TAMPEREEN TEKNILLINEN YLIOPISTO
TAMPERE UNIVERSITY OF TECHNOLOGY

TURKKA KALLIORINNE

MATERIAL PURCHASING MANAGEMENT IN DISTRIBUTION NETWORK BUSINESS

Master of Science Thesis

Examiner: Professor Pertti Järventausta
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ABSTRACT

In the last decade noticeable and long distribution outages around Finland have been caused by severe weather conditions. The outages have changed the public opinion and a more reliable electricity distribution is demanded. Lastly the Ministry of Employment and the Economy (TEM) has composed a new, more demanding law concerning of the electricity market, which came into the effect at 1.9.2013. The new law reduced allowed outage times caused by weather conditions to six hours in an urban area and to 36 hours in rural area. The new requirements have to be fulfilled at the latest in 2028 and during that time it is estimated that 3,5 billion euros have to be used for the network investments.

This thesis work is done for Elenia Oyj, which has been in the past years one of the foregoing in the branch of business. It is said that Elenia has taken the contractor partnership network management to the new level in the branch of business. Elenia has also introduced a brand that is focused for underground cabling, called as “weather proof”, a framework that has begun as early as 2009.

These heavily increased investment levels are a driver for the more sophisticated management methods for material purchasing. The objective of this thesis is to research and implement the key aspects of the modern material purchasing methods and practices based on the literature review and group studies. During the research process it came clear that special attention is needed for four different purchasing management areas: material portfolio analysis, supplier selection, supplier performance evaluation and demand forecasting. These aspects were selected because of the detected potential of efficiency improvement.

In the thesis all these four different aspects are presented in own chapters. The main results of the thesis are the introduction of Kraljic portfolio matrix, AHP supplier selection method, supplier scorecard and an improved tool for the demand forecasting.

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TIIVISTELMÄ

Muutaman vuoden takaiset, huomattavan laajoja ja pitkäkestoisia sähkökatkoja aiheuttaneet poikkeukselliset sääolot sekä vanhentuva sähköverkko ovat luoneet merkittävää yhteiskunnallista painetta sähköverkkoyhtiöille toimitusvarmuuden parantamiseksi. Viimeisimpänä valtakunnallisena päätöksenä Työ- ja elinkeinoministeriön valmistelema, päivitetty sähkömarkkinalaki astui voimaan 1.9.2013. Päivitetyssä sähