numerical values that were captured. Interviewees were given brief introduction to the topic and line of interview questions that were going to be asked before each interview, to give them time to prepare for the interview.

Empirical part of this research is done by combining the qualitative information with the quantitative figures by the methods presented in this research. Empirical part also gives introduction to each of the target companies for better understanding of the industry and the companies as their sizes and scopes of business are substantially different.

1.4. Structure of the thesis

This thesis is structured to four chapters. The first chapter, introduction, will give brief introduction what this thesis is all about. Second chapter covers theoretical background this thesis' theory relies on. It provides literature review on the most important research findings found in previous academic literature and explains what have been done earlier with the methods this thesis is using. The second chapter will also give numerical introduction to Fuzzy AHP and TOPSIS methods. Following that is the case where Finnish mechanical power transmission companies are evaluated with multiple criteria decision making tools. The third chapter shows the data which is going to be used and tells which companies were selected for this research and why. Also, brief introduction on each company is presented. Then it proceeds to discuss the criteria that are used on evaluation of the companies. Analysis of the data is presented in a step by step method. In the end of the case chapter the results are given. Fourth and final chapter concludes this research with conclusions and limitations of this research. It will also provide suggestions for future research.

2. Theoretical background

This chapter describes the theoretical foundations this thesis relies upon. It reviews the literature that has been written on these topics and presents the main findings. Literature review discusses what has been accomplished with these methods. It is divided into five subsections according to the main theoretical frames for this thesis. First section discusses Multiple Criteria Decision Making (MCDM) and Analytic Hierarchy Process (AHP). Second section focuses on Fuzzy Theory. Third part reviews literature on TOPSIS and shows numerical introduction to the mathematics behind the algorithm. Fourth part does the same to Fuzzy AHP as was done to TOPSIS. Fifth section combines Fuzzy AHP and TOPSIS creating a decision support tool, which can be utilized in situations where imprecise information is combined with precise information. This decision tool is applied to real data in the case part of this thesis. Literature is found from google scholar and after interesting research papers were found their list of references were great source to increase the literature base.

2.1. Multiple Criteria Decision Making and Analytic Hierarchy Process

Multiple criteria decision making (MCDM) is used to help decision maker to make the best decisions from many alternatives and often the decision has multiple criteria to be considered, hence multi criteria. Different multiple criteria decision-making methods differ for example by having different way of assigning weights, they use mixed ways to select the best solution and some have additional conditions that affect the final solution. Zavadskas and Turskis in 2011 combined research of different multi criteria methods and their differences. Multi criteria decision making methods can be grouped by what kind of initial measurements they can take. Initial measures can be quantitative, qualitative, comparative preference based on pairwise comparisons, qualitative measures which are not transformed to numbers. From this main group the methods can be then classified whether they are continuous or discrete. TOPSIS, LINMAP, MOORA, COPRAS and COPRAS-G take quantitative numbers. Analytic hierarchy process and fuzzy set theories are based on qualitative initial measures. Methods that are based on pairwise comparison method are ELECTRE, PROMETHEE, TACTIC and ORESTE. These methods are effective way to solve complicated problems in economics. Research on these methods has increased from around 500 publications a year in 1993 to over 4000 publications per year in 2010. (Zavadskas & Turskis, 2011)

MCDM is widely studied and one of the approaches is the analytic hierarchy process was first introduced in 1980 by Saaty. In AHP one compares different criteria or objects pairwise to each other and forms comparison matrices. This allows simple measurements where one only needs to compare two objects at a time and assign relative weights for each pair. As real-world problems are complex in their design it is essential to break them into smaller pieces and analyze them in more simpler setting. AHP can be thought as inverted tree where the main goal is at the top and then on every step alternatives are compared to each other to derive the best solution. In his article Saaty showed how AHP can be utilized for example to select the best of three houses by using eight different criteria. Each criterion was compared pairwise, and results of that comparison were inserted to comparison matrix where elements which were on the rows were compared to the ones at columns. Element which is more important of the two gets full value and the less important one is assigned its inverse number. (Saaty, 1983) Saaty’s work on AHP was fundamental as many scientists have utilized it and developed it further.

AHP has been used for example in analyzing operational performance of telecommunications companies in Brazil. Balance Score Card was used to indicate key performance indicators which were then prioritized using AHP. According to the researchers the new organizational prioritization led to performance which was substantially better than the previous one and that AHP was suitable tool for the problem at hand, even though they noted that biases and limitations affected their results’ validity. However, as stated, the performance of the company was better after the adjustments which the AHP model suggested were implemented. (Bentes, Carneiro, Silva & Kimura, 2012)

For instance, AHP model which enables the user to manage the benefits, opportunities, costs and risks was used to obtain the most ideal location for a wind farm in China. Researchers implemented questionnaires for group of professionals from different backgrounds and according to the answers derived from those questionnaires, the feasibility evaluation of five different sites could be conducted. As all criteria’s which are evaluated in the wind farm project are not the same type, some are negative, and some are positive, method which can facilitate both negative and positive criteria is needed. The standard AHP does not allow for simultaneous analysis of such criteria. (Lee, Chen & Kang, 2009)

Bustince, Barrenechea, Calvo, James and Beliakov used penalty functions to achieve consensus among multiple experts over a problem. They applied their method for medical use where they derived the best medication to cure hypertension. (Bustince, Barrenechea, Calvo, James & Beliakov, 2014) To select the best machine tooling systems linguistic multicriteria model was applied and the use of linguistic values allowed to gather excess information which could be used in other analysis. Researchers applied this method to select the best lathe among four alternatives and transformed the numerical mechanical criteria values to linguistic form for easier understanding. (Devedzic and Pap, 1999) Dong, Xu and Yu proposed a method to combine linguistic preferences when different decision makers gave them in different scales. Thus, it is not necessary to force decision makers to give their preferences in the same scale, but they can use scale that is, most suitable for them. (Dong, Xu & Yu, 2009) Human decision making was modelled in a paper by Kim and McLeod (1999) and they compared experts' decision making to linear and nonlinear models which imitated human decision making. They used bankruptcy prediction to compare how the different models performed and found out that human experts were slightly better than any mathematical model. However, they noted that their study was simplified to use only ten financial ratios and no at all any qualitative measures. Experts opinions are hard to surpass. (Kim & McLeod, 1999) Experts opinions were also used in the field of financial analysis by Matsatsinis, Doumpos and Zopounidis where they elicited knowledge from experts to assess corporate performance and viability. They used the experts' information to gather a knowledge base which was used with a multicriteria knowledge-based decision support system called Fineva. By combining different criteria and experts' information they can analyze company, and are provided with analysis of the financial performance and viability of that company. These analyses can be then used to compare different companies and select the best one of them. (Matsatsinis, Doumpos & Zopounidis, 1997)

When more than one expert from the same area of expertise are used to gather information, the results should be more accurate. It is more time consuming and makes process more complex when multiple experts are used to get information. However, it was found that the benefits of using more than one expert outweigh the disadvantages of knowledge gathering. In a bridge building project, the time that was lost in the information gathering from multiple experts was later recovered in the building phase due to larger amount of information that was available. (Moore & Miles, 1991) Similarly a method to combine experts' judgments was suggested by Morris in 1977. His idea was to calibrate the experts and then asses the joint information of multiple experts. (Morris, 1977) Multi attribute group decision making was studied by Pang and Liang and their paper focused on how much one decision makers answers differed from the rest. They defined three key indices, closeness, consistency and uniformity to evaluate the decision-making effect by comparing the cumulative answers to the individual answers. These measures can then be combined to show total values for the whole group. This way the decision-making effect of individual decision makers and the group decision making can be analyzed. (Pang & Liang, 2012) Capital structure decision making was studied in Australia by Romano, Tanewski and Smyrnios. They used statistical methods such as principal component analysis, confirmatory factor analysis and structural equation modelling to find out what aspects affected the capital structure decisions and how family owned businesses financed themselves. They found that interaction of the owner, family and company characteristic have the greatest influence on capital structure decisions. Size of the family business affected what kind of external funding was used, smaller companies relied more on shareholders equity and credit whereas the larger companies are using more outside funding. (Romano, Tanewski & Smyrnios, 2000) A frame knowledge system to help managing expert's decision knowledge was proposed in a paper by Shiue, Li and Chen. They assessed financial health of Taiwanese companies and used new method to overcome problems in knowledge representation. They gathered financial statement analysis knowledge from well-established certified public accountant and used that information to frame the knowledge to make financial statement analysis more structured. (Shiue, Li & Chen, 2008)

To cope with uncertainty with decision makers evidential reasoning approach was proposed by Yang and Singh. Their method was able to combine both qualitative and quantitative decision making problems with uncertainty. They were able to qualify and represent uncertain judgments that the decision makers gave. (Yang & Singh, 1994) To increase human consistency in decision making and decision models linguistic ordered weighted averaging model was proposed by Herrera, Herrera-Viedma and Verdegay. They first showed the rationality of linguistic ordered weighted averaging and then applied it to group decision making in a linguistic application. Using fuzzy techniques increases the human consistency in decision making. (Herrera, Herrera-Viedma & Verdegay, 1996) Herrera and

Martinez studied the management of multigranular linguistic context which is a hard process. They presented method to manage such information in decision making easily and without loss of information. They applied their method to multi expert decision-making problem and noted that their method can also be applied to different decision problems. (Herrera & Martinez, 2001)

2.2. Fuzzy logic

Fuzzy theory was presented by Zadeh in 1965 and it has been used widely with different kind of multi criteria decision making methods. Fuzzy sets are composed of fuzzy numbers and Zadeh described fuzzy sets as follows “A fuzzy set is a class of objects with a continuum of grades of membership. Such a set is characterized by membership function which assigns to each object a grade of membership ranging between zero and one.” (Zadeh, 1965). For instance, this can be utilized in assigning criteria weights by experts where they would give rate of importance to the criteria by saying, this criterion is belonging 0,6 to the set of important criteria’s and the other criterion is belongs 1 to the set. Different classes in the real world do not have precise mathematical point which can separate ambiguous cases. For example, heap of bananas is still a heap of bananas if you remove one banana, but if you keep removing bananas one by one, at some point, it is not anymore, a heap but a single banana. When did the heap of banana ceased being a heap? Such questions are hard to answer without fuzzy numbers. When allowing the use of fuzzy number all the information from inputs and expansion of usable knowledge can be taken into consideration (Balmat, Lafront, Maifret & Pessel, 2011). Thus, it can provide even more accurate information for the decision makers. Fuzzy numbers are used in variety of instances in different spheres of research and applications. For example, Balmat et al showed new way to assess risks in maritime traffic by identifying common factors which were then analyzed and expressed to decision makers by fuzzy method. Their method helped to manage the risk in more appropriate way.

Flood damages were reduced by help of a fuzzy system that ranks actions by their potential of reducing harm from frequent floods. Both structural and non-structural measures were mixed in a way which benefitted on national and local decision-making levels. (Esogbue, Theologidu & Guo, 1992)

Fuzzy theory and numbers are useful in choosing among different alternatives when criterions are conflicting. Laarhoven and Pedrycz (1893) extended the pairwise comparison presented by Saaty. They used triangular fuzzy numbers which allowed them to keep calculations relatively simple, their method was able to cope in situations when there was either no information or it is plentiful. In their study they presented a method where one can take from different decision makers their opinion on how to weight different criteria. Decision makers input their relative importance on matrix and then by fuzzy rules it is transformed to a weight vector. They then extended the problem originally presented by Lootsma (1980) where university was hiring a new professor, by applying fuzzy logic. They reason that the results are more accurate and can provide information which would not be attainable by using crisp numbers. (Laarhoven & Pedrycz, 1983)

Buckley (1985) criticized the paper by Laarhoven and Pedrycz (1983) of not being accurate in calculating the fuzzy numbers. As Laarhoven and Pedrycz used algebraic equations with fuzzy numbers they do not always produce unique results, thus the results are not consistently accurate. Similarly, their weights for the criteria were obtained by triangular fuzzy numbers and as their methods do not consistently provide accurate triangular fuzzy numbers they were forced to use approximations to keep the shape of the fuzzy number. Buckley used trapezoidal fuzzy numbers to overcome the problems. To demonstrate these applications they were presented where government was trying to rank chemicals and energy sources. Chemicals according to their harmfulness to the environment and energy sources by their importance to the nation. In both cases data for evaluations was gathered by taking inputs from group of experts who fill fuzzy reciprocal matrices for each criterion which was used for the evaluation. (Buckley, 1985)

Zopounidis and Pouleizos (1992) used multi criteria decision support system to analyze company performances based on financial data. They combined both qualitative and quantitative measures to utilize such aspects of criteria as managerial performance, quality of management, financial profitability and solvency. For financial statements they used common size ratios where every figure in the income statement was shown as a proportion of total sales and proportion of total assets in the balance sheet. Financial ratios were then classified into three distinct categories: solvency, managerial performance and profitability. These categories were divided into subcategories which each containing different ratios.

The use of this classification allowed the decision maker to utilize the information of those categories which make the most sense in each case. Ranking of 25 companies was conducted by MINORA software using 25 different criteria, both qualitative and quantitative, and ranked order of companies was the result of procedure. They suggested that this kind of decision support systems can be beneficial for broad audience ranging from banks assessing the probability of loan payback to venture capitalist selecting which companies or industries to invest. The article of Zopounidis et al. is already quite old and multicriteria methods have evolved rather substantially from the early days as is shown by increasing number or developed multicriteria methods which are used in research.

2.3. TOPSIS

To analyze the performance of the companies within the same industry TOPSIS method is applied. TOPSIS stands for Technique for Order of Preference by Similarity to Ideal Solution and it was developed Hwang and Yoon in 1981. Their idea was that the best alternative should have the shortest distance to the positive ideal solution and greatest distance to the negative ideal solution.

2.3.1. Literature review of TOPSIS

TOPSIS was used to evaluate different alternatives and their effectiveness for implementing renewable energy usage in EU. Papapostolou, Karakosta and Doukas used linguistic variables in assessing alternative scenarios and transformed qualitative information to quantitative form. They found that indicative renewable energy usage targets were more attractive than binding ones to the member states of EU. In their research they had three experts, but they note that their method can easily cope with more decision makers. (Papapostolou, Karakosta and Doukas, 2016) Similarly Zulqarnain and Dayan used fuzzy numbers combined with TOPSIS to cope with vagueness of linguistic variables. They noted that crisp values are not suitable when imprecision of the answers is present. Difference of classical TOPSIS to fuzzy TOPSIS is that the first used precisely known ratings and weights for criteria. In the real world applications such a precision is hard to obtain. (Zulqarnain & Dayan, 2017) Zeng and Xiao used TOPSIS to select where to invest among investment alternatives. They used intuitionistic fuzzy numbers to catch the attitudinal character of decision maker and subjective importance of criteria to the same formulation. They claim that the importance degree of both subjective information and attitudinal are being reflected in their method which gives it advantage over other methods. They applied this method to situation where an investment company is trying to select which market to invest. (Zeng & Xiao, 2016) The efficiency of the Malaysian Islamic banks was studied and the banks were ranked using TOPSIS method by Wanke, Azad and Barros. They found that the banks in Malaysia were less efficient than banks in USA and Europe. To analyze the banks better they also used neural networks to identify the causes of inefficiency. (Wanke, Azad & Barros, 2016)

Textile companies in China were studied by Deng, Yeh and Willis (2000) with modified TOPSIS methods. They identified four different financial ratios to be the ones that would be used to evaluate the companies. Seven companies were selected for the comparison and the financial ratios which were used were, profitability, productivity, market position and debt ratio. Profitability, productivity and market position are measures where increase is a good trait, hence it is benefit criteria, and debt ratio is such where lower ratio yields better results, hence cost criterion. They transformed the debt ratio to benefit criteria by using reversed values derived from the original values which then in turn allowed them to use four benefit criteria in their analysis. The rankings are then normalized so that the modified TOPSIS method can be used.

Positive ideal solution is composed by taking the best rank of each criteria and negative ideal solution is gathered by taking the worst ranks of each criteria. Then the normalized criteria are compared to the positive ideal value and negative ideal value and the distances of each criteria to both is calculated. As each criteria of every company are compared to the both positive and negative ideal solutions, one can derive how the company performs against the best performer and the worst performer on each criterion. This allowed to find the performance indicators, or criteria, where the company would need to most improve their performance to rank better among the competitors. This would also allow for identification of measures that are needed to be taken to compete better against competitors.

Due to the difficulty of giving the right weights for different criteria, as there hardly is a one truth, different methods are developed to overcome this problem. Decision makers can have different perceptions of the importance rank of the criteria and their relative strength in ranking the companies. (Diakoulaki, Mavrotas and Papayannakis 1995) One can always give equal weights for each criterion by mean weight method where the given weight for criteria is derived by dividing one with the number of criteria. This method is obviously free of subjective reasoning or preference towards some criteria and thus is objective. The four criteria were then weighed by four different methods, entropy measure, CRITIC, S.D and Mean weight method. CRITIC stands for Criteria Importance Through Intercriteria Correlation and it was presented by Diakoulaki et al. in 1995. It relies on conflicting nature of the criteria as financial ratios are often highly correlated. Criteria that are highly similar do not add the information value of the analysis and thus bringing in a criterion that gives different ranking of companies adds the information value immensely and makes the decision process better. CRITIC is useful in taking the problems presented above in consideration. Entropy measure represents the uncertainty in the information derived from probability theory and it assigns weights for the criteria based on how much they differ from other criteria, thus giving higher weight for criteria that is enough different from the others. Thus, similar criteria are given lesser weights.

The researchers applied the different weighing methods and found that the profitability ratio had the highest importance which was also in accordance to the managers interviewed among the industry. The ranking of the companies slightly changes with different methods, but the top 3 companies were the same regardless of the method. This suggest that researchers should not rely solely on one method, but risk of false positives is not however evident. (Deng, Yeh, Willis 2000) Similarly in research of Greek pharmaceutical companies top four companies were the same regardless of the weighing method in the article of Diakoulaki et al. (1995).

The Greek agriculture companies were studied by Baourakis, Doumpos, Kalogeras and Zopounidis (2002) and they used principal component analysis to identify the key financial ratios over which the analysis was conducted. They ran the statistical method of principal component analysis separately for each year to see which financial ratios where those that explained most of the financial performance on that year. In most cases the ratios that represented profitability and solvency were those which had the greatest explanatory power. This shows that these two criteria are essential in describing the financial performance of agribusinesses. The ratios that were finally selected were profitability ratios: Net income per net working capital, Earning Before Interest and Taxes per Total Assets, Gross Profit per

Sales, Solvency ratios: Current Assets per Current Liabilities, Long Term Debt per Long Term Debt plus Net Working Capital and Managerial performance ratios: Inventory times 360 per Sales and Accounts receivables times 360 per Sales.

The underlying assumption in the concept of maximum and minimum distances is that utility is increasing or decreasing monotonically. Monotonic utility means simply that more is better in benefit criteria and less is better in cost criteria. In the setting of this thesis for example, the higher the return on equity is the better and the higher the debt level is worse. However, in some cases the same ratio can be either cost criteria or benefit criteria depending on the side one is taking. For instance, if price to earnings ratio is high, potential buyer can consider it to be a negative thing and seller is happy if the ratio gets even higher, as he would get a better price for the stock. In this thesis the ratios which are used have monotonic utility. There are criteria of both type, cost and benefit.

The ideal solution is composed of by combining each of the best values for every criterion and the negative ideal solution is done similarly, but taking only the worst criteria values. TOPSIS then compares the distances to both points simultaneously by relative closeness. This is superior method compared to Euclidean distance where on would just minimize the distance to the positive ideal solution point and then argue that it would thus have the greatest distance. This is not always the case as it is possible for the alternative to have shortest distances to both positive and negative ideal solutions. For example, if the alternative which has the shortest distances to both points lies on the line formed between the negative and positive points and the second alternative is below or under the line it has greater distance to the solutions. Thus, it could be hard to reason why the first alternative is better as it is closer to both points. As TOPSIS considers the relative distances it results to an absolute preference order of solution as is proven by Dasarathy (1976).

2.3.2. Numerical introduction of TOPSIS

The following six relatively simple steps of TOPSIS are presented below. They are as Hwang and Yoon (1981) presented them. In the process the following decision matrix is evaluated (see Figure 2.). The matrix is composed of alternatives, which in this thesis are the companies to be evaluated, and criteria which are assigned for every alternative.

$$
\begin{array}{cc}
 & \begin{array}{ccc} C_1 & C_2 & C_j \end{array} \\
\begin{array}{c} A_1 \\ A_2 \\ A_i \end{array} & \begin{pmatrix} X_{11} & X_{12} & X_{1j} \\ X_{21} & X_{22} & X_{2j} \\ X_{i1} & X_{i2} & X_{ij} \end{pmatrix}
\end{array}
$$

Where Ai is the alternative, or company, considered, C_i is the criteria that is used for the evaluation and X_{ij} is the outcome of that alternative regarding to that criterion.

Figure 2. TOPSIS decision matrix (Hwang and Yoon, 1981).

As the values in the decision matrix are numerical all the criteria which are qualitative in nature must be quantified appropriately. The values which each criterion has can be on a different scale compared to the other criteria. For example, when comparing mobile phones, one criteria can be price which can range from 100 euros to 1000 euros and other criteria can be megapixels in a camera where the range is, say from five to 15. To bring all the criteria to same scale, the first step is that the matrix is normalized by taking each criteria value and dividing it by the square root of the sum of squared values which the criteria has by equation 1.

$$r_{ij} = \frac{x_{ij}}{\sqrt{\sum_{i=1}^{m} x_{ij}^2}} \quad (1)$$

Equation 1. Normalization

Second step is to compose the weighted normalized decision matrix by multiplying each criterion column with the weight it has been assigned to.

$$V = \begin{pmatrix} V_{11} & V_{12} & V_{1j} \\ V_{21} & V_{22} & V_{2j} \\ V_{i1} & V_{i2} & V_{ij} \end{pmatrix} = \begin{pmatrix} w_1 r_{11} & w_2 r_{12} & w_m r_{1j} \\ w_1 r_{21} & w_2 r_{22} & w_m r_{2j} \\ w_1 r_{i1} & w_2 r_{i2} & w_m r_{ij} \end{pmatrix}$$

Figure 3. Criterion columns multiplied with their respective weights (Hwang and Yoon, 1981).

Step three is to identify the positive ideal solution and the negative ideal solution. Positive ideal solution is derived by taking best weighed criterion value which each criterion has. The negative solution is derived similarly taking worst criterion value the criteria have. If the criteria are all the same type, either cost type or benefit type, the ideal solutions can be formed simply by taking maximum and minimum values respectively. However, if the criteria types are mixed, then the solutions are defined as follows where A* stands for positive solution and A^- stands for negative solution:

$$A^* = \{(\max v_{ij} \mid j \in J), (\min v_{ij} \mid j \in J') \mid i = 1, 2, \dots, m\} = \{V_1^*, V_2^*, \dots, V_j^*\} \quad (2)$$

Where J = { j = 1,2,…,n | j associated with benefit criteria} and

J' = { j = 1,2,…,n | j associated with cost criteria}

Equation 2. Determining Positive ideal solution (Hwang and Yoon, 1981).

$$A^- = \{(\min v_{ij} \mid j \in J), (\max v_{ij} \mid j \in J') \mid i = 1, 2, \dots, m\} = \{V_1^-, V_2^-, \dots, V_j^-\} \quad (3)$$

Where J = { j = 1,2,…,n | j associated with benefit criteria} and

J' = {j = 1,2, …, n | j associated with cost criteria}

Equation 3. Determining Negative ideal solution (Hwang and Yoon, 1981).

Fourth step is to calculate the separation measures between each alternative. Separation of the alternatives from the positive ideal solution is calculated with equation 4.

$$S_{i^*} = \sqrt{\sum_{J=1}^{m} \left(v_{ij} - v_j^*\right)^2} \qquad (4)$$

Equation 4. Separation of each alternative from the ideal one (Hwang and Yoon, 1981).

Equivalently the separation from the negative ideal solution is calculated with equation 5.

$$S_{i^*} = \sqrt{\sum_{J=1}^{m} \left(v_{ij} - v_j^*\right)^2} \qquad (5)$$

Equation 5. Separation of each alternative from the negative one (Hwang and Yoon, 1981).

Fifth step is to calculate the relative closeness to the ideal solution. Relative closeness of alternative Ai against the positive solution is defined by:

$$C_{i^*} = s_i - /(s_{i^*} + s_i -) \qquad (6)$$

Where Ci is between zero and one*

Equation 6. Relative closeness of an alternative against positive solution (Hwang and Yoon, 1981).

The closer the alternative is to the ideal solution the higher the value of C is. As the relative closeness value C approaches zero then the alternative is closer to the negative ideal solution. Likewise, if the value of C is going towards one then the alternative is closer to the ideal solution and is thus better.

The sixth and final step of TOPSIS is to rank the alternatives according to their relative closeness value C which was calculated in the previous step. Alternatives are ranked in descending order to get the preference ranking.

2.4. Fuzzy AHP

In this thesis the criteria weights which are to be used with the TOPSIS method are derived from group of experts who each cover different perspective of the industry. These experts are asked to rank the criteria pairwise as Saaty (1983) suggested. Saaty's scale is from one to nine and odd numbers are assigned. One can use the even numbers which lie between the odd numbers to express approximate values. As multiple experts who have different view of the industry are used the weighing for the criteria should be as objective as possible. From the multiple pairwise comparison matrices a fuzzy comparison matrix in composed and then Fuzzy Analytic Hierarchy Process is applied as is proposed by Chang in 1996.

2.4.1. Literature review of Fuzzy AHP

The standard AHP requires humans to give exact numerical values for the comparison matrices which in many real-life situations can be rather demanding and at some cases impossible. This can be due to imprecise information that is available for the decision maker, the information is not in standardized form or the ignorance of decision maker. Thus, fuzzy evaluation is needed to cope with vague information. Chang, Wu and Lin in 2009 proposed a AHP-based method where fuzzy numbers are used in comparison matrices instead of exact numbers. (Chang, Wu & Lin, 2009) Fuzzy analytic hierarchy process is an extension to the classical AHP which takes pairwise comparison to order alternatives in hierarchical order and pairwise comparison is taken in crisp numbers. Fuzzy AHP uses fuzzy numbers instead of crisp numbers to incorporate the vagueness and uncertainty that is in real life decision making situations. Cheng used fuzzy AHP to determine the best naval tactical missile system. He calculated grade values of membership functions which then represented the performance of different missile systems. This allowed flexibility and efficiency in evaluation of subjective preferences of the decision makers. (Cheng, 1996) Global supplier selection problem was solved with fuzzy AHP by Chan an Kumar when they evaluated nineteen criteria to select from three potential suppliers. They claim that the ease of using this method will extend the usage as it would be simpler to solve multi criteria decision making problems with fuzzy AHP. They also calculated the degree of how much one triangular fuzzy number representing a criterion is greater than the other fuzzy number to rank the criteria and alternatives. (Chan & Kumar, 2007)

To select the most suitable digital video recording system Chang, Wu and Lin proposed fuzzy analytic hierarchy process method. They used eleven experts who gave points for each of the six criteria that they used to rate the systems to select the best among four candidates. They used eigenvalue method to defuzzify the fuzzy numbers which they derived from the experts' criteria evaluations and finally got the weighted values for each alternative. (Chang, Wu & Lin, 2009)

Zhang and Liu proposed intuitionistic fuzzy multi criteria group decision making tool to select the most suitable employee for an organization. They used grey relational analysis which measures the degree of similarity between two sets based on their relation. This means that optimal set is compared to each alternative set and the one that is closest will get the best greyness degree. They applied their method to select software engineer for a company, three decision makers evaluated all the four candidates via five different criteria. Candidates were then ranked among the grey relational degree to obtain the most suitable one. (Zhang & Liu, 2011) Similarly Luukka and Collan presented a method to select best candidate for human resources problem. Their method can cope with need of having a candidate that does well in at least two of the criteria but does not discriminate which of the criteria are the strongest ones. This is suitable for situations where it can be hard to select which criteria are the important ones and when any combination of some of the criteria would lead to good solution. Ranking of alternatives is based on fuzzy similarity measure to ideal solution. Their application was to select summer trainee for university among six candidates with five benefit criteria. (Luukka & Collan, 2013)

Performance of international airports in East Asia were studied by Chang, Cheng and Wang (2003). They used Fuzzy Analytic Hierarchy Process to get their criteria weights which also included qualitative criteria which were transformed to quantitative numbers. To analyze the performance both TOPSIS and Fuzzy Synthetic Decision methods were used, and their results were compared against each other. Their outcome of the two methodologies did not show significant difference in the rankings of the airports. Regardless of the ranking methods, the alternatives which perform well, will be the winners and the ones which are not operating that well will be behind. (Chang, Cheng & Wang, 2003) This suggests that there is not such a big difference which method one applies.

Similarly, fuzzy group decision making methods were compared in a paper by Bozda, Kahraman and Ruan in 2003. They compared Blin's fuzzy relation method, Yager's weighted goals method and Fuzzy AHP method to same problem of a company selecting the best computer integrated manufacturing system. They note that when comparing the ranking of the outcomes from each of the different methods two main contradiction rates can be determined. Firstly, is the rate of how many times the best alternative is the same by different methods and secondly how much the rankings differ from method to method. In their application the rankings of the computer integrated manufacturing systems were the same regardless of the ranking method. They note that if the decision maker is consistent in deriving the data and assigning weights for criteria then there should not be difference between ranking methods. (Bozdag, Kahraman & Ruan, 2003)

Shipping companies were studied by Chou and Liang (2001) by combining fuzzy set theory, analytic hierarchy process and the concept of entropy. They ultimately propose a fuzzy multiple criteria decision-making method for performance evaluation of shipping companies which could be used for example by an investment company seeking investment targets. Chou and Liang combined criteria which express the quality and service ability of the companies which were gathered in linguistic form, to financial criteria which express financial structure, debt payment ability, operational efficiency and ability to make profits. (Chou & Liang, 2001)

2.4.2. Numerical introduction of Fuzzy AHP

First step is that each expert assigns his or her own pairwise comparison matrix. E1 stands for expert number one, E2 for expert number two and E3 for third expert.

E1	C_1	C_2	C_j
C_1	X_{11}	X_{12}	X_{1j}
C_2	X_{21}	X_{22}	X_{2j}
C_i	X_{i1}	X_{i2}	X_{ij}

E2	C_1	C_2	C_j
C_1	X_{11}	X_{12}	X_{1j}
C_2	X_{21}	X_{22}	X_{2j}
C_i	X_{i1}	X_{i2}	X_{ij}

E3	C_1	C_2	C_j
C_1	X_{11}	X_{12}	X_{1j}
C_2	X_{21}	X_{22}	X_{2j}
C_i	X_{i1}	X_{i2}	X_{ij}

Figure 4. Experts pairwise comparison matrices.

Experts' evaluation matrices are composed of fuzzy numbers and those fuzzy matrices are aggregated to one matrix using the following equations. Next the values are transformed to triangular fuzzy numbers by using equation 5 from Chen, Lin and Huang (2006)

$$L_{ij} = min\{a_{ijk}\}$$
$$M_{ij} = \frac{1}{K}\sum b_{ijk} \qquad (7)$$
$$U_{ij} = max\{c_{ijk}\}$$

Where L stands for the lower value, M for the modal value and U for the upper value of triangular fuzzy number. Minimum and maximum values are taken over all experts' matrices, K stands for number of experts.

Equation 7. Forming of fuzzy numbers (Chen, Lin and Huang, 2006)

Where the fuzzy number begins with the lowest criteria weight assigned by the experts. The support, or the middle value for the fuzzy number is taken by summing up all the given criteria weights and multiplying that by one divided by the number of given weights. And the maximum value is just the greatest weight value assigned to that criteria pair.

	C_1	C_2	C_3
C_1	(1, 1, 1)	(1, 2.3, 3)	(3, 5, 7)
C_2	(0.33, 0.55, 1)	(1,1,1)	(1, 3, 5)
C_3	(0.1, 1.5, 3)	(0.2, 1.6, 4)	(1, 1, 1)

Figure 5. Fuzzy pairwise comparison matrix.

In order to make calculations with triangular fuzzy numbers their basic operations are given here according to Chang (1996). Consider two triangular fuzzy numbers M_1 and M_2, $M_1 = (l_1, m_1, u_1)$ and $M_2 = (l_2, m_2, u_2)$, where l stands for lower value, m for modal value and u for upper value. Their operational laws are as follows:

1. $(l_1, m_1, u_1) \oplus (l_2, m_2, u_2) = (l_1 + l_2, m_1 + m_2, u_1 + u_2)$
2. $(l_1, m_1, u_1) \otimes (l_2, m_2, u_2) \approx (l_1 l_2, m_1 m_2, u_1 u_2)$
3. $(\lambda, \lambda, \lambda) \otimes (l_1, m_1, m_1) = (\lambda l_1, \lambda m_1, \lambda u_1)$, $\quad \lambda > 0,\ \lambda \in R$
4. $(l_1, m_1, u_1)^{-1} \approx (1 / l_1, 1 / m_1, 1 / u_1)$

After the fuzzy pairwise comparison matrix is formed then the final weights for the criteria are derived with the use of Fuzzy Analytic Hierarchy Process. Operation is defined by Chang (1996) as follows: $X = \{x_1, x_2, ..., x_n\}$ is an object set and $U = \{u_1, u_2, \ldots, u_m\}$ is a goal set. Each object is iterated over each goals to get extent analysis values: $M_{gi}^1, M_{gi}^2, \ldots, M_{gi}^m$ are values of extent analysis of i_{th} object for m goals, where all the M_{gi}^j ($j = 1,2,\ldots,m$) are triangular fuzzy numbers. Then the fuzzy synthetic values are calculated with the following formula using the basic operational laws presented above:

$$S_i = \sum_{j=1}^{m} M_{gi}^j \otimes \left[\sum_{i=1}^{n} \sum_{j=1}^{m} M_{gi}^j \right]^{-1} \qquad (8)$$

Equation 8. Calculation of synthetic values according to Ertugrul and Karakasoglu (2009).

Next step is to determine which one of two triangular fuzzy numbers is greater than the other. This is expressed as follows according to Chang (1996):

$$V(M_2 \geq M_1) = hgt(M_1 \cap M_2) = \mu_{m_2}(d) \qquad (9)$$

The previous equation can be expressed as below, where the degree of possibility of M_2 being greater or equal to M_1 is calculated (Chang, 1996). These calculations are made to each triangular fuzzy number.

$$V(M_2 \geq M_1) = \begin{cases} 1 & if\ m_2 \geq m_1 \\ 0 & if\ l_1 \geq l_2 \\ \frac{l_1 - u_2}{((m_2 - u_2) - (m_1 - l_1))} & otherwise \end{cases} \qquad (10)$$

To compare both triangular fuzzy numbers M_1 and M_2 both values of V(M_1 >= M_2) and V(M_2 >= M_1) are needed. Then the smallest value of the compared probabilities is gathered, and they provide the non-normalized weight vector for the criteria. These values are derived with the following equation where the degree of possibility for a convex fuzzy number to be greater than k convex fuzzy number (Chang, 1996):

$$d(A_i) = \min V(S_i \geq S_k) \qquad (11)$$

Equation 11. Smallest value of compared distances (Ertugrul and Karakasoglu, 2009).

And then the weight vector is defined with equation 12.

$$W' = (d(A_1), d(A_2) \ldots d(A_n))^T \qquad (12)$$

Equation 12. Definition of weight vector (Ertugrul and Karakasoglu, 2009).

The weight vector is then normalized with equation 1, which was presented earlier to get the normalized weights which can be used for the TOPSIS method weight the criteria.

2.5. Fuzzy AHP and TOPSIS combination

This part shows how Fuzzy AHP and TOPSIS are combined to solve decision making problems like in this thesis. Previous research where similar combination was utilized is reviewed. Combination of these two methods will act as decision support tool that will be applied to the case data.

Chen used fuzzy numbers with TOPSIS and calculated the distances from the fuzzy positive ideal solution and fuzzy negative ideal solution with vertex method which is used for triangular fuzzy ratings. This way he can keep the vagueness of fuzzy numbers in the distance comparison. There are many methods to calculate the distances between fuzzy numbers but in Chen's application vertex method proved to be an effective and simple way to calculate the distances. (Chen, 2000) Supplier selection problem was solved by intuitionistic fuzzy topsis method where Boran, Genc, Kurt and Akay (2009) selected best supplier for an automotive company based on four criteria. They aggregated the decision makers opinions by intuitionistic fuzzy averaging which proved to be suitable method as it also captures the vagueness of decision makers opinions. Singh, Gunasekaran and Kumar studied third party logistic service providers in India where they used ten different criteria to select the most suitable one. They applied hybrid approach of fuzzy AHP and fuzzy TOPSIS as the real business situation involves high uncertainty and fuzziness. Fuzzy AHP was used to select correct weight for evaluation criteria and then after the weights had been determined they ranked the alternatives with fuzzy TOPSIS method. Incorporating fuzziness to real life decision improved both reliability and credibility of their decision-making process. (Singh, Gunasekaran & Kumar, 2017)

Utilization of fuzzy numbers combined with AHP was applied by for example Ertugrul and Karakasoglu in 2009 when they analyzed the performance of cement firms in Turkey. The analysis was based on financial ratios which were categorized to main and sub-criteria. Main ratio criteria were liquidity, financial leverage, activity, profitability and growth. Liquidity ratio was divided into three sub-criteria: current ratio, quick ratio and cash ratio. Financial Leverage ratio combined shareholders equity divided by assets, debt ratio, fixed assets divided by shareholders equity and fixed assets divided by long term debt. Activity ratios which try to capture the management's execution were account receivable ratio, inventory turnover ratio, current assets turnover ratio, total assets turnover ratio and accounts payable turnover ratio. Profitability combined two ratios: Net profit margin and Return on Equity. Growth ratios were sales growth, operating profit growth, shareholder's equity growth and assets growth. To assign correct weight for each of the main and sub-criteria Fuzzy AHP was utilized. The researchers interviewed three experts each from different background and different subjective importance for the criteria. The proposed method allows to minimize the uncertainty and it can cope with subjective reasoning when assigning the weights for the criteria. Each expert inputted their weights for the criteria in the decision matrices which then were combined to one matrix and transformed to triangular fuzzy numbers. After the ideal weights for the criteria were obtained the performance of the companies could be evaluated against each other. The researchers used TOPSIS method to calculate the ranking of companies among the Turkish cement manufacturers. (Ertugrul & Karakasoglu 2009)

Similarly, financial performance of Turkish manufacturing was evaluated with fuzzy multicriteria decision making methods by Yalcin, Bayrakdaroglu and Kahraman in 2012. The companies which they studied were part of the Istanbul Stock Exchange. They combined traditional accounting-based performance measures, such as return on assets, return on equity, earnings per share and price to earnings (P/E - ratio) with value-based performance measures which illustrate the company value, such as economic value added, market value added, cash flow return on investment and cash value added. They argue that as modern-day investors are requiring companies to increase their shareholder value, financial performance should also be measured accordingly. Also, due to increasing globalization, movement of capital and internationalization of the financial markets, the efficient use of resources have become crucial for the existence of the company. Each of their measures were selected by group of experts from the stock exchange which also gave the weights for the criteria by use of linguistic variables, which were transformed to fuzzy numbers.

Yalcin et al used two different multiple criteria decision-making methods to rank the companies within the industries, they applied TOPSIS and VIKOR methods. This allowed them to get more accurate results as the two methods differ in how they are doing the ranking. Both methods have similar steps but for example VIKOR derives one reference point, distance from the most ideal point whereas TOPSIS has two reference points, distance to positive ideal solution, which should be minimized and distance to negative ideal solution, which should be minimized. TOPSIS method does not take account the weight of those two reference points. In calculation of accounting-based ratios, the researchers used values from the income and balance sheets. For value-based ratios some assumptions, such that everyone had the same lending rate, same cost of capital and same required rate of return, were made. When the two methods were applied to seven different industries of the Istanbul Stock Exchange in five industries both TOPSIS and VIKOR identified the same company as the best performer. In first industry the best company by TOPSIS was second best by VIKOR and in the seventh industry the best company by TOPSIS was only the fifth best company according to VIKOR. (Yalcin, Bayrakdaroglu & Kahraman, 2012) This indicates that the companies which perform well are top performers independent on the method of ranking them.

In the case part of this thesis Fuzzy AHP is used to get the linguistic information from the experts to numerical form. This information provides the weights for criteria which are used in the TOPSIS model. TOPSIS model then ranks the companies based on their financial figures which are weighed by the Fuzzy AHP model. Such model is suitable for many applications where inputs are taken in from different sources and in different formats.

3. Case: Fuzzy AHP and TOPSIS evaluation of Finnish mechanical power transmission companies

This chapter presents the case where the analysis shows how the companies which are selected for this research were chosen. Also, it gives brief introduction of the companies that are analyzed so the reader can have better understanding of what kind of companies are studied here. It is critical to understand that the companies are not fully equal peers but have different structures, customer bases, different level of subcontracting and are of different sizes. Source and method for gathering this data are also given in the following pages. Then the evaluation criteria which are used to rank the companies are presented. These criteria are then weighed by the three experts. After this the chapter proceeds to the analysis phase where the analysis tool is implemented to the case data. Results are given in the end.

3.1. Data gathering

Eight biggest companies in the Finnish Mechanical Power Transmission industry by revenue were selected for this research. Data is from 2007 to 2016 so for ten years. Due to ratios which are calculated from previous year the scope of this research is from 2008 to 2016. Nine years should cover enough time to show how the companies have evolved and are the best companies always stayed the same. As one company in the set was bankrupt in 2017 it is also interesting to see the possible decline in the ranking if it was ranked better among the peers.

Data is gathered from Amadeus database which provides comparable financial information for public and private companies across Europe (Bureau van Dijk, 2017). It is exported to excel sheet for easy modification and further calculations. This database would allow to understand corporate structures, as it shows also global ultimate owners, top managers and subsidiaries.

The list of companies operating in the mechanical power transmission is obtained from the Technology Industries of Finland under the Power Transmission Manufacturers. The Technology industries of Finland is the lobbying organization for technology industry companies. (Technology Industries of Finland, 2017) Supplementary data is gathered from

Finnish data provider, Asiakastieto, which provides key figures for free. The following table is combined from Technology Industries of Finland and from Asiakastieto.

Table 1. List of companies, their latest turnover and industry classification (Finnish Industries of Technology, 2017 and Suomen Asiakastieto Oy, 2017).

Company	**Latest turnover**	**Industry (in Finnish) from Asiakastieto**
Konecranes Finland Oy	€680,761,000	Nosto- ja siirtolaitteiden valmistus (28220)
AGCO Power Oy	€273,452,000	Moottoriajoneuvojen valmistus (29100)
Moventas Gears Oy	€105,030,000	Laakereiden, hammaspyörien, vaihteisto- ja ohjauselementtien valmistus (28150)
Santasalo Gears Oy	€48,178,000	Laakereiden, hammaspyörien, vaihteisto- ja ohjauselementtien valmistus (28150)
SEW-Eurodrive Oy	€33,588,000	Laakereiden, hammaspyörien, vaihteisto- ja ohjauselementtien valmistus (28150)
SEW Industrial Gears Oy	€26,634,000	Muualla luokittelematon yleiskäyttöön tarkoitettujen koneiden valmistus (28290)
ATA Gears Oy	€26,179,000	Laakereiden, hammaspyörien, vaihteisto- ja ohjauselementtien valmistus (28150)
Kumera Drives Oy	€25,744,000	Laakereiden, hammaspyörien, vaihteisto- ja ohjauselementtien valmistus (28150)
Katsa Oy	€20,671,000	Laakereiden, hammaspyörien, vaihteisto- ja ohjauselementtien valmistus (28150)
Kotka Power Tech Oy	€14,887,000	Metallirakenteiden ja niiden osien valmistus (25110)
Black Bruin Oy	€12,071,000	Kone- ja prosessisuunnittelu (71127)
Tasowheel Gears Oy	€8,562,000	Laakereiden, hammaspyörien, vaihteisto- ja ohjauselementtien valmistus (28150)
Okun Hammaspyörä Oy	€6,135,000	Laakereiden, hammaspyörien, vaihteisto- ja ohjauselementtien valmistus (28150)
Ahmotuote Oy	€4,109,000	Laakereiden, hammaspyörien, vaihteisto- ja ohjauselementtien valmistus (28150)
Tasowheel Group Oy	€855,000	Pääkonttorien toiminta (70100)

The industry classification is gathered from Asiakastieto and it helps to categorize the companies which are in the scope of this thesis. The industry that is in our interest is "Laakereiden, hammaspyörien, vaihteisto- ja ohjauselementtien valmistus (28150)" which roughly translates to "Manufacturing of bearings, gear wheels and driving elements". Financial data for these companies is collected from Amadeus database. Latest data that is available from Amadeus is from year 2016 and it provides it for the last ten years if the data is obtainable. From all companies in our industry the data is not provided for the full ten years. Thus, these companies which do not provide data for the period are excluded from this research. One company, Takoma Gears Oy, went to bankruptcy during 2017 and it was not listed in the list of Finnish Industries of Technology, but it is taken to the group of companies studied in this thesis. It can show some interesting patterns and can show if other companies in the group are in risk of going insolvent. For 2016 Takoma should be the worst company, at least in financial structure ratios as it had problems before it went under on 21.3.2017.

Table 2. Companies on the selected industry and number of years financials were available.

Company	Years of data
Moventas Gears Oy	10
SEW-Eurodrive Oy	10
ATA Gears Oy	10
Kumera Drives Oy	10
Katsa Oy	10
Okun Hammaspyörä Oy	10
Ahmotuote Oy	10
Takoma Gears Oy	10
Tasowheel Gears Oy	7
Santasalo Gears Oy	2

3.2. Company presentations

Finally, we are left with eight companies to analyze. What follows is a brief view of all the companies and their key figures. Each of the companies are divided onto their own subsections.

3.2.1. Ahmotuote Oy

Ahmotuote Oy was established in year 1985. Company is located in Iisalmi in Eastern Finland and has one location. They produce mainly machined parts, especially toothed parts. They sell mainly to Finnish machine and equipment manufacturers and thus indirectly most of the production of Ahmotuote goes to export. Company is still relatively small; their turnover has ranged from three to five million euros during last ten years. They employ about

30 employees and their total assets are slightly less than five million euros. Company has stayed profitable on both EBITDA level and before taxes during our period. Company is managed by Pertti Taskinen, whom is also an owner. (Ahmotuote Oy, 2018)

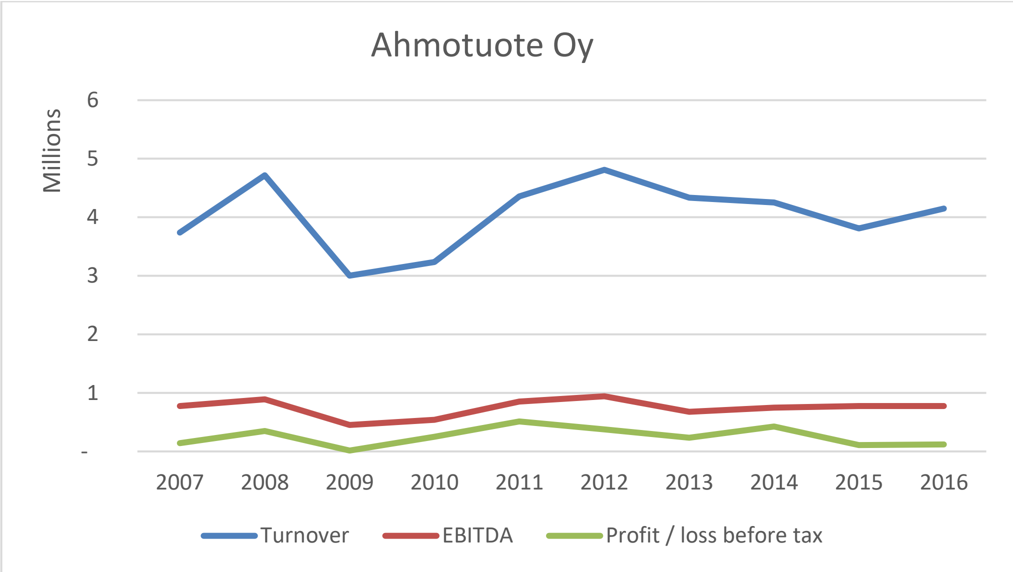

Figure 6. Turnover, EBITDA and Profit / loss before tax of Ahmotuote Oy for 2007 to 2016.

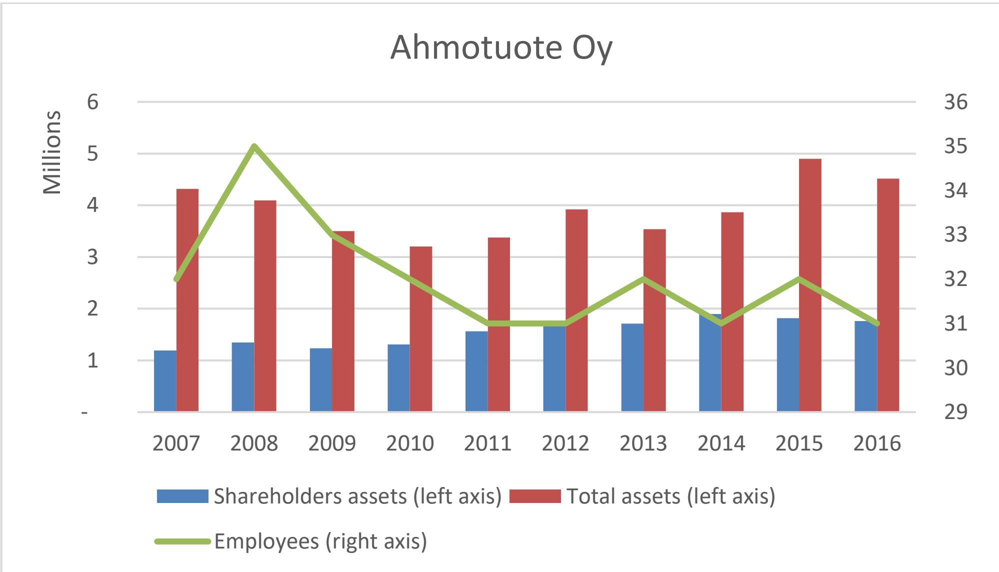

Figure 7. Shareholders assets, Total assets and Employees of Ahmotuote Oy for 2007 to 2016.

3.2.2. Ata Gears Oy

Ata Gears Oy was established in year 1937 and it is headquarters are located in Tampere. Ata Gears are specialized in spiral bevel gears which applications are used especially in marine equipment. In the early days the company was focused on car equipment such as gears but has then redefined their business model to spiral bevel gears. Ata claims that they are one of the most respected spiral bevel gear supplier for ship propulsion systems and every main manufacturer of propulsion units used Ata’s gears. Ata’s turnover has ranged from 40 million euros to 50 million euros but for the last two years the sales have plummeted to 25 million euros. Profitability has followed the sales and due to the recent decline in sales the company has made loss for last two years. Their assets have grown rather steadily but the two unprofitable years have taken toll on shareholders assets. (Ata Gears Oy, 2018)

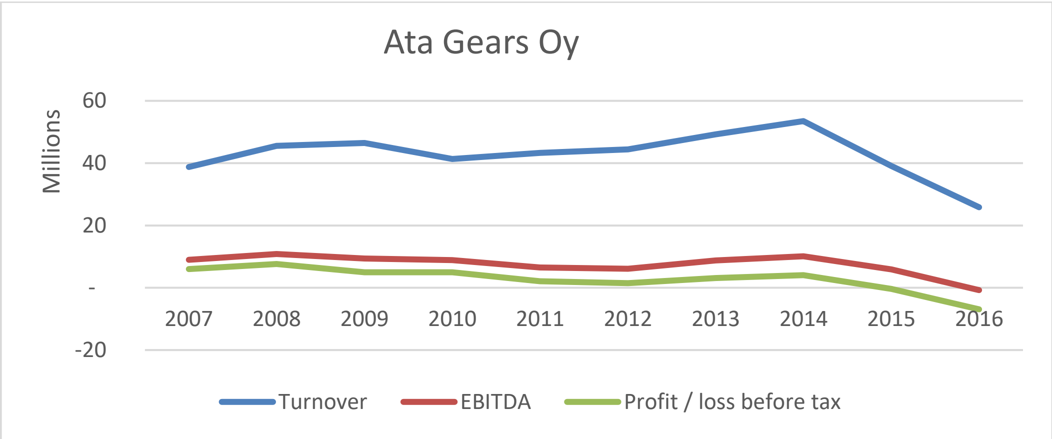

Figure 8. Turnover, EBITDA and Profit / loss before tax of Ata Gears Oy for 2007 to 2016.

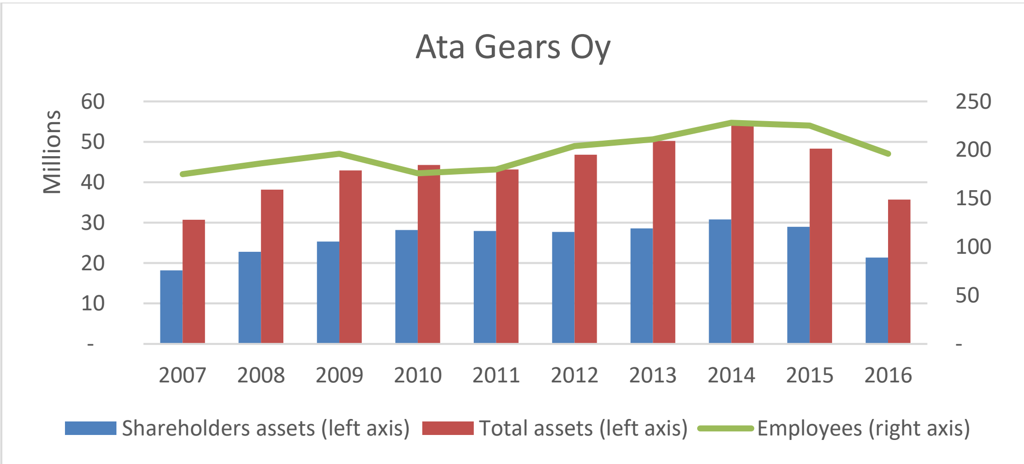

Figure 9. Shareholders assets, Total assets and Employees of Ata Gears Oy for 2007 to 2016.

3.2.3. Katsa Oy

Katsa Oy was established in year 1955 and is headquartered in Tampere. Katsa has three plants near Tampere. Katsa has manufactured diesel engine gear wheels for engine factories and this has become its core business. These engines are applied in marine applications. Katsa is able to manufacture quality special gears according to customers' needs. Turnover for the company has been between 20 to 30 million euros after 2010. Before that turnover ranged in around 40 million euros. Due to declined sales company has had troubles keeping profits on the positive side. This has led to reduction of employees and declined total assets. However, the company has minimal debt which allows them to invest in new machinery. (Katsa Oy, 2018)

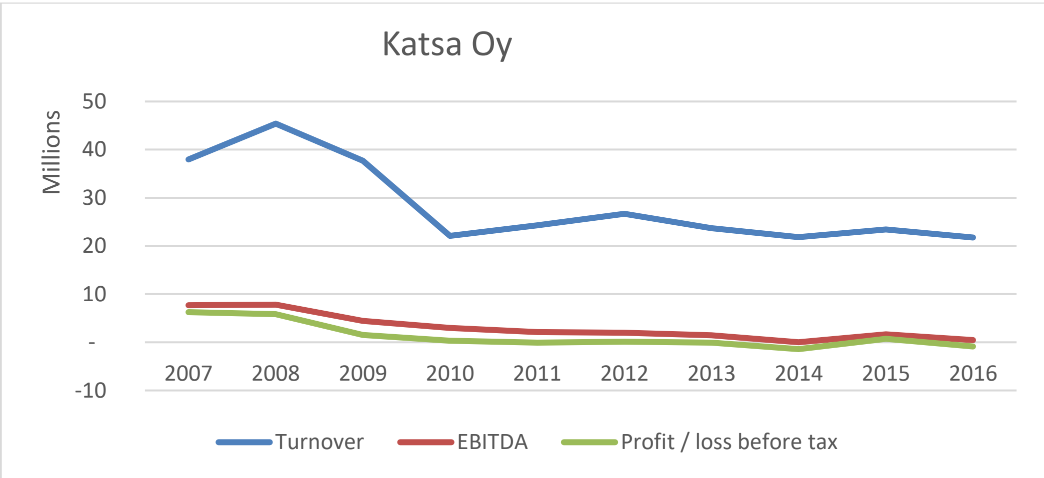

Figure 10. Turnover, EBITDA and Profit / loss before tax of Katsa Oy for 2007 to 2016.

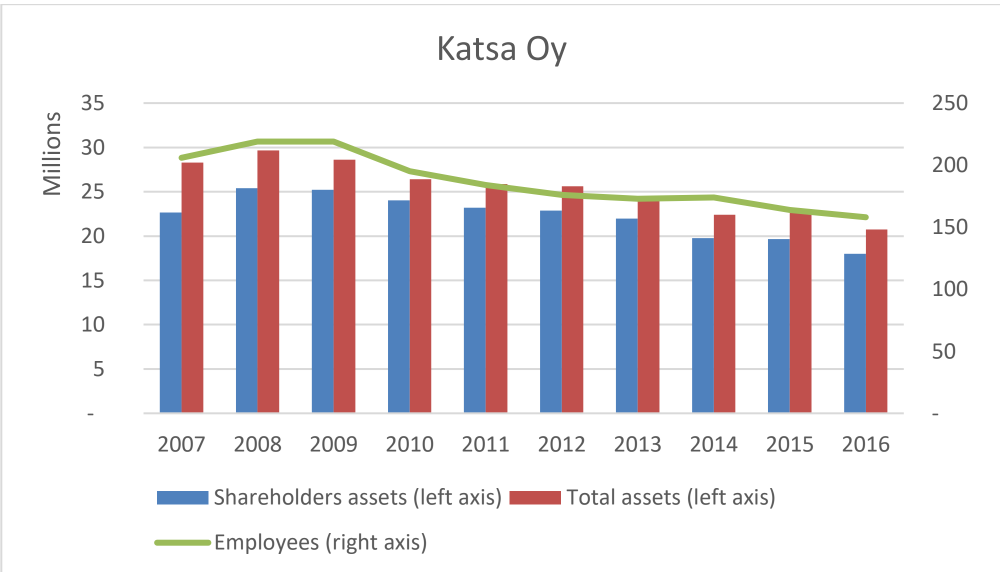

Figure 11. Shareholders assets, Total assets and Employees of Katsa Oy for 2007 to 2016.

3.2.4. Kumera Drives Oy

Kumera Drives Oy was established in year 1945 and is now located in Riihimäki. Kumera is part of conglomerate which has operations in Finland, Norway, Austria and China. They offer wide product range and are specialized on pulp and paper industry and mining and minerals industry. Turnover has ranged from 20 to 30 million euros and company has been profitable for the whole-time period. It employs little less than 140 people and the number of employees has declined through the period. Their assets have increased, and the shareholders assets take up most of the total assets. (Kumera, 2018)

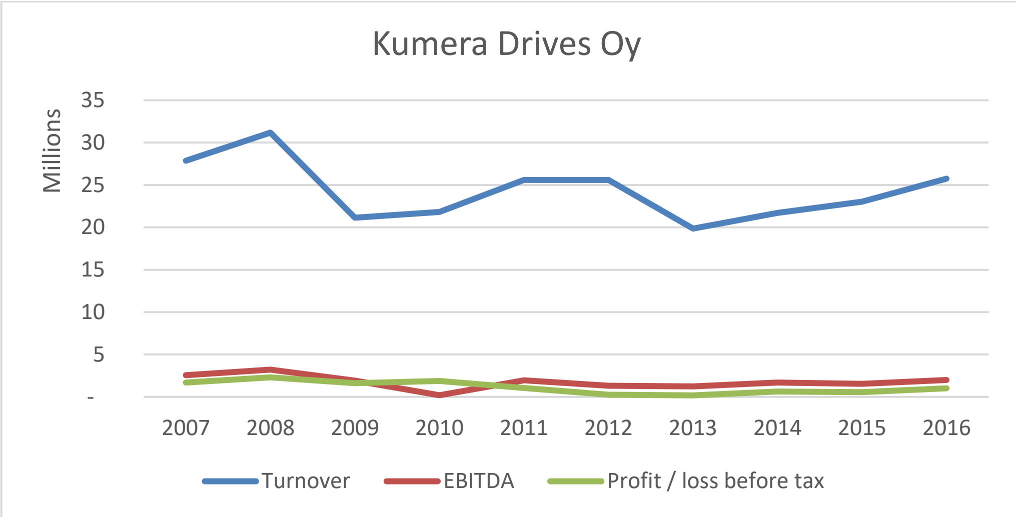

Figure 12. Turnover, EBITDA and Profit / loss before tax of Kumera Drives Oy for 2007 to 2016.

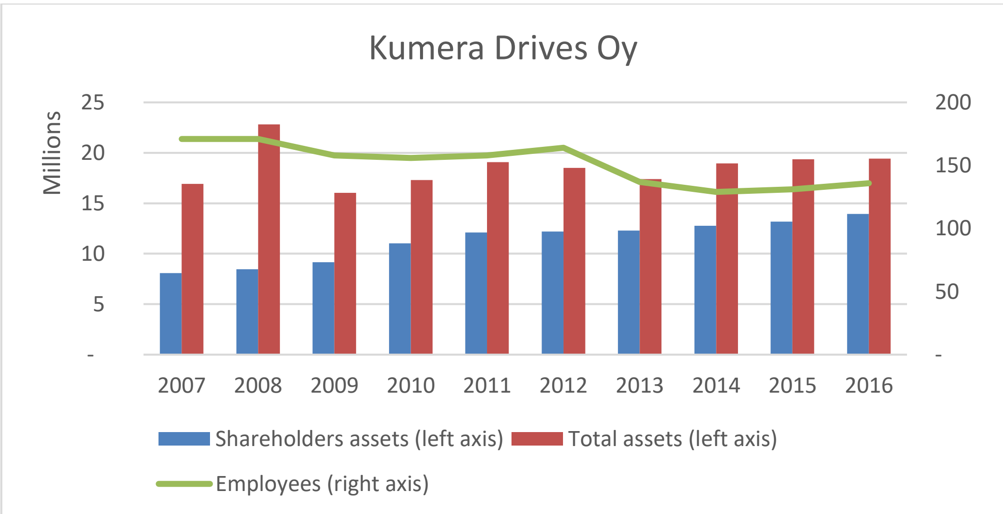

Figure 13. Shareholders assets, Total assets and Employees of Kumera Drives Oy for 2007 to 2016.

3.2.5. Moventas Gears Oy

Moventas Gears Oy is the biggest gear manufacturer in this research and has two facilities in Jyväskylä and one facility in Karkkila. It has versatile history and its predecessors were established in the 1940's. It has been part of large Finnish manufacturing companies Metso and Valmet and was then sold to private equity funds. In 2011 Finnish subsidiaries of Moventas applied for restructuring and the main company applied for bankruptcy. In the end of 2011 the whole company was sold to British company Clyde Blowers. Moventas is specialized in wind turbine gearbox manufacturing and has over 35 years' experience on wind turbine gear applications. Turnover has varied from nearly 250 million euros to 50 million euros. Decline in sales is due to the impact of the financial crisis, as investments on wind power declined. Company has struggled with profitability and during the ten-year period has made staggering 150-million-euro loss. EBITDA has finally become positive in 2016 and it is interesting to see whether the company has really been turned over when the 2017 financials become available. For year 2014 there was no data available for number of employees but regardless of that the number of employees has varied a lot. Shareholders have had to make capital injections to keep the company running. (Moventas Gears Oy, 2018)

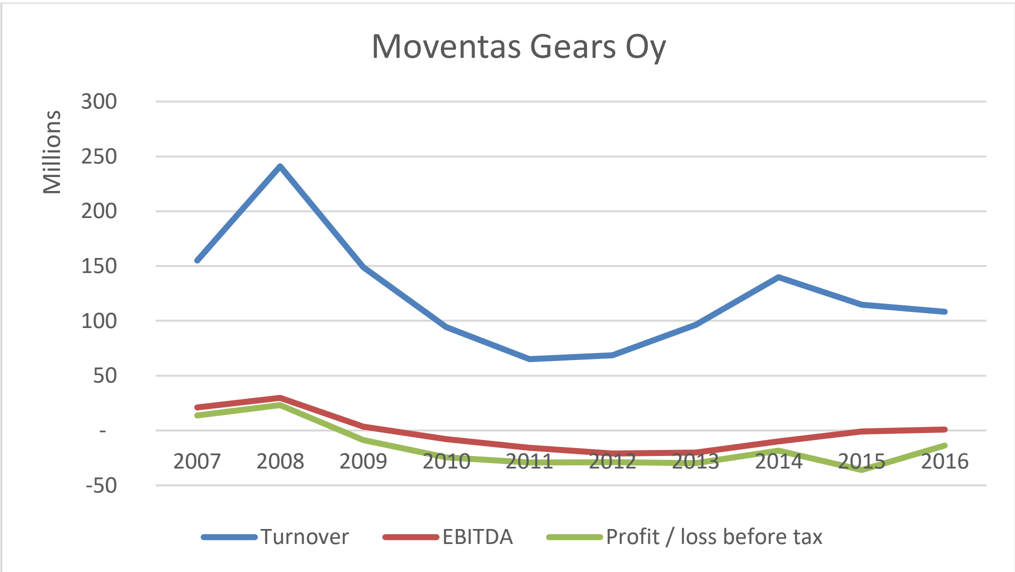

Figure 14. Turnover, EBITDA and Profit / loss before tax of Moventas Gears Oy for 2007.

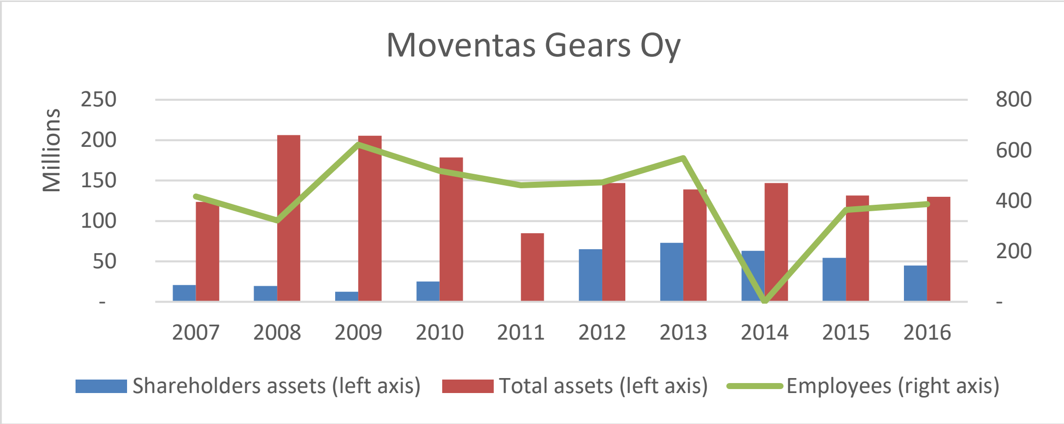

Figure 15. Shareholders assets, Total assets and Employees of Moventas Gears Oy for 2007 to 2016.

3.2.6. Okun Hammaspyörä Oy

Okun Hammaspyörä Oy was first established as an independent company but in 1996 it was bought by its current owner, New Steel Oy. It is in Outokumpu in Finland. Company does not have its own product line but is a full subcontractor and makes pieces according to customers drawings and specifications. Many customers are forest machine makers and Okun Hammaspyörä is an established producer of their parts. Their turnover has ranged from seven to three million euros and they have constantly been profitable. They employ around 30 people but for 2015 and 2016 the data was not available. Their shareholders assets have declined during the period and thus debt levels are increasing. This however, can be due to the corporate structure. (NS Group Oy, 2018)

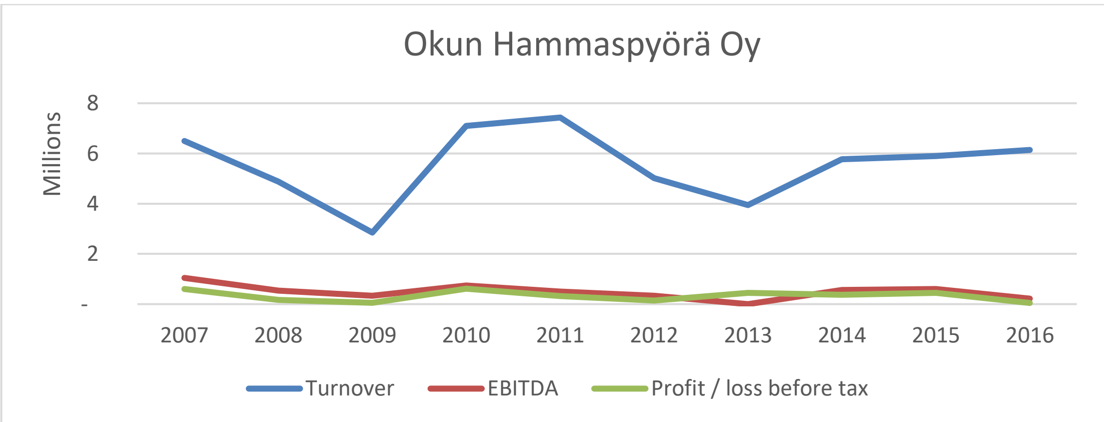

Figure 16. Turnover, EBITDA and Profit / loss before tax of Okun Hammaspyörä Oy for 2007 to 2016.

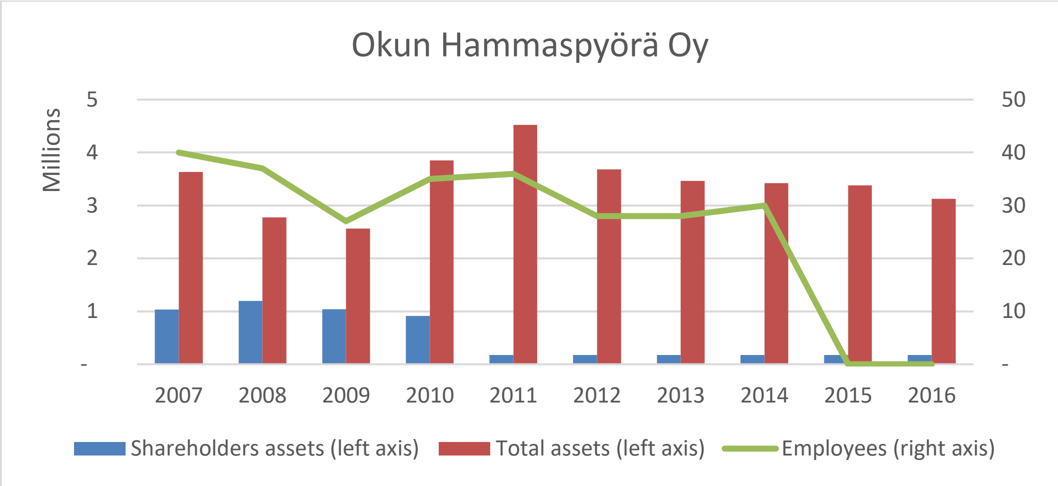

Figure 17. Shareholders assets, Total assets and Employees of Okun Hammaspyörä Oy for 2007 to 2016.

3.2.7. SEW-Eurodrive Oy

SEW-Eurodrive Oy is a Finnish subsidiary to German SEW-Eurodrive conglomerate. Finnish entity has its roots in Santasalo gears, same as Moventas. SEW-Eurodrive acquired the Finnish part in 1994. The group has turnover over 2,7 billion euros. The Finnish entity's turnover has ranged from 17 million euros to 33 million euros. It has been profitable for the entire research period. It employs around 70 people and their assets have increased steadily throughout the period ignoring year 2009. (Wikipedia, 2018a)

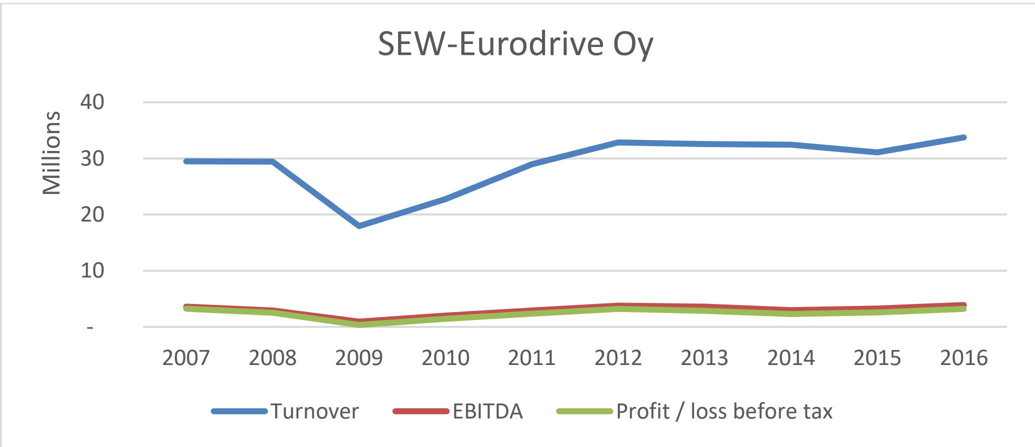

Figure 18. Turnover, EBITDA and Profit / loss before tax of SEW-Eurodrive Oy for 2007 to 2016.

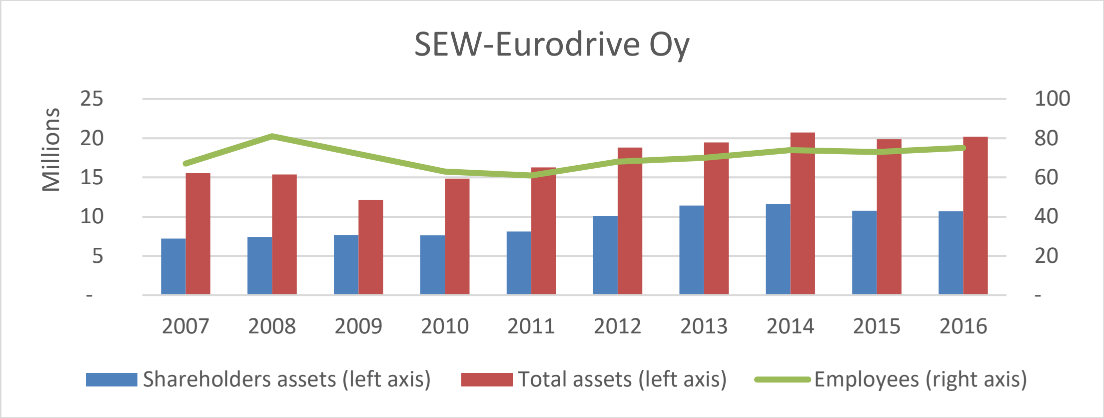

Figure 19. Shareholders assets, Total assets and Employees of Ahmotuote Oy for 2007 to 2016.

3.2.8. Takoma Gears Oyj

Takoma Gears Oyj is the only publicly listed company in this research. It went bankrupt on spring 2017. Takoma was established in 2007 when two companies, Tampereen Laatukoneistus Oy and Hervannan Koneistus Oy in Tampere were combined. Their main products were to shipbuilding and offshore industry. Their turnover ranged from 10 to 25 million euros. During 2016 their shareholders assets went to the negative and due to losses, that they incurred. (Wikipedia, 2018b)

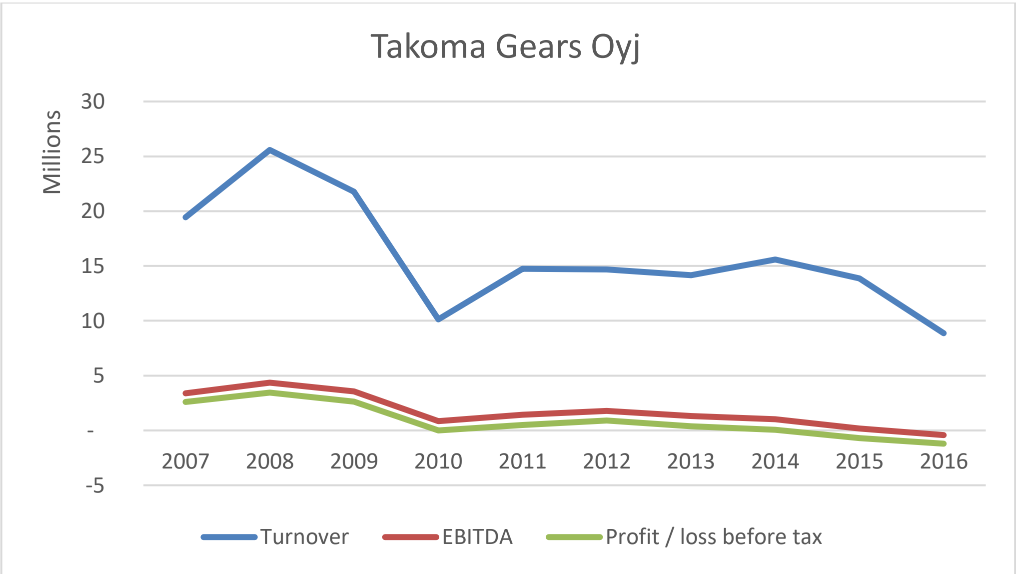

Figure 20. Turnover, EBITDA and Profit / loss before tax of Takoma Gears Oyj for 2007 to 2016.

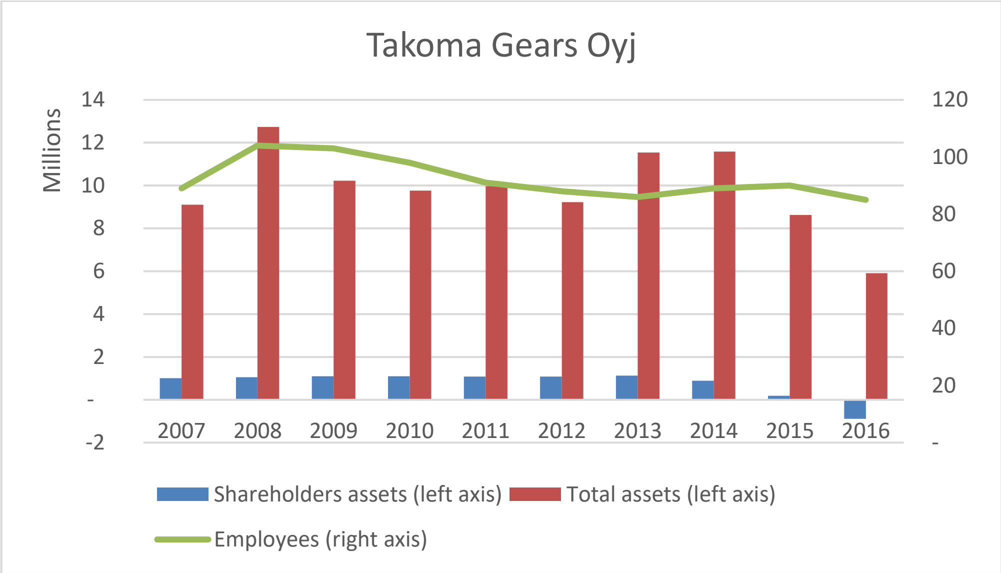

Figure 21. Shareholders assets, Total assets and Employees of Takoma Gears Oyj for 2007 to 2016.

3.3. Criteria for evaluation

This section is divided into five subsections according to the five criteria in the main group. The main group of criteria are Financial leverage, Liquidity, Management activity (comprising of credit terms, inventory turnover and employee-based ratios), Profitability and Growth. Each sub criteria are presented on their respective chapters.

Criteria that are selected for the evaluation of the companies are listed here and explained in detail. Each criterion has also sub criteria of which the main criterion is composed of. Criteria were selected based on earlier literature, for example Ertugrul et. al. (2009) and bearing in mind the objective of grasping as wide understanding as possible of these companies financially. The selected criteria are such which are also available for every company within this research. It is identified that some criteria are stronger and more suitable for analysis purposes than others. However, weights that are derived from experts should weigh important criteria much higher than less important ones. Also, the figures for each criterion and for each company are presented for every year.

3.3.1. Financial leverage

Financial leverage ratios tell that how well the company can meet its short and long-term obligations to debtors and they show the proportion of which the company is financed with debt and not with shareholders capital. There is discussion about the optimal debt level for a company and at least in theory companies should use as much debt as possible. Maximum debt would increase the shareholders return, and also the debt tax shield effect would help the company against the tax obligations. Leverage would increase firm value due to the tax shield effect (Fernandes, 2014). However, this thesis assumes that the companies have thought their financing and are using leverage that is suitable for them. Thus, the financial leverage ratios are considered as a cost criterion, which mean that the lower the value the better since none of the companies are free of debt. This also suggest that they are using debt to some extent.

Debt ratio is calculated by taking current and non-current liabilities and dividing that with total assets. This ratio tells how much the company's assets are financed by debt. As the ratio becomes closers to one the company is more financed with debt than equity. If the ratio is greater than one, then it means that the company is bankrupt, and equity is negative. Debt ratio is cost criteria as higher debt levels are considered worse than moderate ones. If the company wishes to take a new loan the creditors might require that the company will keep its debt ratio under certain level. (Bearly & Meyers, 2003)

$$Debt\ ratio = \frac{Current\ and\ Non{-}current\ liabilities}{Total\ assets} \qquad (13)$$

Equation 13. Debt ratio (Bearly & Meyers, 2003).

Table 3. Debt ratios of the companies from 2007 to 2016.

Debt ratio	2016	2015	2014	2013	2012	2011	2010	2009	2008	2007
Ahmotuote Oy	0.61	0.63	0.51	0.52	0.57	0.54	0.59	0.65	0.67	0.72
Ata Gears Oy	0.40	0.40	0.43	0.43	0.41	0.35	0.36	0.41	0.40	0.41
Katsa Oy	0.13	0.13	0.12	0.09	0.11	0.10	0.09	0.12	0.14	0.20
Kumera Drives Oy	0.28	0.32	0.33	0.29	0.34	0.37	0.36	0.43	0.63	0.52
Moventas Gears Oy	0.65	0.59	0.57	0.48	0.56	1.00	0.86	0.94	0.90	0.83
Okun Hammaspyörä Oy	0.94	0.95	0.95	0.95	0.95	0.96	0.76	0.60	0.57	0.72
SEW-Eurodrive Oy	0.47	0.46	0.44	0.41	0.46	0.50	0.49	0.37	0.52	0.54
Takoma Gears Oyj	1.15	0.98	0.92	0.90	0.88	0.89	0.89	0.89	0.92	0.89

Shareholders equity divided by total assets ratio tells how much of the company's assets are financed with equity. This ratio is of benefit type as higher value would indicate that company is financed more with equity than debt. To make it cost criteria the ratio is changed to total assets divided by shareholders equity. This is also known as equity multiplier. Now the higher ratio indicates that the proportion of equity is small and thus the company has more debt. When the ratio becomes closer to one then the company is financed with equity. (Ross, Westerfield & Jaffe, 2013)

$$Equity\ multiplier = \frac{Total\ assets}{Shareholders'equity} \qquad (14)$$

Equation 14. Equity multiplier (Ross, Westerfield & Jaffe, 2013).

Table 4. Equity multipliers of the companies from 2007 to 2016.

Equity multiplier	2016	2015	2014	2013	2012	2011	2010	2009	2008	2007
Ahmotuote Oy	2.56	2.70	2.04	2.06	2.30	2.16	2.45	2.83	3.04	3.63
Ata Gears Oy	1.67	1.67	1.76	1.76	1.69	1.55	1.57	1.69	1.68	1.69
Katsa Oy	1.15	1.16	1.13	1.10	1.12	1.12	1.10	1.14	1.17	1.25
Kumera Drives Oy	1.39	1.47	1.48	1.41	1.52	1.58	1.57	1.75	2.70	2.10
Moventas Gears Oy	2.90	2.42	2.33	1.91	2.26	7719.27	7.07	16.38	10.51	5.96
Okun Hammaspyörä Oy	17.55	19.00	19.21	19.47	20.80	25.99	4.23	2.47	2.32	3.51
SEW-Eurodrive Oy	1.89	1.85	1.79	1.70	1.86	2.01	1.95	1.59	2.08	2.16
Takoma Gears Oyj	-6.67	45.02	13.03	10.24	8.47	9.14	8.94	9.31	12.00	9.08

Fixed assets to shareholders equity ratio explains how much of the fixed assets that the company has are financed with equity. When the ratio is below one then all of the fixed assets are financed with equity. Higher values indicate that the company is financing its fixed assets with debt instead of equity and thus is obligated to pay interest on those assets. That is why this is cost type criteria. (Ertugrul & Karakasoglu, 2009)

$$Fixed\ assets\ to\ shareholders'\ equity = \frac{Fixed\ assets}{Shareholders'equity} \qquad (15)$$

Equation 15. Fixed assets to shareholders’ equity (Ertugrul & Karakasoglu, 2009).

Table 5. Fixed assets to shareholders' equity of the companies from 2007 to 2016.

Fixed assets to shareholders' equity	2016	2015	2014	2013	2012	2011	2010	2009	2008	2007
Ahmotuote Oy	1.66	1.77	1.18	1.06	1.23	1.22	1.37	1.63	1.61	2.02
Ata Gears Oy	1.14	1.02	1.04	1.10	1.10	0.89	0.86	0.94	0.91	0.90
Katsa Oy	0.36	0.36	0.37	0.32	0.32	0.39	0.43	0.51	0.44	0.37
Kumera Drives Oy	0.60	0.61	0.65	0.74	0.80	0.83	0.88	0.98	1.05	1.03
Moventas Gears Oy	0.79	0.75	0.61	0.70	0.90	3816.27	3.48	7.72	4.29	2.64
Okun Hammaspyörä Oy	7.65	8.29	9.23	10.12	10.34	11.41	1.56	1.11	1.15	1.54
SEW-Eurodrive Oy	0.47	0.51	0.50	0.56	0.65	0.56	0.63	0.69	0.79	0.76
Takoma Gears Oyj	-2.03	12.07	3.25	3.15	3.42	3.97	4.48	4.88	4.01	2.69

3.3.2. Liquidity

Liquidity is necessary for every company so that they can pay their obligations which are coming due. In most conservative form it means cash on hand, but it can also consist assets that are easily transformed to cash. Liquidity ratios tell does the company have means to survive the few upcoming months or does it need financing to get cash. These ratios indicate the short-term ability to pay its bills. These measures are particularly interesting to short-term creditors. Current assets and current liabilities have the benefit that, due to their short time period, their market values are close to their book values, thus really often there is no appreciation or depreciation on those assets. (Ross, Westerfield & Jaffe, 2013)

Current ratio measures the current assets to current liabilities. Current assets include cash and assets that can be converted to cash within the next 12 months. When the ratio is greater than 1,5 then the company is considered to have enough assets to pay the liabilities. If current ratio is decreasing quickly it can indicate problems, but that might not always be the case as if company is using short-term debt to invest in securities and does not affect net working capital, but it would decrease the ratio. Thus, one might adjust the ratio by taking off short-term debt and investments away when calculating current ratio. (Bearly & Meyers, 2003)

$$Current\ ratio = \frac{Current\ assets}{Current\ liabilities} \qquad (16)$$

Equation 16. Current ratio (Bearly & Meyers, 2003).

Table 6. Current ratios of the companies from 2007 to 2016.

Current ratio	2016	2015	2014	2013	2012	2011	2010	2009	2008	2007
Ahmotuote Oy	1.41	1.70	2.22	2.27	2.06	1.52	1.87	2.04	2.48	2.55
Ata Gears Oy	1.46	1.71	1.66	1.43	1.63	1.88	2.26	2.00	1.69	1.92
Katsa Oy	5.22	5.12	5.69	7.47	6.72	6.30	6.79	4.60	4.35	3.51
Kumera Drives Oy	2.10	1.89	1.77	1.97	1.78	1.61	1.26	1.69	1.51	2.34
Moventas Gears Oy	3.41	3.52	2.20	3.48	3.17	0.67	2.53	3.92	1.36	1.18
Okun Hammaspyörä Oy	0.60	0.60	0.55	0.53	0.62	0.69	0.90	1.00	1.22	1.12
SEW-Eurodrive Oy	1.60	1.58	1.63	1.62	1.41	1.44	1.39	1.53	1.20	1.21
Takoma Gears Oyj	1.24	1.50	1.49	0.78	1.02	1.13	1.28	0.85	1.02	1.06

Quick ratio is more conservative to current ratio as it deducts inventory from the current assets and is then divided by current liabilities. This illustrates better the immediate liquidity as quite often the inventory is not for sale and it would be rather hard for the company to transform it to a cash. Company’s inventory is subject to structural liquidity risk especially in hard economic times and items on the inventory that are easy subjects to theft, obsolescence and deterioration can become worthless or disappear. Thus, the quick ratio is independent to such unwanted events. When the ratio is one, then the company has just barely sufficient capability to cope with payments and has no safety cushion. Quick ratio is also known as acid test ratio. (Grossman & Livingstone, 2009)

$$Quick\ ratio = \frac{(Current\ assets - Inventory)}{Current\ liabilities} \qquad (17)$$

Equation 17. Quick ratio (Grossman & Livingstone, 2009).

Table 7. Quick ratios of the companies from 2007 to 2016.

Quick ratio	2016	2015	2014	2013	2012	2011	2010	2009	2008	2007
Ahmotuote Oy	1.02	1.40	1.96	2.01	1.84	1.26	1.68	1.70	2.21	2.39
Ata Gears Oy	1.07	1.31	1.13	0.91	0.94	1.17	1.56	1.30	0.68	0.83
Katsa Oy	3.31	3.16	3.60	4.93	4.20	3.89	3.92	1.47	1.52	1.85
Kumera Drives Oy	1.38	1.15	1.04	0.90	0.90	0.84	0.72	0.76	0.83	1.13
Moventas Gears Oy	2.54	2.38	1.58	2.38	2.10	0.53	1.36	1.70	0.69	0.61
Okun Hammaspyörä Oy	0.32	0.32	0.28	0.24	0.28	0.32	0.45	0.50	0.63	0.79
SEW-Eurodrive Oy	1.28	1.25	1.27	1.27	1.01	1.07	1.00	1.05	0.78	0.89
Takoma Gears Oyj	0.68	0.69	0.93	0.53	0.51	0.50	0.62	0.28	0.41	0.35

The most conservative liquidity ratio is cash ratio. Cash ratio shows how much the company has cash on hand to pay the current liabilities. This shows the ability to pay if for some reason creditors would need the payment right away. Short term financier may be interested in cash ratio. (Ross, Westerfield & Jaffe, 2013)

$$Cash\ ratio = \frac{(Cash + Cash\ equivivalent)}{Current\ liabilities} \qquad (18)$$

Equation 18. Cash ratio (Ross, Westerfield & Jaffe, 2013).

Table 8. Cash ratios of the companies from 2007 to 2016.

Cash ratio	2016	2015	2014	2013	2012	2011	2010	2009	2008	2007
Ahmotuote Oy	0.20	0.80	0.28	0.41	0.49	0.45	0.81	0.46	0.73	0.06
Ata Gears Oy	0.55	0.71	0.27	0.30	0.25	0.55	0.86	0.61	0.12	0.15
Katsa Oy	0.32	1.46	0.70	2.20	2.62	2.44	2.49	0.28	0.22	0.43
Kumera Drives Oy	0.02	0.00	0.00	0.00	0.00	0.00	0.01	0.00	0.00	0.04
Moventas Gears Oy	0.22	0.32	0.16	0.32	0.22	0.02	0.01	0.01	0.00	0.00
Okun Hammaspyörä Oy	0.03	0.08	0.06	0.07	0.02	0.00	0.03	0.07	0.33	0.11
SEW-Eurodrive Oy	0.66	0.68	0.66	0.65	0.41	0.57	0.52	0.51	0.25	0.34
Takoma Gears Oyj	0.30	0.11	0.08	0.00	0.09	0.05	0.22	0.01	0.01	0.00

3.3.3. Management activity ratios

Activity ratios tell how the management is using the resources the company has in most efficient way possible. Activity ratios include payment times for purchases and sales, how effective is the use of employees and how often the inventory is turned over within operating year. These ratios could also be called as operational ratios.

Credit period measured in days show how many days the company can wait before it has to pay for suppliers. This ratio shows the negotiation power the company has over its suppliers. Credit period affects the working capital of the company, in ideal situation the company gets to collect payments from customers before it has to pay for the suppliers. This ratio is benefit type as higher number indicates more time to pay for the suppliers and more financial freedom. (Ross, Westerfield & Jaffe, 2013)

$$Credit\ period\ in\ days = \frac{Creditors}{Operating\ reveneu * 360} \qquad (19)$$

Equation 19. Credit period in days (Ross, Westerfield & Jaffe, 2013).

Table 9. Credit periods in days of the companies from 2007 to 2016.

Credit period in days	2016	2015	2014	2013	2012	2011	2010	2009	2008	2007
Ahmotuote Oy	31	26	15	16	14	11	3	7	10	23
Ata Gears Oy	31	27	28	38	26	33	28	20	39	28
Katsa Oy	20	19	19	14	19	22	18	21	24	34
Kumera Drives Oy	18	0	32	0	13	22	20	17	0	14
Moventas Gears Oy	56	49	40	46	61	10	70	39	77	59
Okun Hammaspyörä Oy	22	16	20	22	18	13	16	89	32	57
SEW-Eurodrive Oy	4	0	2	2	4	2	4	2	1	4
Takoma Gears Oyj	13	14	11	65	32	33	30	27	0	41

Collection Period days tells how long it takes for the company to get paid after the products are delivered to the customer. In ideal situation this figure would be negative as the customers would make prepayments and the operations of the company, including paying to the suppliers, would be financed with customers money. This is cost type criteria as when the number get larger it means that the company is financing its customers and they must wait for longer to get their money. (Ross, Westerfield & Jaffe, 2013)

$$Collection\ period\ in\ days = \frac{Debtors}{Operating\ revenue * 360} \qquad (20)$$

Equation 20. Collection period in days (Ross, Westerfield & Jaffe, 2013).

Table 10. Collection period in days of the companies from 2007 to 2016.

Collection period in days	2016	2015	2014	2013	2012	2011	2010	2009	2008	2007
Ahmotuote Oy	79	53	65	68	62	53	71	44	52	63
Ata Gears Oy	42	46	67	48	52	41	38	45	40	41
Katsa Oy	58	61	52	50	46	50	47	30	39	42
Kumera Drives Oy	51	0	52	0	43	41	46	24	0	42
Moventas Gears Oy	48	45	48	43	102	56	105	65	57	53
Okun Hammaspyörä Oy	48	44	41	34	47	40	55	69	21	55
SEW-Eurodrive Oy	52	0	47	45	53	41	47	36	42	44
Takoma Gears Oyj	16	39	94	79	42	54	53	21	34	32

Inventory turnover ratio illustrates how much sales the company can generate from its inventory. As holding inventory is a cost it is better that the inventory moving quickly. It shows the efficiency company has in transforming inventory to sales. The ratio can be increased by increasing sales or lowering inventory. This is benefit type criteria as higher value indicates higher efficiency for the inventory. (Moyer, McGuigan, Rao & Kretlow, 2011)

$$Inventory\ turnover\ = \frac{Operating\ revenue}{Inventory} \quad (21)$$

Equation 21. Inventory turnover (Moyer, McGuigan, Rao & Kretlow, 2011).

Table 11. Inventory turnover of the companies from 2007 to 2016.

Inventory turnover	2016	2015	2014	2013	2012	2011	2010	2009	2008	2007
Ahmotuote Oy	9	13	22	22	25	17	22	12	22	32
Ata Gears Oy	8	9	8	7	6	6	7	7	4	5
Katsa Oy	4	4	4	4	4	4	3	4	4	4
Kumera Drives Oy	7	5	5	4	6	6	7	5	5	6
Moventas Gears Oy	4	4	5	3	2	7	2	2	4	5
Okun Hammaspyörä Oy	7	7	7	6	5	5	6	4	7	11
SEW-Eurodrive Oy	11	10	10	12	9	10	8	8	9	11
Takoma Gears Oyj	5	4	5	5	5	5	4	7	5	5

Total assets per employee in thousands shows how much assets the company has per employee. If the company has all the newest equipment’s it should have higher value. However, if the company has invested for automation and is more efficient with less employees this number would decrease. This ratio alone does not tell whether the company is efficient or not but when we assume that the company is not having employees just for the sake of having employees but adjusting employee number to be as efficient as possible, we can consider this ratio to be one sign of efficiency. It is thus benefit type criteria.

$$Total\ assets\ per\ employee = \frac{Total\ assets}{Number\ of\ employees} \quad (22)$$

Equation 22. Total asset per employee

Table 12. Total assets per employee in thousands of the companies from 2007 to 2016.

Total assets per employee in thousands of euros	2016	2015	2014	2013	2012	2011	2010	2009	2008	2007
Ahmotuote Oy	146	158	125	114	127	109	103	106	117	139
Ata Gears Oy	183	215	238	239	230	240	253	219	206	176
Katsa Oy	132	139	129	141	146	141	136	131	136	138
Kumera Drives Oy	143	148	148	127	113	121	111	102	134	99
Moventas Gears Oy	336	362	n.a.	245	311	184	345	331	642	297
Okun Hammaspyörä Oy	n.a.	n.a.	114	124	136	129	110	95	77	91
SEW-Eurodrive Oy	270	273	284	282	280	271	236	171	192	235
Takoma Gears Oyj	70	96	132	136	105	110	101	99	124	103

Operating revenue per employee in thousands show how much sales is one employee generating. This ratio shows the efficiency of employees as more can be produced with less amount of people. Operating revenue per employee is benefit criteria because higher number indicates that the company can sell more per employee. Its good measure to quickly understand different industries.

$$Operating\ revenue\ per\ employee\ = \frac{Operating\ revenue}{Number\ of\ employees} \qquad (23)$$

Equation 23. Operating revenue per employee

Table 13. Operating revenue per employee of the companies from 2007 to 2016.

Operating revenue per employee in thousands of euros	2016	2015	2014	2013	2012	2011	2010	2009	2008	2007
Ahmotuote Oy	134	123	137	140	155	140	104	91	135	121
Ata Gears Oy	133	174	236	234	218	241	236	237	246	221
Katsa Oy	139	143	126	138	152	132	114	173	208	185
Kumera Drives Oy	189	176	170	145	156	163	140	135	183	163
Moventas Gears Oy	280	316	n.a.	170	145	141	182	240	751	372
Okun Hammaspyörä Oy	n.a.	n.a.	192	188	186	212	203	106	135	162
SEW-Eurodrive Oy	450	426	444	472	490	482	361	253	367	446
Takoma Gears Oyj	104	154	177	167	167	162	104	211	248	221

3.3.4. Profitability

Profitability ratios are essential to understand which companies are profitable and can survive in the long term. They show whether the company can make more sales than it has costs. Such ratios should be top priority of any company as they are tasked to increase the shareholder wealth. Both shareholder and creditors should be interested on these ratios as when they get better, the chances are better that they are getting paid back. Customers might look at these ratios from different perspective, are they paying too much for the services if the company is really profitable. Also, the suppliers might think that should they increase their prices if the company would have good profits to pay them. However, these ratios are considered benefit criteria and higher profitability is always better.

Cash flow per operating revenue in percentages shows how well company can make cash of its sales. As the ratio grows bigger it means that the company is getting more cash per sales. This is benefit type criteria.

$$Cash\ flow\ per\ operating\ revenue - \% = \frac{Cash\ flow}{Operating\ revenue} \quad (24)$$

Equation 24. Cash flow per operating revenue

Table 14. Cash flow per operating revenue -% of the companies from 2007 to 2016.

Cash flow per operating revenue -%	2016	2015	2014	2013	2012	2011	2010	2009	2008	2007
Ahmotuote Oy	17.06	18.87	14.94	13.4	16.61	15.6	13.61	13.79	15.11	17.76
Ata Gears Oy	16.2	15.45	13.12	15.49	10.34	14.39	14.32	13.7	18.4	17.54
Katsa Oy	2.59	6.91	-1.44	6.53	8.9	9.88	12.25	8.84	14.04	16.49
Kumera Drives Oy	7.62	6.99	7.87	6.12	3.84	7.07	10.74	5.72	2.26	2.36
Moventas Gears Oy	-6.06	-17.33	-12.82	-19.68	-16.36	-21.59	-11.66	0.52	1.71	4.74
Okun Hammaspyörä Oy	2.23	2.31	2.74	n.a.	3.35	2.07	2.69	10.29	18.14	12.73
SEW-Eurodrive Oy	5.19	3.34	3.27	6.28	7.64	4.08	2.75	4.83	2.12	2.2
Takoma Gears Oyj	-5.673	-0.381	4.066	5.244	4.768	4.868	6.361	3.78	3.011	3.179

EBITDA margin shows the profitability of the company before taxes, interest payments, deductions and amortizations. It shows the operating profitability. If companies can't keep this ratio positive it means they need operational reforms. It is good measure as it ignores deductions, which on highly capital-intensive industry are quite substantial, so companies are not penalized for investments on equipment. Also, it ignores the capital structure as interest payments on debt are not included. As all the companies operate in Finland the tax rate is same for everyone but if the companies were from different countries the tax rate would affect the profitability rewarding those with smaller tax rates. (Ross, Westerfield & Jaffe, 2013)

$$EBITDA\,margin = \frac{EBITDA}{Operating\ revenue} \qquad (25)$$

Equation 25. EBITDA margin (Ross, Westerfield & Jaffe, 2013)

Table 15. EBITDA margin of the companies from 2007 to 2016.

EBITDA margin -%	2016	2015	2014	2013	2012	2011	2010	2009	2008	2007
Ahmotuote Oy	18.74	20.36	17.60	15.57	19.58	19.59	16.70	15.05	18.84	20.76
Ata Gears Oy	-2.95	15.08	18.80	17.74	13.77	15.07	21.38	20.08	23.80	23.10
Katsa Oy	2.05	7.18	0.03	6.21	7.44	8.72	13.49	11.81	17.22	20.31
Kumera Drives Oy	7.72	6.74	7.80	6.27	5.11	7.63	0.90	9.16	10.32	9.13
Moventas Gears Oy	0.84	-0.79	-7.18	-20.90	-30.53	-24.28	-8.21	2.28	12.36	13.61
Okun Hammaspyörä Oy	3.49	10.28	9.81	n.a.	6.68	6.65	10.51	11.56	10.96	16.07
SEW-Eurodrive Oy	11.53	10.47	9.22	11.06	11.50	10.00	8.93	5.20	10.03	12.14
Takoma Gears Oyj	-4.80	1.17	6.62	9.20	12.18	9.76	8.38	16.33	17.04	17.47

Return on Equity based on net income ratio takes all cost into consideration and it tells how much profit is left to the shareholders. It also shows the ability of the company to turn net assets to profits. This is benefit criteria, the higher value for ROE the better. (Bearly & Meyers, 2003)

$$Return\ on\ equity = \frac{Net\ income}{Shareholders'equity} \qquad (26)$$

Equation 26. Return on equity (Bearly & Meyers, 2003)

Table 16. Return on equity of the companies from 2007 to 2016.

Return on equity -%	2016	2015	2014	2013	2012	2011	2010	2009	2008	2007
Ahmotuote Oy	5.28	4.96	17.81	10.39	16.55	24.17	14.08	0.89	19.37	8.62
Ata Gears Oy	-8.37	0.03	4.21	7.94	0.63	7.30	7.86	9.29	24.56	23.35
Katsa Oy	-4.12	1.76	-9.36	0.08	2.07	0.78	0.20	1.24	16.47	19.93
Kumera Drives Oy	6.76	4.76	5.39	1.67	0.30	8.19	14.39	5.75	0.92	1.34
Moventas Gears Oy	-30.41	-48.57	-40.74	-37.04	-28.94	n.s.	-88.27	-56.22	2.26	12.57
Okun Hammaspyörä Oy	0.00	0.00	0.00	0.56	1.70	8.62	8.65	3.63	46.99	42.85
SEW-Eurodrive Oy	9.95	3.05	2.89	11.47	18.66	7.20	0.30	3.33	1.13	3.02
Takoma Gears Oyj	n.s.	-363.98	-9.12	3.29	-0.11	-0.09	-0.57	3.43	5.98	0.44

Return on Asset based on net income shows the ability to turn total assets to profits. Similarly, to Return on Equity Return on Assets are important to grasp the ability of the company to use its resources efficiently. If company uses debt return on equity should be greater than return on assets. Both return on equity and return on assets should show similar results. This ratio is also benefit criteria, higher values are better. (Moyer, McGuigan, Rao & Kretlow, 2011)

$$Return\ on\ assets\ = \frac{Net\ income}{Total\ assets} \quad (27)$$

Equation 27. Return on assets (Moyer, McGuigan, Rao & Kretlow, 2011)

Table 17. Return on assets of the companies from 2007 to 2016.

Return on assets -%	2016	2015	2014	2013	2012	2011	2010	2009	2008	2007
Ahmotuote Oy	2.06	1.84	8.75	5.04	7.19	11.20	5.75	0.31	6.37	2.38
Ata Gears Oy	-5.02	0.02	2.40	4.52	0.37	4.72	5.00	5.49	14.66	13.82
Katsa Oy	-3.58	1.52	-8.26	0.08	1.85	0.70	0.18	1.10	14.11	15.96
Kumera Drives Oy	4.85	3.24	3.63	1.18	0.20	5.19	9.18	3.29	0.34	0.64
Moventas Gears Oy	-10.49	-20.11	-17.46	-19.44	-12.81	-29.73	-12.48	-3.43	0.22	2.11
Okun Hammaspyörä Oy	0.00	0.00	0.00	0.04	0.08	0.33	2.04	1.47	20.30	12.21
SEW-Eurodrive Oy	5.26	1.65	1.62	6.73	10.01	3.59	0.15	2.10	0.54	1.40
Takoma Gears Oyj	-19.42	-8.08	-0.70	0.32	-0.01	-0.01	-0.06	0.37	0.50	0.05

Profit per employee is our final profitability ratio. Similarly, to turnover per employee it shows how much profits one employee would bring. This ratio should be kept on a positive level, so the company does not need to lay off its employees. In order to improve this ratio, the company will increase profits or reduce workforce.

$$Profit\ per\ employee\ = \frac{Profit\ or\ loss\ before\ taxes}{Number\ of\ employees} \qquad (28)$$

Equation 28. Profit per employee

Table 18. Profit per employee in thousands of euros of the companies from 2007 to 2016.

Profit per employee in thousands of euros	2016	2015	2014	2013	2012	2011	2010	2009	2008	2007
Ahmotuote Oy	4.00	4.00	14.00	8.00	12.00	17.00	8.00	0.00	10.00	5.00
Ata Gears Oy	-36.00	-2.00	18.00	15.00	7.00	11.00	28.00	25.00	41.00	34.00
Katsa Oy	-5.00	4.00	-8.00	-1.00	1.00	0.00	2.00	7.00	27.00	31.00
Kumera Drives Oy	7.00	4.00	5.00	1.00	2.00	7.00	12.00	10.00	14.00	10.00
Moventas Gears Oy	-35.00	n.s.	n.a.	-52.00	-61.00	-63.00	-47.00	-14.00	72.00	33.00
Okun Hammaspyörä Oy	n.a.	n.a.	13.00	21.00	5.00	9.00	18.00	2.00	5.00	15.00
SEW-Eurodrive Oy	43.00	35.00	31.00	42.00	47.00	39.00	23.00	5.00	32.00	49.00
Takoma Gears Oyj	-14.22	-7.73	0.60	4.48	10.31	5.57	-0.11	25.55	33.50	29.56

3.3.5. Growth criteria

Fifth group of criteria are growth ratios. They exemplify the growth of the company against previous year. All companies should grow and the ones which are able to grow faster are more likely to survive. Growth also shows that the company can renew its product offering in a changing world and it can also fulfill its customers growing needs. Growth is good, so these measures are benefit type criteria.

Turnover growth shows how much the revenues have grown from the previous year. In some cases, the turnover has decreased and thus the growth has been negative. In 2009 due to the financial crisis almost every company had negative growth. This shows that the whole industry suffered instead of just one company. Growth is shown in percentages and higher percentage is better.

$$Turnover\ growth_t = \frac{Operating\ turnover_t}{Operating\ turnover_{t-1}} - 1 \qquad (29)$$

Equation 29. Turnover growth at time t.

Table 19. Turnover growth of the companies from 2008 to 2016.

Turnover growth	2016	2015	2014	2013	2012	2011	2010	2009	2008
Ahmotuote Oy	0.09	-0.10	-0.02	-0.10	0.10	0.34	0.08	-0.36	0.26
Ata Gears Oy	-0.34	-0.27	0.09	0.11	0.03	0.05	-0.11	0.02	0.17
Katsa Oy	-0.07	0.07	-0.08	-0.11	0.10	0.10	-0.41	-0.17	0.20
Kumera Drives Oy	0.12	0.06	0.09	-0.22	0.00	0.17	0.03	-0.32	0.12
Moventas Gears Oy	-0.05	-0.18	0.45	0.40	0.06	-0.31	-0.37	-0.38	0.55
Okun Hammaspyörä Oy	0.04	0.02	0.46	-0.21	-0.32	0.05	1.49	-0.42	-0.25
SEW-Eurodrive Oy	0.09	-0.04	0.00	-0.01	0.13	0.27	0.27	-0.39	0.00
Takoma Gears Oyj	-0.36	-0.11	0.10	-0.04	0.00	0.46	-0.53	-0.15	0.32

Total assets growth illustrates growth of the whole company and its balance sheet. Balance sheet can be filled up with dept to increase the growth but in all cases that is not the optimal situation. However, if the company can increase its total assets then the company would invest to new machines and new production plants. Higher growth is better in this case also.

$$Total\ assets\ growth_t = \frac{Total\ assets_t}{Total\ assets_{t-1}} - 1 \qquad (30)$$

Equation 30. Total assets growth at time t.

Table 20. Total assets growth of the companies from 2008 to 2016.

Total assets growth	2016	2015	2014	2013	2012	2011	2010	2009	2008
Ahmotuote Oy	-0.08	0.27	0.09	-0.10	0.16	0.05	-0.08	-0.15	-0.05
Ata Gears Oy	-0.26	-0.11	0.08	0.07	0.08	-0.03	0.03	0.12	0.24
Katsa Oy	-0.09	0.02	-0.08	-0.05	-0.01	-0.02	-0.08	-0.04	0.05
Kumera Drives Oy	0.00	0.02	0.09	-0.06	-0.03	0.10	0.08	-0.30	0.35
Moventas Gears Oy	-0.01	-0.10	0.05	-0.05	0.73	-0.52	-0.13	0.00	0.67
Okun Hammaspyörä Oy	-0.08	-0.01	-0.01	-0.06	-0.19	0.18	0.50	-0.08	-0.24
SEW-Eurodrive Oy	0.02	-0.04	0.07	0.04	0.15	0.10	0.22	-0.21	-0.01
Takoma Gears Oyj	-0.31	-0.26	0.00	0.25	-0.07	0.02	-0.05	-0.20	0.40

Shareholder funds growth show clearly the ability to grow the equity that belongs to the shareholders. Unlike the total assets growth this ratio can’t be jacked up with taking new debt to the company, but it requires genuine equity growth. Shareholders’ funds should grow so that the company can pay dividends to the shareholders. Likewise, higher growth leads to better outcome.

$$Shareholders'funds\ growth_t = \frac{Shareholders'equity_t}{Shareholders'equity_{t-1}} - 1 \qquad (31)$$

Equation 31. Shareholders' funds growth at time t.

Table 21. Shareholders' funds growth of the companies from 2008 to 2016.

Shareholders' funds growth	2016	2015	2014	2013	2012	2011	2010	2009	2008
Ahmotuote Oy	-0.03	-0.04	0.11	0.01	0.09	0.20	0.06	-0.08	0.13
Ata Gears Oy	-0.26	-0.06	0.08	0.03	-0.01	-0.01	0.11	0.11	0.25
Katsa Oy	-0.08	0.00	-0.10	-0.04	-0.01	-0.04	-0.05	-0.01	0.12
Kumera Drives Oy	0.06	0.03	0.04	0.01	0.01	0.10	0.20	0.08	0.05
Moventas Gears Oy	-0.18	-0.13	-0.14	0.12	5918.64	-1.00	1.01	-0.36	-0.06
Okun Hammaspyörä Oy	0.00	0.00	0.00	0.01	0.02	-0.81	-0.12	-0.14	0.16
SEW-Eurodrive Oy	-0.01	-0.07	0.02	0.13	0.24	0.07	-0.01	0.03	0.03
Takoma Gears Oyj	-5.63	-0.78	-0.21	0.03	0.00	0.00	-0.01	0.04	0.06

3.4 Analysis

This section showcases how the analysis of this research has been conducted and how the methods presented earlier are applied to real data. This part also slightly presents the results of these analyses, but proper discussion of the results is provided later in this chapter. This section is useful for proper understanding how the numbers drawn and why some companies are ranked higher than others.

3.4.1. Fuzzy AHP application with case data

Three independent experts are interviewed and asked to fill pairwise comparison matrices for main criteria group and for each of sub criteria groups. This will allow the researcher to get as objective as possible weights for the comparison criteria. Experts that are really similar would provide us with redundant data since some criteria might get too high or too low weights. Thus, the heterogeneity among experts is suggested. (Clemen & Winkler,

1999) First interviewed expert comes from one of the companies and is considered to give such weights that would represent the idea of manager or owner of the company, which ratios are more important for them than other ratios. Second expert represents creditors or banks' view of the industry. The second expert expresses thoughts what criteria are important for one who would be lending money for companies in this industry. For highly capital-intensive industry it is important being able to lend money for reasonable price. The criteria weights given by this expert would also indicate to companies which ratios they should keep their eye on if they have debt or are planning to get more debt in the future. Third and final expert represents private equity's view for the industry. This expert's weights for the criteria show how possible buyout or consolidation targets would be analyzed or which criteria would be important for assessing potential upside that the outside investor could bring up.

To derive the final weights for the criteria, each of the sub criteria weight is multiplied by the main group criteria weight. By this way the expert can assess the importance of some main group criteria and thus give them higher importance against other criteria. Other reason to split the criteria to sub groups is that smaller matrices are easier to cope with when the experts are giving weights for them. It would be hard to think how much more one criterion is important to the remaining 18 other criteria. Thus, each expert fills multiple pairwise comparison matrices which are in the end combined for final weights. Pairwise comparison matrices for main criteria group and sub criteria are presented in appendix 1. for each expert. From these three, different experts' opinions a fuzzy comparison matrix is composed by using equation 7. Fussy comparison matrices for each criteria group is shown in appendix 2.

From each of the matrices, synthetic values are calculated by using equation 8 and are shown in appendix 3. These matrices are used to compare what is the degree of possibility that first fuzzy number is equal or greater than the second. If the modal value of the first triangular fuzzy number is greater than the modal value of the second triangular fuzzy number, then the degree of probability that the first fuzzy number is greater than the second fuzzy number is one. Otherwise it is calculated with equation 10. Synthetic values are shown in appendix 3.

The degree possibility that the fuzzy numbers are greater than their counterparts are needed for weight determination. They are calculated with equation 11. For each criterion group the degrees are shown in appendix 4.

Non-Normalized weight vector is derived by taking the minimum value of each degree possibility group that the fuzzy numbers were compared. Normalization is done via equation 1 and the normalized criteria weights are presented below (see table 22.) for each criteria group.

Table 22. Normalized weights of each criteria

Criteria group	Criteria	Weight
Main group	Financial leverage	0.224887
Main group	Liquidity	0.108346
Main group	Management	0.17761
Main group	Profitability	0.254878
Main group	Growth	0.234279
Financial leverage	Debt ratio	0.411481
Financial leverage	Assets/Shareholders equity	0.373094
Financial leverage	Fixed assets / shareholders' equity	0.215424
Liquidity	Quick Ratio	0.370996
Liquidity	Current Ratio	0.188191
Liquidity	Cash ratio	0.440813
Management	Credit period days	0.267178
Management	Collection period days	0.281058
Management	Inventory turnover	0.322214
Management	Total assets per employee	0.144939
Management	Operating revenue per employee	-0.01539
Profitability	Cash flow per operating revenue	0.285686
Profitability	EBITDA margin	0.28209
Profitability	Return on equity	0.265355
Profitability	Return on assets	0.240133
Profitability	Profit per employee	-0.07326
Growth	Turnover growth	0.60041
Growth	Total assets growth	-0.01771
Growth	Shareholders' funds growth	0.417295

Then to get final weights, each sub criterion groups weight is multiplied with their respective main criteria group weight.

Table 23. Final weights for criteria.

Criteria group	Criteria	Final weight
Financial leverage	Debt ratio	0.092536844
Financial leverage	Assets/Shareholders equity	0.08390407
Financial leverage	Fixed assets / shareholders' equity	0.048446147
Liquidity	Quick Ratio	0.040195815
Liquidity	Current Ratio	0.020389727
Liquidity	Cash ratio	0.047760246
Management	Credit period days	0.047453421
Management	Collection period days	0.049918668
Management	Inventory turnover	0.057228442
Management	Total assets per employee	0.02574258
Management	Operating revenue per employee	-0.002733144
Profitability	Cash flow per operating revenue	0.072815152
Profitability	EBITDA margin	0.071898578
Profitability	Return on equity	0.067633232
Profitability	Return on assets	0.061204532
Profitability	Profit per employee	-0.018673437
Growth	Turnover growth	0.140663494
Growth	Total assets growth	-0.004147928
Growth	Shareholders' funds growth	0.09776356

These normalized weights are then used for the TOPSIS method to stress the importance of specific criteria over others.

3.4.2. TOPSIS application with case data

TOPSIS part of the methodology explains how the theory is implemented in this thesis. TOPSIS provides ranking of the alternatives after all the weighted criteria are considered. The method compares each alternative's distance to the positive ideal solution and to the negative ideal solution and selects the best alternative which has shortest distance to the positive solution and is farthest away from the negative solution.

First step is to normalize each of the criteria via equation 1. Criteria for TOPSIS were presented in the data part of this research. Normalized values are multiplied with the criteria weight derived by Fuzzy AHP method explained above. After the criteria are properly normalized and weighed positive ideal solution and negative ideal solution are calculated. These numbers are calculated as follows. Positive ideal solution takes the maximum values of the benefit type criteria and minimum value for cost type criteria. The positive ideal solution is thus composed from the best values that any alternative has gotten from each criterion. Negative ideal solution is the opposite; the maximum values are taken from the cost type criteria and minimum values from benefit type criteria. Positive ideal solution is calculated with equation 2 and negative ideal solution is calculated with equation 3. Both positive and negative ideal solutions for each year are given in appendix 5.

After the positive and negative ideal solutions are derived the distance for each criterion per each company are calculated. It takes distances of each criteria from both ideal solutions and then combines them to the final distance from each solution. Distance from ideal solution is calculated with equation 4 and distance from negative ideal solution is derived by equation 5. Distances are shown in appendix 6 for each year. From the figures in appendix 6 the companies are in some cases distributed evenly between the best and worst company and for some cases, especially in years 2009, 2011, 2013 and 2016 the worst performer is really far away from the rest of the companies.

After the distances are solved the Closeness Coefficient is calculated with equation 6. Closeness coefficient is for each company and shows in one figure the same as the graphs above. Finally, the companies are ranked based on the closeness coefficient. Closeness coefficients and ranks are shown in appendix 7.

To illustrate how the rankings have changed during the years the following figure show the ranks for each year. The ranks have been ordered ascending so that the best rank is highest on the figure.

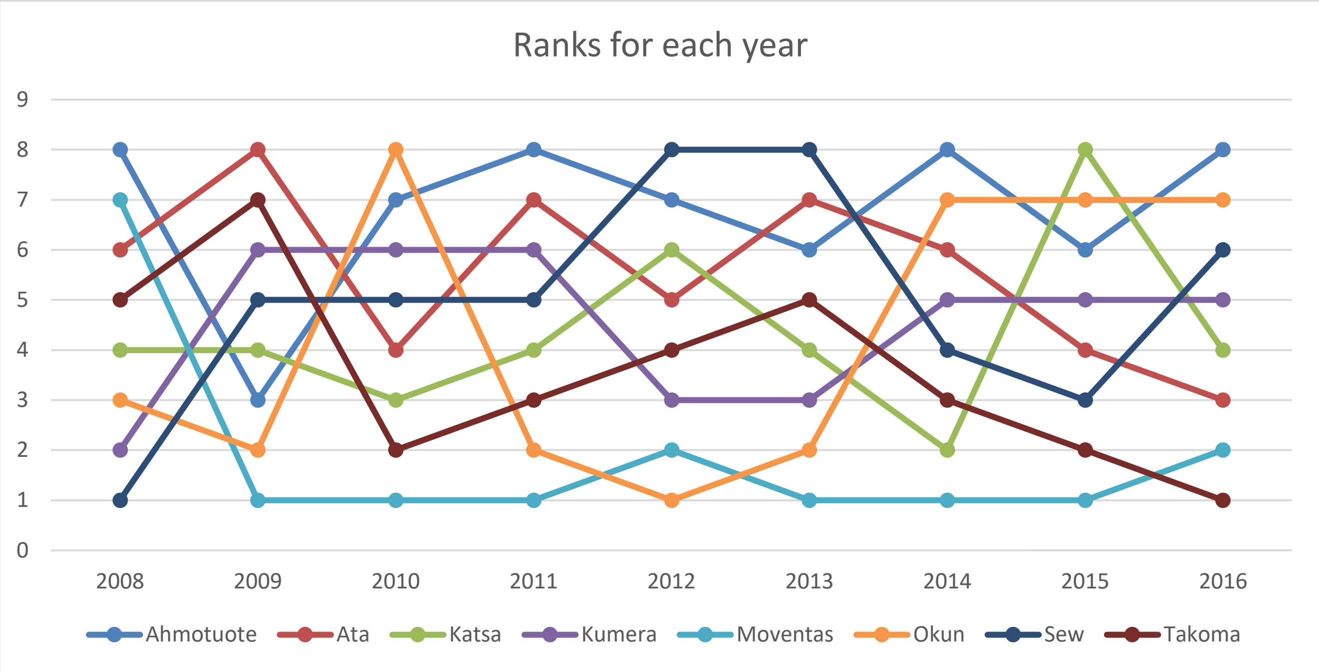

Figure 22. TOPSIS ranks for each year.

From the figure above, we can see that there are some substantial shifts in the rankings that the companies have had. The changes illustrate that the company has been worse or better than the competitors. Increase, or decrease, in the rank does not tell anything on the real performance, only relative to peers.

3.5. Results

In this final section the results are presented concisely. From the weights it is evident that the most important main criteria groups were profitability, growth and financial leverage. Liquidity ratios were the least important among the main criteria. The most important criteria come however from growth and financial leverage groups. Turnover growth is the most important individual criteria with 14 percent weight and then is shareholders asset growth with 9,7%, third most important criteria is the debt ratio and fourth is assets to shareholders funds. This is explained by the fact that in both growth and financial leverage groups the other criteria were evaluated to be significantly less important thus the two received greater weights in their respective groups. In profitability group four out of five criteria were valued at almost equal weights thus no one single criterion was pushed upwards as in growth and financial leverage groups. Every expert stressed that per employee criteria were useless and therefore they are the least important criteria. This means that the aforementioned criteria drive towards better performance ranks. Companies which have been successful in those criteria were the better performers.

Profitability and turnover growth measures tend to be good as there is little one can do to manipulate them, which is the case with balance sheet figures. Also, turnover growth and profitability figures are not that much time dependent than the balance sheet figures. For example, two companies which are equally good but differ slightly in that the other one gets paid at the end of the year whereas the other just the day after closing books. Then when looking at the balance sheet the first of the two companies presents more money in the sheets than the other and thus it would be considered better performer due to higher liquidity. Similarly, with the shareholders equity can be affected by the dividend needs of the owners, two equally good companies of which other pays all excess capital to shareholders and other just keeps it in balances, the latter would be considered better. For such reasons the criteria selection should focus on measures which do need little adjustments and are as little as possible vulnerable for biases and manipulation. It should also be noted that these criteria are not that suitable to evaluate the business potential going forward and quite often it is more interesting to know, who is going to be better tomorrow rather than who was the best yesterday.

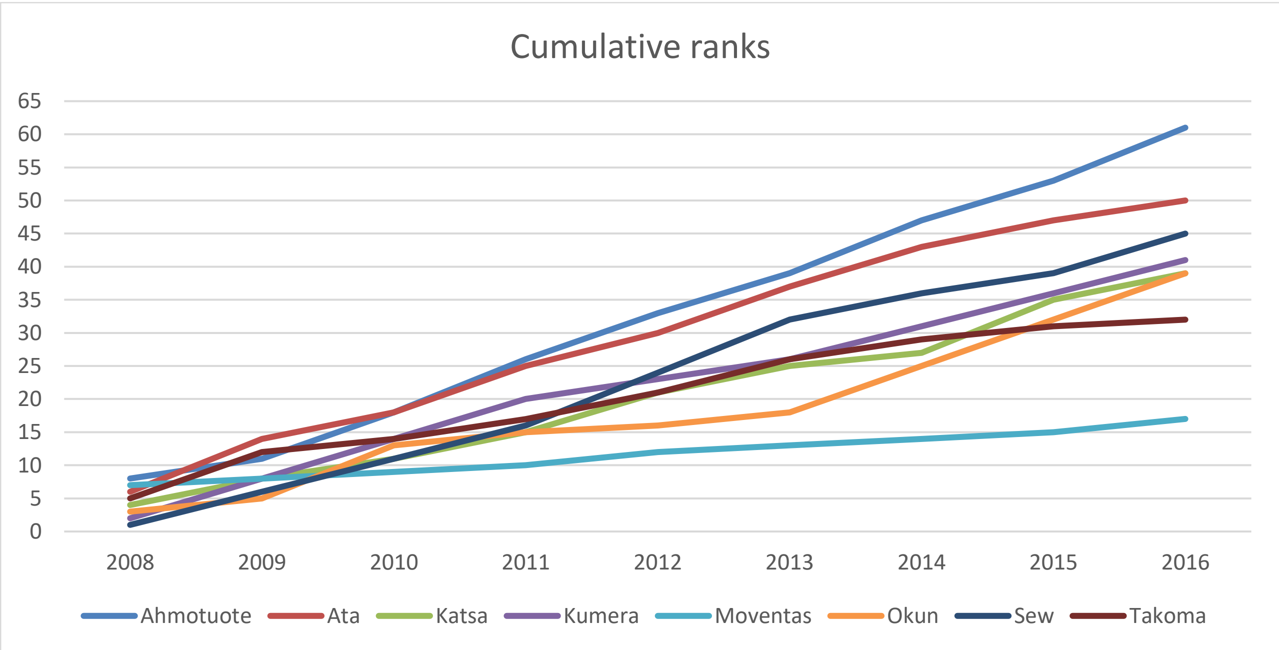

Figure 23. Cumulative ranks where higher value is better.

Cumulative ranks (see figure 23.) are calculated by taking the rank in descending order (higher value is better) and then adding next year’s rank to the previous one by assigning equal weight for each year. This shows how the rank difference widens for certain companies. It also shows the disadvantage of ranks from previous years, as previous performance is carried over. For example, Ata Gears Oy seems to have second best position in Figure 23, but when looking at Figure 22, we can see that for the last year it was only in the sixth place.

However, the ranks show the performance of the companies when compared against each other and with the ranks it is evident that clear ranking was established. When looking how the companies are ranked against each other we can see that some companies tend to be ranked better over time. For example, Ahmotuote Oy, which was ranked best in the beginning was also best in the last year of the period. The company was ranked four times out of nine the best and other times third or second. Second best ranked company is Ata Gears Oy. Ata had good rankings until 2014 and after that the ranking has declined. This goes in line with its significant decline of turnover during the last two years. Third best company is Sew-Eurodrive. It started with worst rank and for two years, between 2012 and 2013, it was ranked the best and for last year it was on third place. Reasons for the better ranking is their solid performance throughout the period, excluding the two final years of Ata Gears. Ahmotuote Oy has been profitable for the whole period and so has been Sew Eurodrive. The impacts of financial crisis had an effect for all of the companies in 2009 and thus it did not worsen any single company compared to their peers. For the poor performers reasons lie in poor profitability and decline in sales. Moventas Gears Oy started off with second best rank, and 2008 their figures were really good, but then due to decline in wind power plant investments their sales have declined for three straight years. Similarly, their profitability has plummeted to the negative and after 2009 they have made staggering 190 million euros in losses. It is worth to note that Moventas Gears Oy has filed for bankruptcy within this time period, but it was restored by their current owner. Takoma Gears Oyj, which bankrupted in 2017 had steady decline in rank from 2013 until 2016 when it was the worst performer. As anticipated they started to have lower performance ranks when their business was facing troubles. Also, their thin equity was not able to withstand their last two unprofitable years.

From the figures that describe the negative ideal solutions and positive ideal solutions for each year we can see that in most cases the companies are distributed evenly on a line between the worst and the best performer. However, in some cases companies seem to cluster closer together having one significant outlier either in positive or in the negative end. In most cases the negative outlier was Moventas Gears Oy. This is due to huge losses the company has accrued. Clustering of the companies can also be seen from the Closeness Coefficient figures of which the ranks were derived. The Closeness Coefficient figures describe how significant the difference in performance really is. The rank does not clearly describe the significance of the differences between performance as it merely gives the ranks (See Appendix 6.). If closeness coefficients are turned into percentages of total closeness coefficient sum for each year we can see more clearly the clustering. In table 24. below the percentage figures are shown.

Table 24. Closeness coefficient percentages of yearly total closeness coefficient value.

	2008	2009	2010	2011	2012	2013	2014	2015	2016
Ahmotuote	22 %	13 %	15 %	18 %	17 %	16 %	20 %	16 %	19 %
Ata	18 %	19 %	12 %	14 %	13 %	16 %	16 %	12 %	9 %
Katsa	13 %	13 %	9 %	13 %	15 %	12 %	7 %	16 %	12 %
Kumera	2 %	14 %	14 %	14 %	11 %	12 %	15 %	14 %	17 %
Moventas	18 %	2 %	5 %	2 %	10 %	3 %	2 %	6 %	8 %
Okun	12 %	12 %	24 %	11 %	6 %	12 %	17 %	16 %	18 %
Sew	2 %	13 %	13 %	14 %	17 %	16 %	13 %	12 %	17 %
Takoma	13 %	15 %	8 %	13 %	12 %	13 %	9 %	8 %	0 %

If the companies would be equally good, then the changes in percentages would be rather small. In our case this is not happening as the changes in percentages are rather large and illustrate clear groups. For example, in year 2008 Ahmotuote Oy was solely the best, but then Ata Gears Oy and Moventas Gears Oy were together at the second place. Katsa Oy, Okun Hammaspyörä Oy and Takoma Oyj were then on the third place all together leaving the rest at the bottom. The yearly fluctuation of closeness coefficient percentage can be seen from figure 24 below.

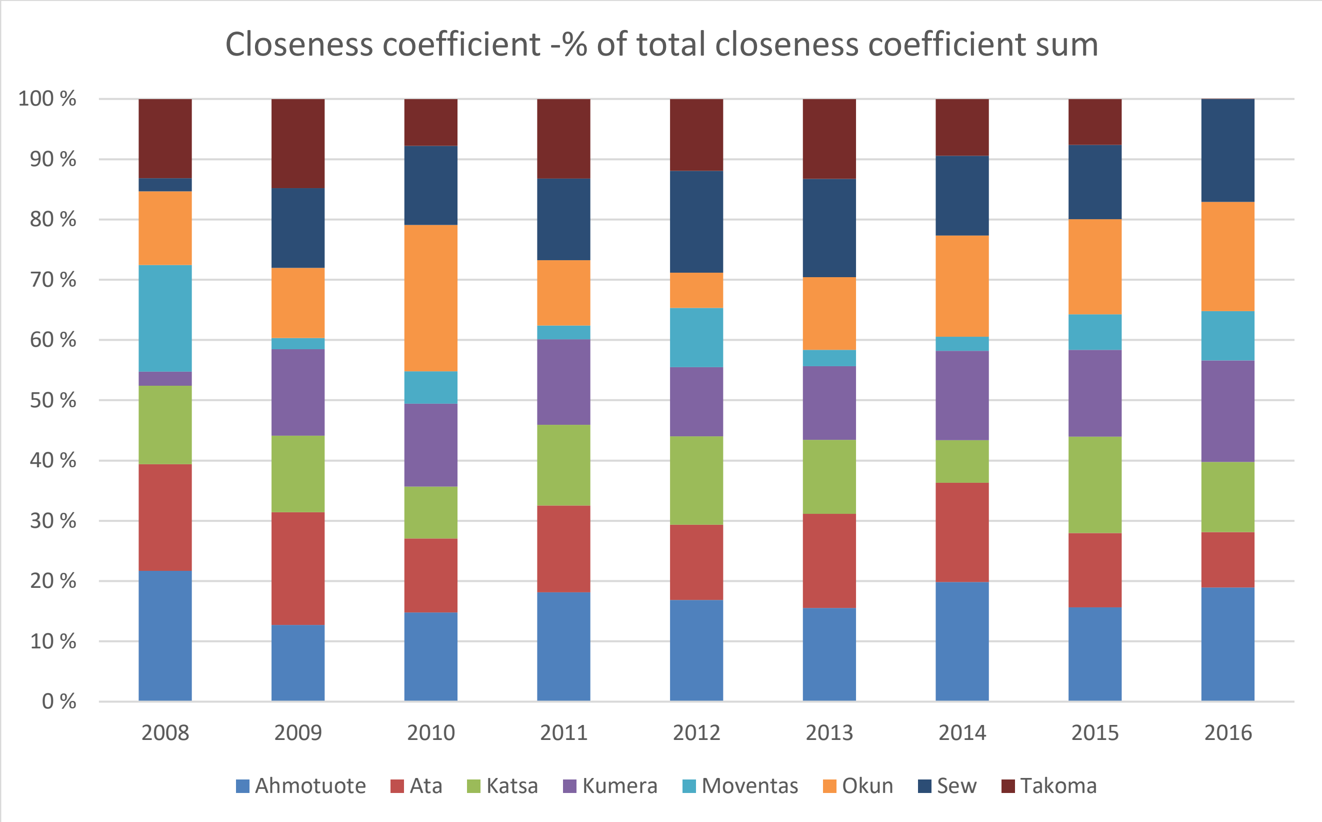

Figure 24. Closeness coefficient -% of total yearly closeness coefficient sum.

From the figure 24 we can see that some companies tend to have relative stable figures whereas some companies' percentage share changes quite substantially year over year. Changes reflect the financial performance and due to high correlation of financial figures, increases or decreases in either turnover growth or profitability has great impact on other financial figures as well. If a company faces strong decline in their sales they can have hard time to adjust their costs to that decline, and in capital intensive business as this kind of manufacturing is, strong decline in sales is almost a synonym for unprofitable year.

4. Conclusions

This chapter concludes the thesis. It summarizes what this thesis has focused on and what are the main research findings of this research. It presents the limitations that are imposed on the research and suggest how future researchers could overcome those limitations. Also, suggestions for future research are given in this chapter. Implications for the industry are presented to provide interesting thoughts and lessons learned for the managers within the industry.

4.1. Answers to the research questions

Research questions for this thesis were: *“How AHP and TOPSIS combination can be used to compare companies based on their financial statements?”, “What different multiple expert multiple criteria methods there are?”, “Which criteria weights are relevant for analysis purposes?”, “What are the main reasons for better performance when compared to competitors?”.* Each answer to these question is now recapped separately as follow.

How AHP and TOPSIS combination can be used to compare companies based on their financial statements?

Companies can be compared using combination of AHP and TOPSIS as was presented in the case of this thesis. There is previous research where such combination was used in different settings and this thesis provides fresh target, Finnish mechanical power transmission industry, where to utilize this decision tool. As can be found in the case results companies do differ from each other when their performance was analyzed with the methods of this research. Some companies were consistently ranked better than others and some had constantly poor performance. Ahmotuote Oy was the best performer among the companies and Ata Gears was the second best whereas Moventas Gears had worst performance ranks. As there is no similar previous research on target companies, or this industry in Finland, it is not possible to compare these results to earlier results. However, similar topics have been researched and according to other researchers’ findings, company rankings tend to be quite unanimous that there is clear rank of companies. This goes according to common logic that some alternatives are better than others and if dug deeper there are clear reasons for the better performance. (Ertugrul & Karakasoglu, 2009, Baourakis, Doumpos, Kalogeras & Zopounidis, 2002 & Chou & Liang, 2001)

What different multiple expert multiple criteria methods there are?

There are vast number of different multiple expert multiple criteria decision-making methods. Methods can be categorized roughly based on the logic they use to rank alternatives. Despite different logics results should not significantly change from method to method as quite often better alternatives are simply better. Some significant methods are Standard AHP, VIKOR, Promethee and Electre. More extensive analysis of different methods was made by Zavadskas and Turskis in 2011.

Which criteria weights are relevant for analysis purposes?

Most relevant criteria for analysis purpose are criteria that are hard to manipulate and are not dependent on specific period. Such are turnover, or profitability related as different financial structures have minimal impact on those whereas balance sheet figures can be manipulated by management. Similarly, two equally good companies of which the second pays dividends would have worse balance sheet than the first. Companies should be analyzed as a whole and single criterion should not have too high impact. Weights for analysis are always unique to the specific research, however, similar trends between researches can be identified. These are tied to industry types as for example for a service industry capital adequacy is not as critical as it is for a banking industry. For example, when Turkish cement firms were analyzed more emphasis were given for profitability and growth ratios similarly as in this research. (Ertugrul & Karakasoglu, 2009 and Yalcin, Bayrakdaroglu & Kahraman, 2012)

What are the main reasons for better performance when compared to competitors?

Reasons for poor performance ranking are significant declines in turnover growth and profitability. Conversely good ranking is awarded to companies which manage to stay more profitable and have lower fluctuations in their turnover than their peers. Good ranking compared to peers does not automatically indicate good financial performance, it is just better than what others had. As stated earlier, previous research has not been conducted to the target companies, thus the earlier findings have to be taken in a more general level. In similar research for different industries, the reasons for better performance have been in better profitability of the companies (Akhisar & Tunay, 2015). When assessing quite similar companies the reasons for better ranking can be absurd and controversial, but when the analysis takes more alternatives, more clear reasons will emerge.

4.2. Lessons learned & implications for the industry

Achieving good ranking among peers is not a main objective for any manager of a company. However, good financial performance is transformed to better ranking against competitors. Thus, the reasons for good ranking are more interesting than the sole ranking. It should not come as a surprise to management that good profitability drives any analysis where companies are compared together. In times when turnover declines it is important to adjust operations to the new situation. Companies which succeed in this will perform better in rankings. Consistency in the rankings is due to more stable financials, huge declines will surely bring company down in the ranking if competitors are able to keep their declines smaller. If company is relying more on debt financing its management should take care that they have, in any situation, sufficient cash flows to service their interest payments. Strong balance sheet alone is not helpful if it is not easily converted to cash which is the case in the industry.

Every manager should keep an eye on their competitors and analysis provided in this thesis can be used as a proxy to see if the managerial actions have led to better performance than competitors have. However, such analysis should only be used as a stepping stone and further analysis is needed to say what are the main reasons for better performance. Reasons can be hard to find as profit and loss statements do not tell why the sales declined or rose and thus analysis of the markets and product range of companies needs to be analyzed.

4.3. Limitations of the study

Eight biggest companies in the Finnish Mechanical Power Transmission industry by revenue were selected for this research. Some of the companies have subsidiaries in other countries but only their Finnish entities were evaluated. This is noted as a potential threat to validity of this research as the companies can conduct internal outsourcing and have synergies which would not be there if the companies evaluated would be totally independent. Similar problem may arise as the companies can have for example support functions which are operated from the group management and their costs are not in the income statements of the power transmission line of businesses, which were studied here. The criteria weights that were derived from the experts can also be biased and subjective for subjective reasoning. For example, one expert may not have such a strong preference for the criteria whereas other expert can have strong preference towards some criteria, thus the aggregated weight given for this criterion will lean towards the expert which had more stronger opinions. Not every financial criteria was used for this research and some of the criteria might not be suitable for evaluating of the companies. Thus, huge assumption is made that the companies are quite similar which in real life is far from the truth. Rankings done in this way do not contemplate the real performance and thus in some cases poor company can get a good rank for being just slightly better from its usual awfulness.

4.4. Suggestions for future research

Much thorough analysis is needed to examine the companies and their real performance including more than financial figures. For example, the different segmentation to different industries should be taken into consideration and data should be adjusted so that every company would be at the peak of their industrial cycle are the same time. True management capability and operational potential of the companies and their employees is not analyzed here. It could show that some companies are more resilient to technological advantages and are able to adapt to upcoming situations better thus having more stronger foundations to survive and create value over time. As the Multi Criteria Decision Making methods increase constantly one could conduct similar research with different methods to compare how the results would change regarding the method used. A model that constantly analyzes the companies and industry would also be interesting in which the most recent financial data would be analyzed and update the rankings based on new information.

As the scope of this research was only in Finland and it limited the number of companies one can study, it would be beneficial to increase the scope to European or to a global scale. Thus, more accurate peers could be identified, and it could be analyzed whether companies from specific geographic area have tendency for better performance. As described in the results section, the usage of ranks does not clearly describe the significance of difference between the companies’ performance. From the negative ideal solutions and positive ideal solutions, the groupings showcase that in some cases some of the companies are really close to each other. One could thus use some method which would give equal weight for similar performers.

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Appendices

Appendix 1. Experts inputs on pairwise comparison matrices

Expert 1		C1	C2	C3	C4	C5
Financial leverage	C1	1	3	4	0.142	0.142
Liquidity	C2	0.333	1	2	0.2	0.2
Management	C3	0.25	0.5	1	0.11	0.11
Profitability	C4	7	5	9	1	1
Growth	C5	7	5	9	1	1

Appendix 1.1. Main criterion group for expert 1

Expert 1		F1	F2	F3
Debt ratio	F1	1	4	2
Assets/Shareholders equity	F2	0.25	1	0.5
Fixed assets / shareholders' equity	F3	0.5	2	1

Appendix 1.2. Financial leverage criteria for expert 1

Expert 1		L1	L2	L3
Quick Ratio	L1	1	2	3
Current Ratio	L2	0.5	1	0.333
Cash ratio	L3	0.333	3	1

Appendix 1.3. Liquidity criteria for expert 1

Expert 1		M1	M2	M3	M4	M5
Credit period days	M1	1	1	0.142	3	2
Collection period days	M2	1	1	0.142	3	2
Inventory turnover	M3	7	7	1	9	9
Total assets per employee	M4	0.333	0.333	0.11	1	0.5
Operating revenue per employee	M5	0.5	0.5	0.11	2	1

Appendix 1.4. Management criteria for expert 1

Expert 1		P1	P2	P3	P4	P5
Cash flow per operating revenue	P1	1	0.3333	0.3333	0.5	9
EBITDA margin	P2	3	1	0.2	0.25	9
Return on equity	P3	3	5	1	2	9
Return on assets	P4	2	4	0.5	1	9
Profit per employee	P5	0.11	0.11	0.11	0.11	1

Appendix 1.5. Profitability criteria for expert 1

Expert 1		G1	G2	G3
Turnover growth	G1	1	5	3
Total assets growth	G2	0.2	1	0.333
Shareholders' funds growth	G3	0.333	3	1

Appendix 1.6. Growth criteria for expert 1

Expert 2		C1	C2	C3	C4	C5
Financial leverage	C1	1	9	7	0.142	9
Liquidity	C2	0.11	1	0.2	0.11	0.11
Management	C3	0.142	5	1	0.125	0.125
Profitability	C4	7	9	8	1	1
Growth	C5	0.11	9	8	1	1

T Appendix 1.7. Main criterion group for expert 2

Expert 2		F1	F2	F3
Debt ratio	F1	1	1	9
Assets/Shareholders equity	F2	1	1	9
Fixed assets / shareholders' equity	F3	0.11	0.11	1

Appendix 1.8. Financial leverage criteria for expert 2

Expert 2		L1	L2	L3
Quick Ratio	L1	1	1	0.333
Current Ratio	L2	1	1	0.333
Cash ratio	L3	3	3	1

Appendix 1.9. Liquidity criteria for expert 2

Expert 2		M1	M2	M3	M4	M5
Credit period days	M1	1	0.333	0.333	9	9
Collection period days	M2	3	1	1	9	9
Inventory turnover	M3	3	1	1	9	9
Total assets per employee	M4	0.11	0.11	0.11	1	1
Operating revenue per employee	M5	0.11	0.11	0.11	1	1

Appendix 1.10. Management criteria for expert 2

Expert 2		P1	P2	P3	P4	P5
Cash flow per operating revenue	P1	1	1	5	2	9
EBITDA margin	P2	1	1	7	5	9
Return on equity	P3	0.2	0.142	1	5	9
Return on assets	P4	0.5	0.2	0.2	1	9
Profit per employee	P5	0.11	0.11	0.11	0.11	1

Appendix 1.11. Profitability criteria for expert 2

Expert 2		G1	G2	G3
Turnover growth	G1	1	9	9
Total assets growth	G2	0.11	1	0.5
Shareholders’ funds growth	G3	0.11	2	1

Appendix 1.12. Growth criteria for expert 2

Expert 3		C1	C2	C3	C4	C5
Financial leverage	C1	1	0.333	0.2	0.25	1
Liquidity	C2	3	1	0.333	0.25	1
Management	C3	5	3	1	0.333	3
Profitability	C4	4	4	3	1	3
Growth	C5	1	1	0.333	0.333	1

Appendix 1.13. Main criterion group for expert 3

Expert 3		F1	F2	F3
Debt ratio	F1	1	3	5
Assets/Shareholders equity	F2	0.333	1	4
Fixed assets / shareholders' equity	F3	0.2	0.25	1

Appendix 1.14. Financial leverage criteria for expert 3

Expert 3		L1	L2	L3
Quick Ratio	L1	1	3	0.2
Current Ratio	L2	0.333	1	0.2
Cash ratio	L3	5	5	1

Appendix 1.15. Liquidity criteria for expert 3

Expert 3		M1	M2	M3	M4	M5
Credit period days	M1	1	3	0.2	9	9
Collection period days	M2	0.333	1	4	9	9
Inventory turnover	M3	5	0.25	1	9	9
Total assets per employee	M4	0.11	0.11	0.11	1	9
Operating revenue per employee	M5	0.11	0.11	0.11	0.11	1

Appendix 1.16. Management criteria for expert 3

Expert 3		P1	P2	P3	P4	P5
Cash flow per operating revenue	P1	1	7	7	8	9
EBITDA margin	P2	0.142	1	6	6	9
Return on equity	P3	0.142	0.16	1	2	9
Return on assets	P4	0.125	0.16	0.5	1	9
Profit per employee	P5	0.11	0.11	0.11	0.11	1

Appendix 1.17. Profitability criteria for expert 3

Expert 3		G1	G2	G3
Turnover growth	G1	1	7	4
Total assets growth	G2	0.142	1	0.142
Shareholders' funds growth	G3	0.25	7	1

Appendix 1.18. Growth criteria for expert 3

Appendix 2. Fuzzy comparison matrices

	C1	C2	C3	C4	C5
C1	(1, 1, 1)	(0.33, 4.11, 9)	(0.2, 3.73, 7)	(0.14, 0.18, 0.25)	(0.14, 3.38, 9)
C2	(0.11, 1.15, 3)	(1, 1, 1)	(0.2, 0.84, 2)	(0.11, 0.19, 0.25)	(0.11, 0.44, 1)
C3	(0.14, 1.8, 5)	(0.5, 2.83, 5)	(1, 1, 1)	(0.11, 0.19, 0.33)	(0.11, 1.08, 3)
C4	(4, 6, 7)	(4, 6, 9)	(3, 6.66, 9)	(1, 1, 1)	(1, 1.67, 3)
C5	(0.11, 2.7, 7)	(1, 5, 9)	(0.33, 5.78, 9)	(0.33, 0.78, 1)	(1, 1, 1)

Appendix 2.1. Fuzzy comparison matrix of main criteria group

	F1	F2	F3
F1	(1, 1, 1)	(1, 2.67, 4)	(2, 5.33, 9)
F2	(0.25, 0.53, 1)	(1, 1, 1)	(0.5, 4.5, 9)
F3	(0.11, 0.27, 0.5)	(0.11, 0.79, 2)	(1, 1, 1)

Appendix 2.2. Fuzzy comparison matrix of financial leverage criteria

	L1	L2	L3
L1	(1, 1, 1)	(1, 2, 3)	(0.2, 1.18, 3)
L2	(0.33, 0.61, 1)	(1, 1, 1)	(0.2, 0.29, 0.33)
L3	(0.33, 2.78, 5)	(3, 3.67, 5)	(1, 1, 1)

Appendix 2.3. Fuzzy comparison matrix of liquidity criteria

	M1	M2	M3	M4	M5
M1	(1, 1, 1)	(0.33, 1.44, 3)	(0.14, 0.23, 0.33)	(3, 7, 9)	(2, 6.67, 9)
M2	(0.33, 1.44, 3)	(1, 1, 1)	(0.14, 1.71, 4)	(3, 7, 9)	(2, 6.67, 9)
M3	(3, 5, 7)	(0.25, 2.75, 7)	(1, 1, 1)	(9, 9, 9)	(9, 9, 9)
M4	(0.11, 0.19, 0.33)	(0.11, 0.19, 0.33)	(0.11, 0.11, 0.11)	(1, 1, 1)	(0.5, 3.5, 9)
M5	(0.11, 0.24, 0.5)	(0.11, 0.24, 0.5)	(0.11, 0.11, 0.11)	(0.11, 1.04, 2)	(1, 1, 1)

Appendix 2.4. Fuzzy comparison matrix of management criteria

	P1	P2	P3	P4	P5
P1	(1, 1, 1)	(0.33, 2.78, 7)	(0.33, 4.11, 7)	(0.5, 3.5, 8)	(9, 9, 9)
P2	(0.14, 1.38, 3)	(1, 1, 1)	(0.2, 4.4, 7)	(0.25, 3.75, 6)	(9, 9, 9)
P3	(0.14, 1.11, 3)	(0.14, 1.77, 5)	(1, 1, 1)	(2, 3, 5)	(9, 9, 9)
P4	(0.13, 0.88, 2)	(0.17, 1.46, 4)	(0.2, 0.4, 0.5)	(1, 1, 1)	(9, 9, 9)
P5	(0.11, 0.11, 0.11)	(0.11, 0.11, 0.11)	(0.11, 0.11, 0.11)	(0.11, 0.11, 0.11)	(1, 1, 1)

Appendix 2.5. Fuzzy comparison matrix of profitability criteria

	G1	G2	G3
G1	(1, 1, 1)	(5, 7, 9)	(3, 5.33, 9)
G2	(0.11, 0.15, 0.2)	(1, 1, 1)	(0.14, 0.33, 0.5)
G3	(0.11, 0.23, 0.33)	(2, 4, 7)	(1, 1, 1)

Appendix 2.6. Fuzzy comparison matrix of growth criteria

Main criteria group	l	m	u
S1	0.017518918	0.208425573	1.250283511
S2	0.014767255	0.060771344	0.345316398
S3	0.017962241	0.115932752	0.682694489
S4	0.125200642	0.358466914	1.381265593
S5	0.026752274	0.256403418	1.286005897

Appendix 2.7. Synthetic values of main criteria group

Financial leverage	l	m	u
S1	0.03852327	0.151228229	0.666817873
S2	0.01685393	0.101285573	0.523928328
S3	0.011771	0.034570898	0.166704468

Appendix 2.8. Synthetic values of financial leverage criteria

Liquidity	l	m	u
S1	0.021187801	0.070199771	0.33340894
S2	0.014767255	0.03192596	0.11113631
S3	0.041733547	0.125090017	0.52392833

Appendix 2.9. Synthetic values of liquidity criteria

Management	l	m	u
S1	0.062371	0.274505	1.063733
S2	0.062371	0.299523	1.238376
S3	0.214286	0.449484	1.571785
S4	0.017657	0.083705	0.513344
S5	0.013911	0.044186	0.195812

Appendix 2.10. Synthetic values of management criteria

Profitability	l	m	u
S1	0.107544	0.342597	1.524155
S2	0.102018	0.328181	1.238376
S3	0.118321	0.266903	1.095487
S4	0.101043	0.213913	0.785892
S5	0.013911	0.024271	0.068799

Appendix 2.11. Synthetic values of profitability criteria

Growth	l	m	u
S1	0.086677	0.224042	0.904967
S2	0.012077	0.024814	0.080971
S3	0.029963	0.087905	0.396915

Appendix 2.12. Synthetic values of growth criteria

Appendix 3. Synthetic values

Main criteria group	l	m	u
S1	0.017518918	0.208425573	1.250283511
S2	0.014767255	0.060771344	0.345316398
S3	0.017962241	0.115932752	0.682694489
S4	0.125200642	0.358466914	1.381265593
S5	0.026752274	0.256403418	1.286005897

Appendix 3.1. Synthetic values of main criteria group

Financial leverage	l	m	u
S1	0.03852327	0.151228229	0.666817873
S2	0.01685393	0.101285573	0.523928328
S3	0.011771	0.034570898	0.166704468

Appendix 3.2. Synthetic values of financial leverage criteria

Liquidity	l	m	u
S1	0.021187801	0.070199771	0.33340894
S2	0.014767255	0.03192596	0.11113631
S3	0.041733547	0.125090017	0.52392833

Appendix 3.3. Synthetic values of liquidity criteria

Management	l	m	u
S1	0.062371	0.274505	1.063733
S2	0.062371	0.299523	1.238376
S3	0.214286	0.449484	1.571785
S4	0.017657	0.083705	0.513344
S5	0.013911	0.044186	0.195812

Appendix 3.4. Synthetic values of management criteria

Profitability	l	m	u
S1	0.107544	0.342597	1.524155
S2	0.102018	0.328181	1.238376
S3	0.118321	0.266903	1.095487
S4	0.101043	0.213913	0.785892
S5	0.013911	0.024271	0.068799

Appendix 3.5. Synthetic values of profitability criteria

Growth	l	m	u
S1	0.086677	0.224042	0.904967
S2	0.012077	0.024814	0.080971
S3	0.029963	0.087905	0.396915

Appendix 3.6. Synthetic values of growth criteria

Appendix 4. Degrees of possibilities of fuzzy number being greater than other one

V(S1 >= S2) = 1, V(S1 >= S3) = 1, V(S1 >= S4) = 0.88, V(S1 >= S5) = 0.96

V(S2 >= S1) = 0.69, V(S2 >= S3) = 0.86, V(S2 >= S4) = 0.43, V(S2 >= S5) = 0.62

V(S3 >= S1) = 0.88, V(S3 >= S2) = 1, V(S3 >= S4) = 0.7, V(S3 >= S5) = 0.82

V(S4 >= S1) = 1, V(S4 >= S2) = 1, V(S4 >= S3) = 1, V(S4 >= S5) = 1

V(S5 >= S1) = 1, V(S5 >= S2) = 1, V(S5 >= S3) = 1, V(S5 >= S4) = 0.92

For financial leverage criteria the degrees are:

V(S1 >= S2) = 1, V(S1 >= S3) = 1

V(S2 >= S1) = 0.91,V(S2 >= S3) = 1

V(S3 >= S1) = 0.52, V(S3 >= S2) = 0.69

For liquidity criteria the degrees are:

V(S1 >= S2) = 1, V(S1 >= S3) = 0.84

V(S2 >= S1) = 0.7,V(S2 >= S3) = 0.43

V(S3 >= S1) = 1, V(S3 >= S2) = 1

For management criteria the degrees are:

V(S1 >= S2) = 0.98, V(S1 >= S3) = 0.83, V(S1 >= S4) = 1, V(S1 >= S5) = 1

V(S2 >= S1) = 1, V(S2 >= S3) = 0.87, V(S2 >= S4) = 1, V(S2 >= S5) = 1

V(S3 >= S1) = 1, V(S3 >= S2) = 1, V(S3 >= S4) = 1, V(S3 >= S5) = 1

V(S4 >= S1) = 0.7, V(S4 >= S2) = 0.68, V(S4 >= S3) = 0.45, V(S4 >= S5) = 1

V(S5 >= S1) = 0.37, V(S5 >= S2) = 0.34, V(S5 >= S3) = -0.05, V(S5 >= S4) = 0.82

For profitability criteria the degrees are:

V(S1 >= S2) = 1, V(S1 >= S3) = 1, V(S1 >= S4) = 1, V(S1 >= S5) = 1

V(S2 >= S1) = 0.99, V(S2 >= S3) = 1, V(S2 >= S4) = 1, V(S2 >= S5) = 1

V(S3 >= S1) = 0.93, V(S3 >= S2) = 0.94, V(S3 >= S4) = 1, V(S3 >= S5) = 1

V(S4 >= S1) = 0.84, V(S4 >= S2) = 0.86, V(S4 >= S3) = 0.93, V(S4 >= S5) = 1

V(S5 >= S1) = -0.14, V(S5 >= S2) = -0.12, V(S5 >= S3) = -0.26, V(S5 >= S4) = -0.20

For growth criteria the degrees are:

V(S1 >= S2) = 1, V(S1 >= S3) = 1

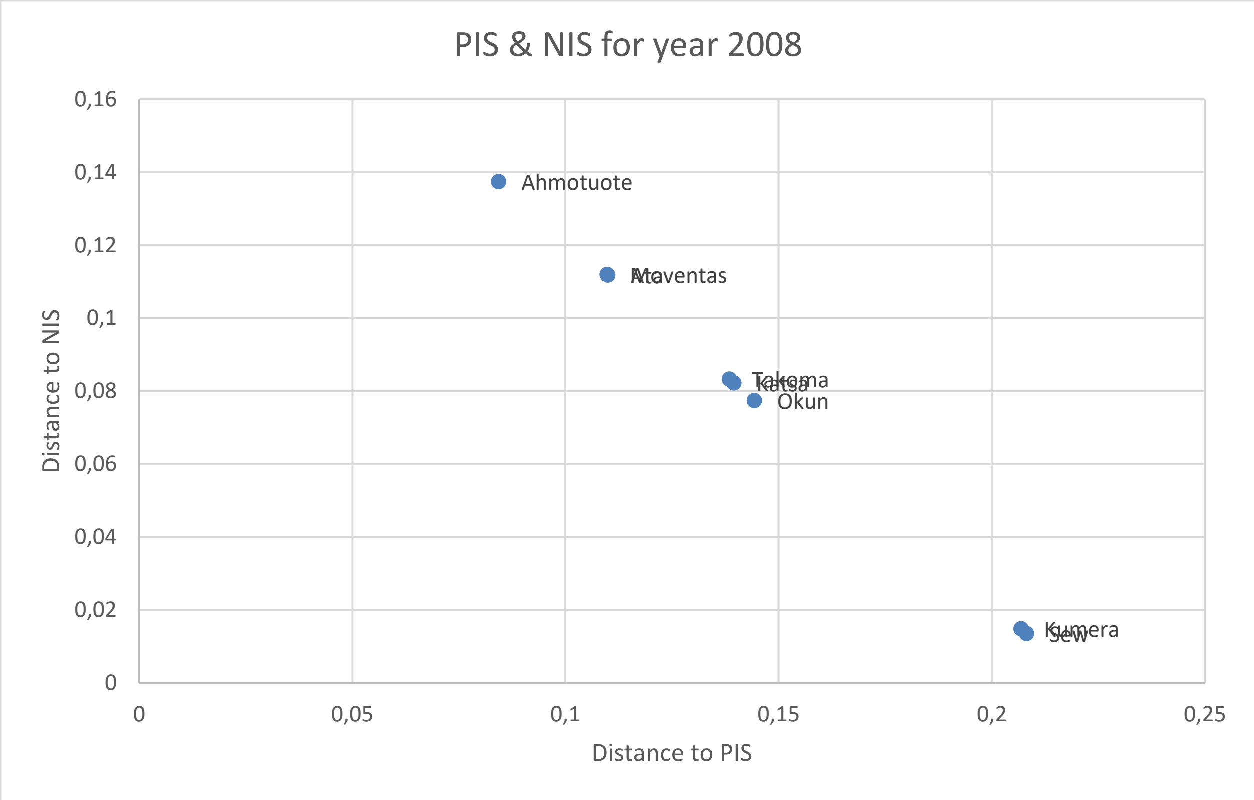
V(S2 >= S1) = -0.3, V(S2 >= S3) = 0.45

V(S3 >= S1) = 0.7, V(S3 >= S2) = 1

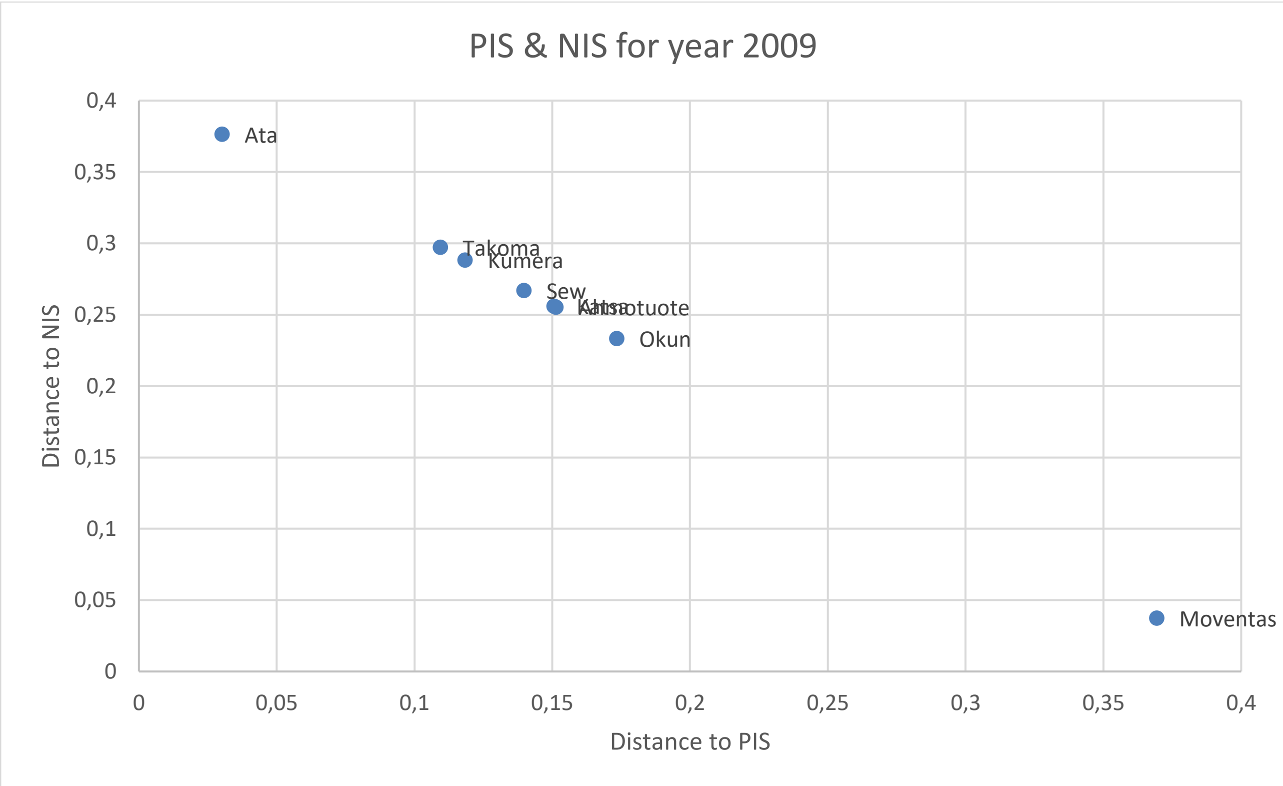
Year		Debt ratio	Assets/Shareholders equity	Fixed assets / shareholders' equity	Quick Ratio	Current Ratio	Cash ratio	Credit period days	Collection period days	Inventory turnover	Total assets per employee	Operating revenue per employee	Cash flow per operating revenue	EBITDA margin	Return on equity	Return on assets	Profit per employee	Turnover growth	Total assets growth	Shareholders' funds growth
2008	NIS	0.01784	0.02837	0.01459	0.00213	0.00140	0.00000	0.00000	0.01000	0.00359	0.00122	-0.00090	0.00166	0.00598	0.00053	0.00024	-0.00573	-0.02565	-0.00197	-0.00737
	PIS	0.00279	0.00276	0.00149	0.01144	0.00598	0.02100	0.01997	0.00000	0.02083	0.01015	-0.00016	0.01791	0.01419	0.02701	0.02178	-0.00040	0.05688	0.00070	0.03331
2009	NIS	0.01975	0.03698	0.02024	0.00127	0.00098	0.00011	0.00043	0.01030	0.00282	0.00195	-0.00048	0.00062	0.00179	-0.13268	-0.01962	-0.00788	-0.02693	-0.00061	-0.11093
	PIS	0.00251	0.00256	0.00134	0.00781	0.00532	0.01491	0.01904	0.00319	0.01381	0.00679	-0.00017	0.01634	0.01578	0.02192	0.03141	0.00432	0.00141	0.00147	0.03498
2010	NIS	0.01865	0.02596	0.01585	0.00160	0.00100	0.00007	0.00075	0.01134	0.00218	0.00186	-0.00068	-0.01663	-0.00819	-0.13769	-0.07829	-0.01191	-0.17022	-0.00419	-0.00995
	PIS	0.00188	0.00319	0.00152	0.01393	0.00758	0.02401	0.01754	0.00410	0.02145	0.00637	-0.00020	0.02042	0.02133	0.02245	0.05759	0.02000	0.47450	0.00110	0.08230
2011	NIS	0.01963	0.08343	0.04820	0.00134	0.00090	0.00003	0.00065	0.00744	0.00357	0.00215	-0.00079	-0.04323	-0.03285	-0.00011	-0.45377	-0.02848	-0.03849	-0.00597	-0.06544
	PIS	0.00203	0.00001	0.00000	0.01632	0.00842	0.02854	0.01075	0.00531	0.01621	0.00535	-0.00022	0.03123	0.02651	0.02910	0.17095	0.04601	0.05671	0.01788	0.01286
2012	NIS	0.02060	0.04360	0.02671	0.00095	0.00069	0.00001	0.00102	0.01140	0.00208	0.00187	-0.00080	-0.03048	-0.04800	-0.18015	-0.11399	-0.03765	-0.51181	-0.00365	0.00000
	PIS	0.00230	0.00235	0.00082	0.01432	0.00745	0.03049	0.01551	0.00467	0.02277	0.00553	-0.00024	0.03094	0.03079	0.11616	0.08907	0.04887	0.21087	0.00093	0.09776
2013	NIS	0.02155	0.04119	0.02762	0.00073	0.00055	0.00001	0.00000	0.01072	0.00310	0.00208	-0.00078	-0.04292	-0.03328	-1.53032	-0.77868	-0.02038	-0.17134	-0.02917	-0.01292
	PIS	0.00215	0.00234	0.00088	0.01505	0.00779	0.02654	0.01516	0.00000	0.01979	0.00516	-0.00023	0.03379	0.02825	0.47389	0.26957	0.02524	0.30730	0.01152	0.04310
2014	NIS	0.02056	0.03769	0.02656	0.00095	0.00065	0.00001	0.00057	0.01008	0.00353	0.00000	-0.00082	-0.02940	-0.00823	-0.09527	-0.10665	-0.00787	-0.00993	-0.00131	-0.09772
	PIS	0.00255	0.00222	0.00108	0.01228	0.00674	0.01499	0.01134	0.00439	0.01964	0.00625	0.00000	0.03427	0.02156	0.04165	0.05345	0.00203	0.05957	0.00110	0.04967
2015	NIS	0.02032	0.05018	0.02304	0.00110	0.00069	0.00002	0.00000	0.01058	0.00400	0.00000	-0.00077	-0.03490	-0.00081	-0.06185	-0.06178	-0.01754	-0.06896	-0.00520	-0.07196
	PIS	0.00280	0.00129	0.00068	0.01089	0.00593	0.01680	0.01544	0.00000	0.01319	0.00670	0.00000	0.03800	0.02077	0.00084	0.00995	0.00387	0.01882	0.00495	0.00292
2016	NIS	0.02291	0.06560	0.03487	0.00111	0.00072	0.00038	0.00098	0.01001	0.00425	0.00000	-0.00086	-0.01127	-0.00943	-0.09836	-0.04512	-0.02217	-0.10323	-0.00008	-0.08978
	PIS	0.00261	-0.02494	-0.00926	0.01147	0.00625	0.01366	0.01365	0.00203	0.01136	0.00676	0.00000	0.03172	0.03680	0.03218	0.01222	0.01856	0.03383	0.00161	0.00092

Appendix 5. Negative ideal solutions and positive ideal solutions for each criterion for each year.

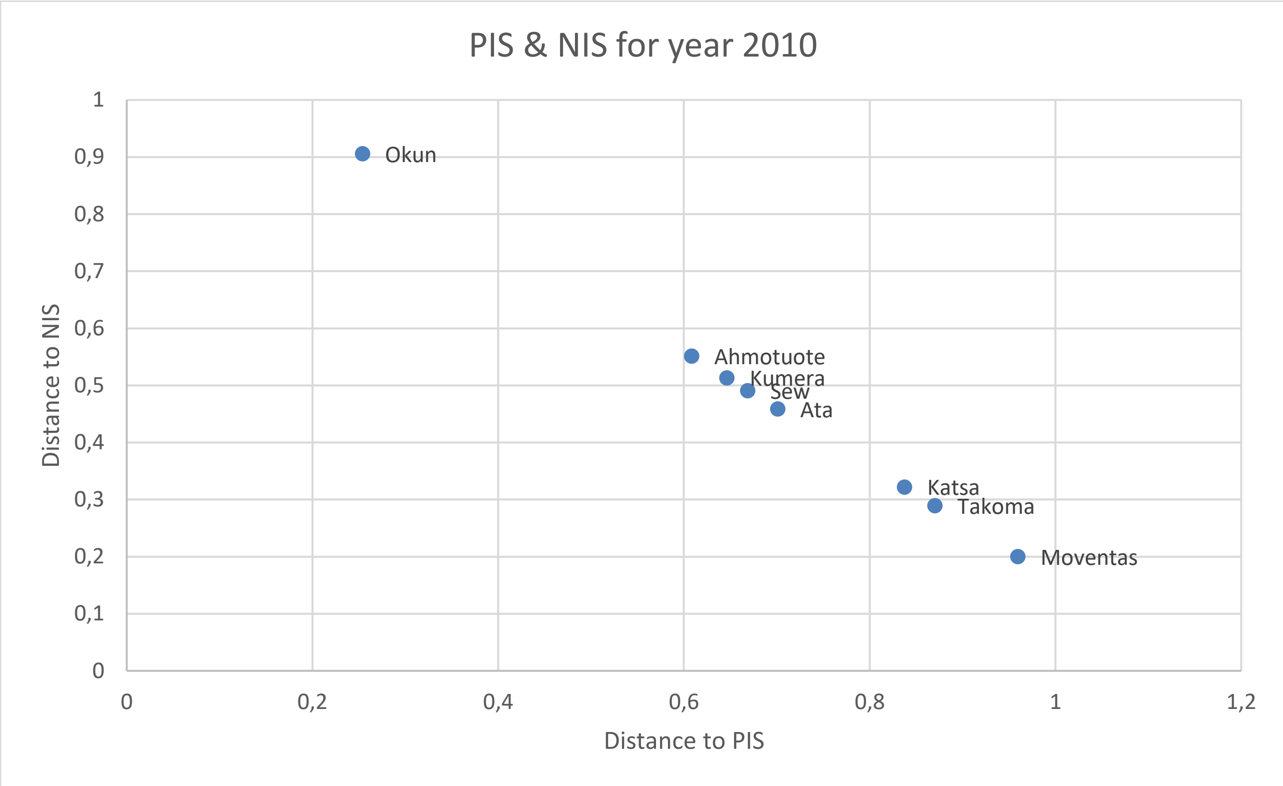
Appendix 6. Positive and negative ideal solutions for each year for each company



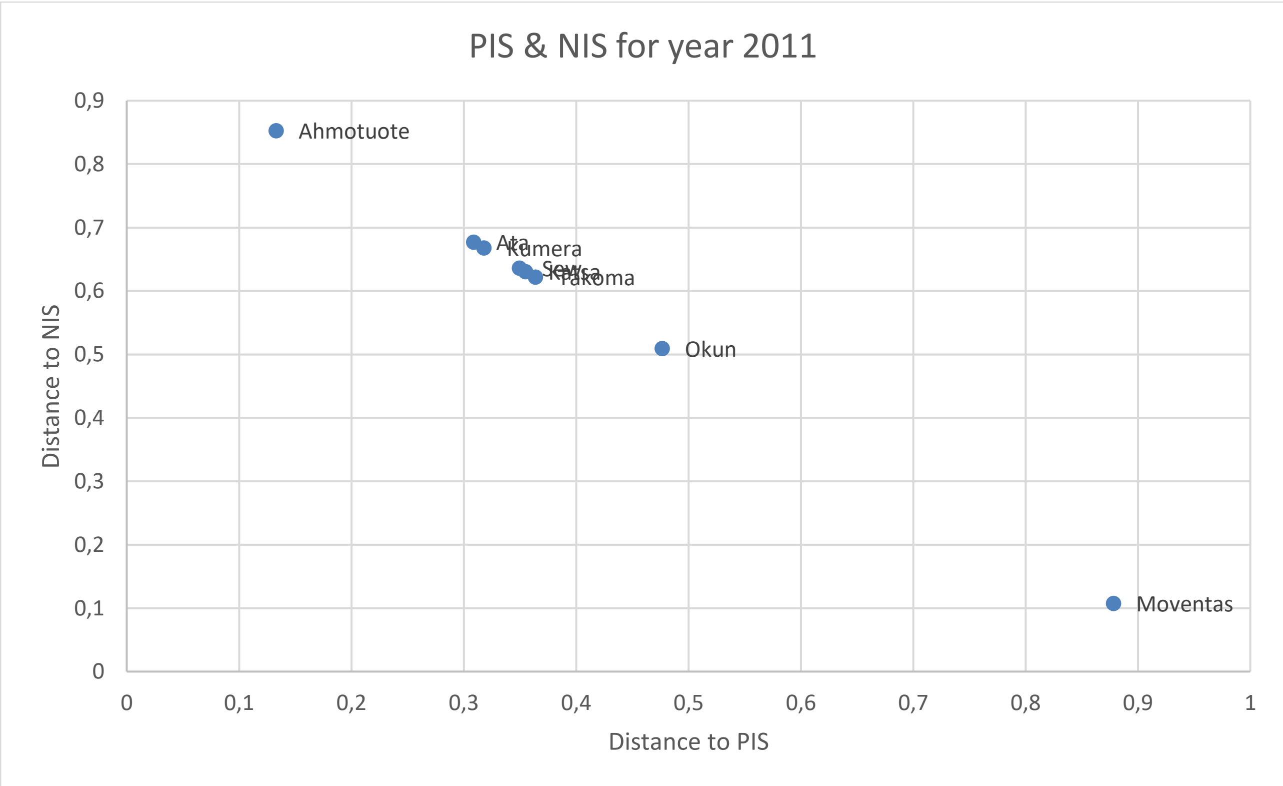
Appendix 6.1. Distances to PIS and NIS for each company in 2008



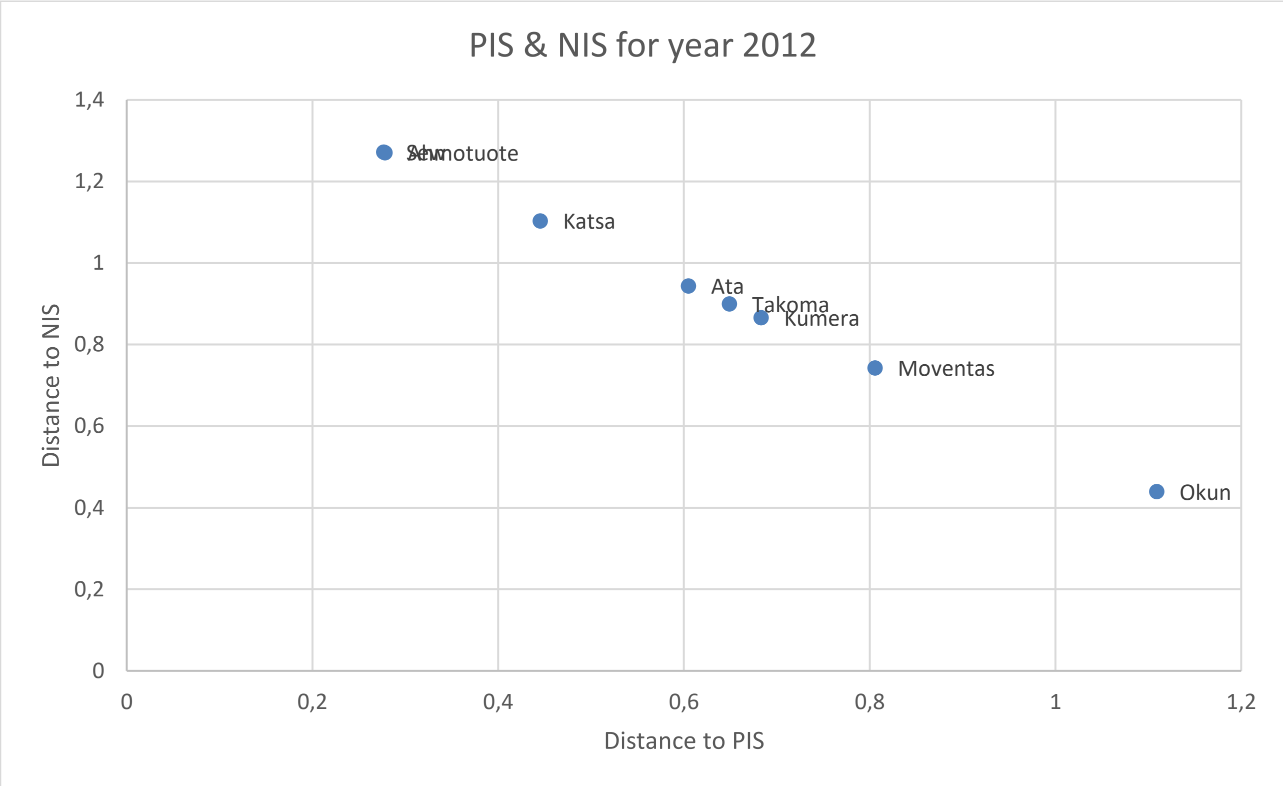
Appendix 6.2. Distances to PIS and NIS for each company in 2009



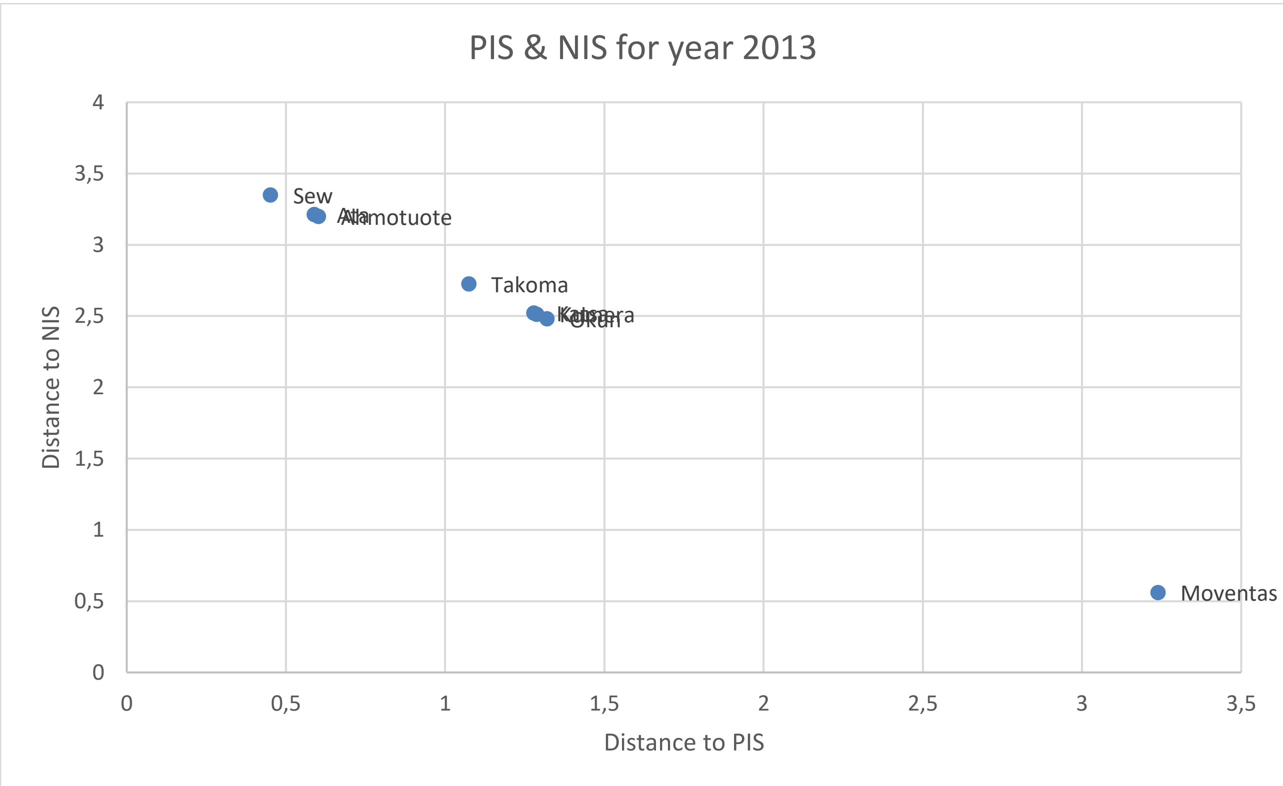
Appendix 6.3. Distances to PIS and NIS for each company in 2010



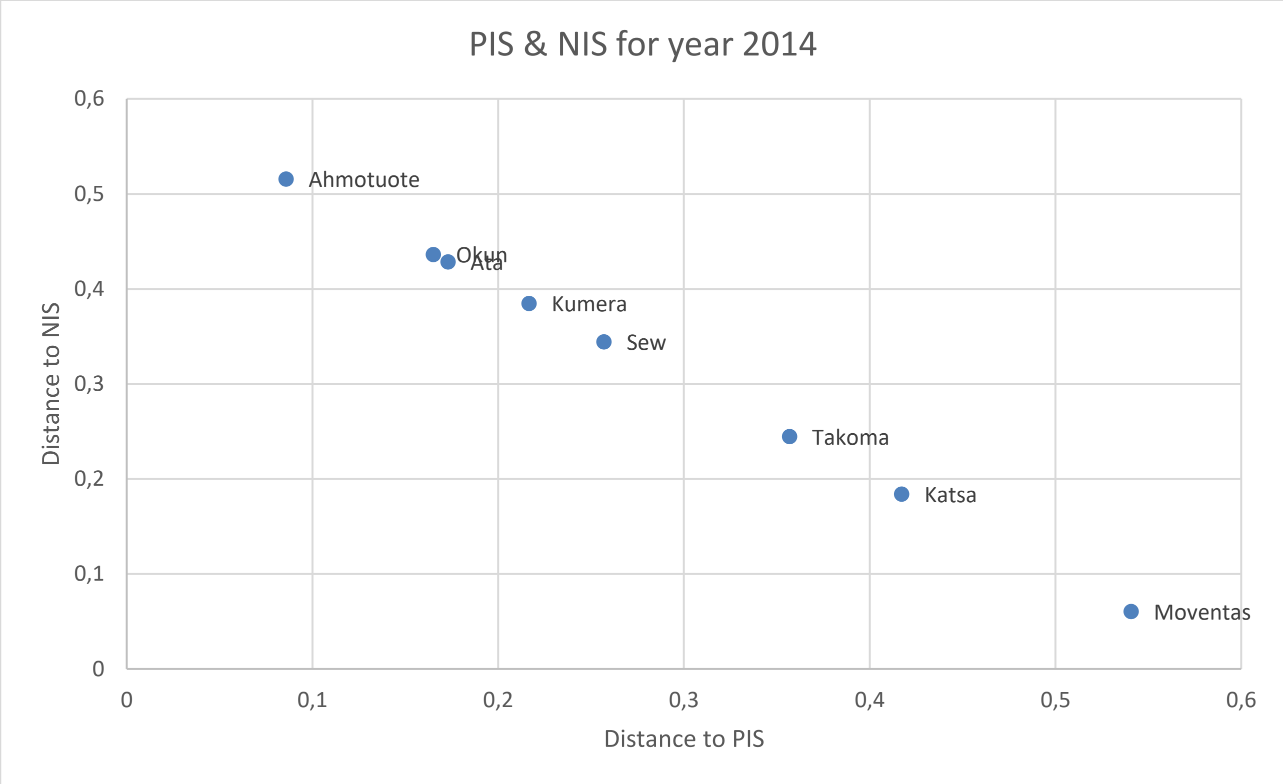
Appendix 6.4. Distances to PIS and NIS for each company in 2011



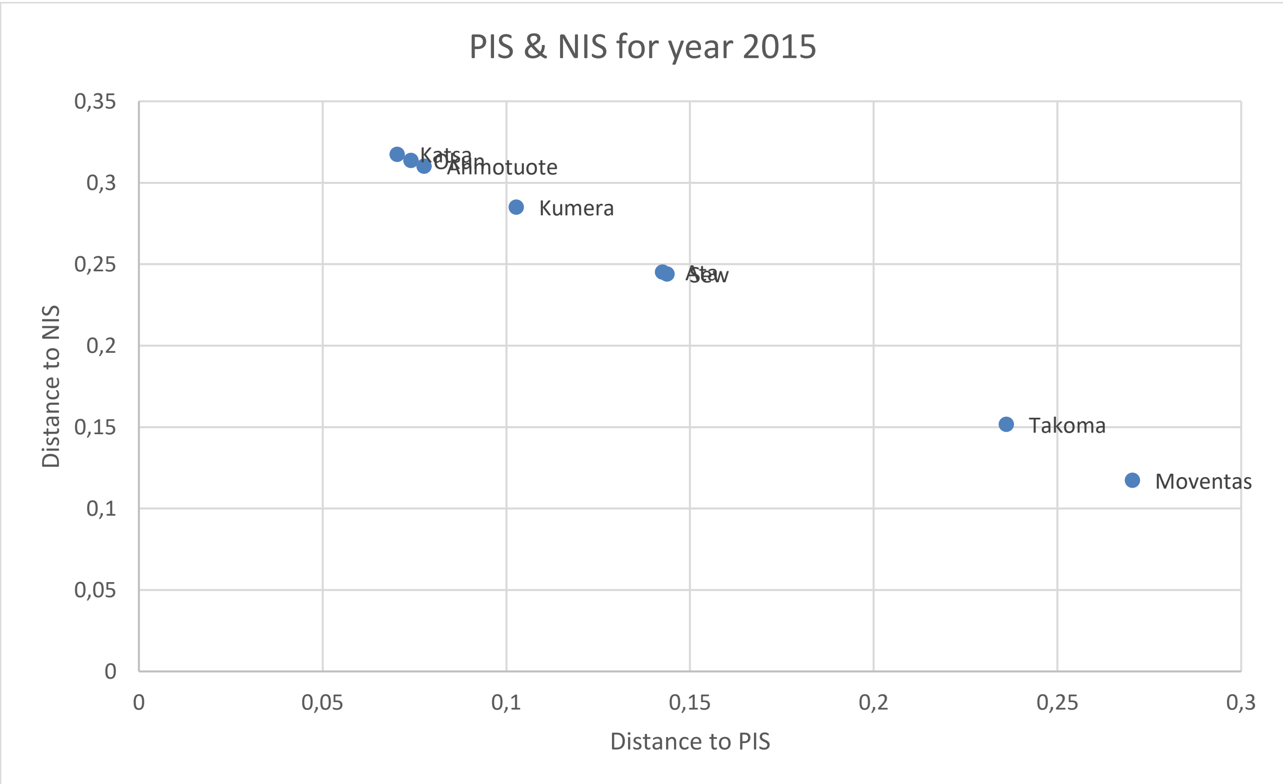
Appendix 6.5. Distances to PIS and NIS for each company in 2012



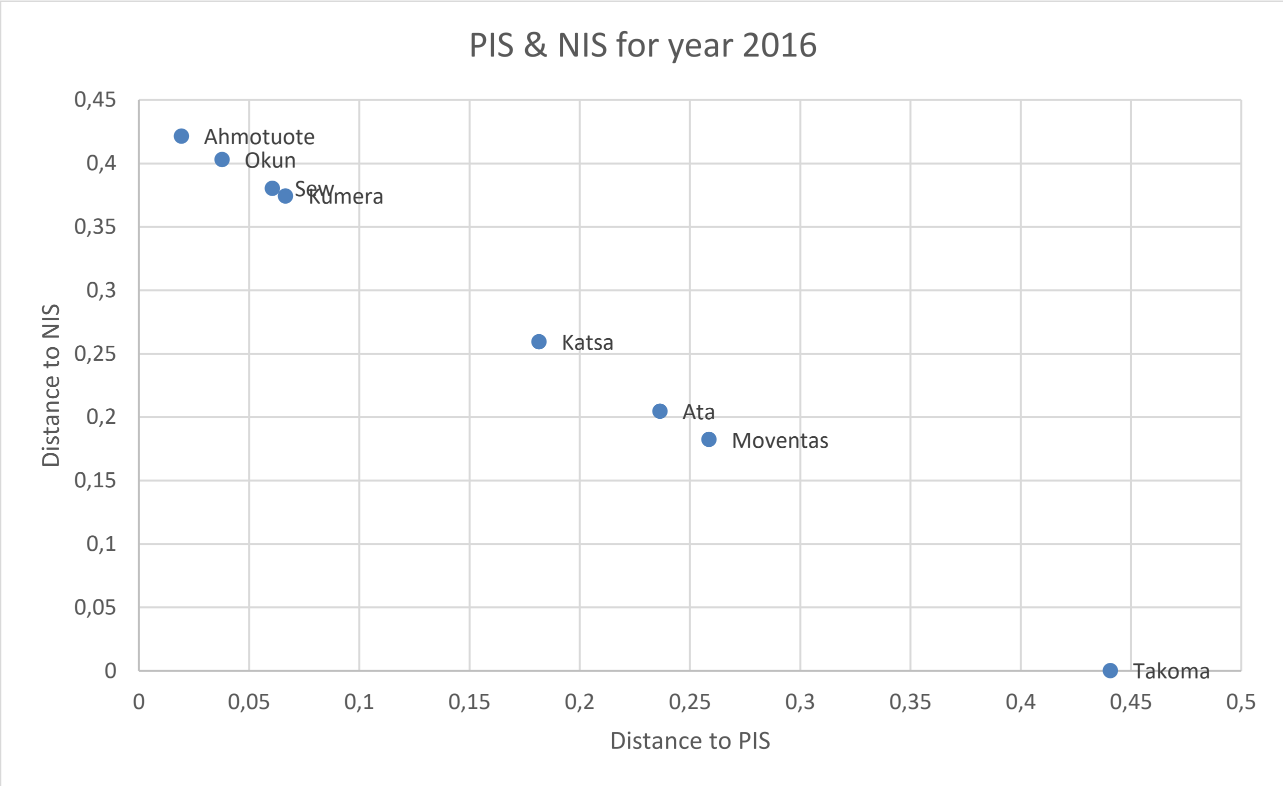
Appendix 6.6. Distances to PIS and NIS for each company in 2013



Appendix 6.7. Distances to PIS and NIS for each company in 2014



Appendix 6.8. Distances to PIS and NIS for each company in 2015



Appendix 6.9. Distances to PIS and NIS for each company in 2016

Appendix 7. Descending ranks and Closeness coefficients for each year.

	2008		2009		2010		2011		2012		2013		2014		2015		2016	
	CC	Rank	CC	Rank	CC	Rank	CC	Rank	CC	Rank	CC	Rank	CC	Rank	CC	Rank	CC	Rank
Ahmotuote	0.62	8	0.628	3	0.476	7	0.865	8	0.821	7	0.842	6	0.857	8	0.8	6	0.956	8
Ata	0.504	6	0.926	8	0.396	4	0.687	7	0.61	5	0.845	7	0.713	6	0.632	4	0.464	3
Katsa	0.371	4	0.63	4	0.278	3	0.64	4	0.713	6	0.664	4	0.306	2	0.819	8	0.589	4
Kumera	0.067	2	0.709	6	0.443	6	0.678	6	0.559	3	0.661	3	0.64	5	0.735	5	0.849	5
Moventas	0.505	7	0.092	1	0.173	1	0.109	1	0.48	2	0.148	1	0.101	1	0.303	1	0.414	2
Okun	0.349	3	0.574	2	0.781	8	0.517	2	0.284	1	0.653	2	0.726	7	0.809	7	0.915	7
Sew	0.061	1	0.657	5	0.424	5	0.646	5	0.822	8	0.881	8	0.573	4	0.629	3	0.863	6
Takoma	0.376	5	0.731	7	0.25	2	0.631	3	0.581	4	0.717	5	0.407	3	0.391	2	7E-04	1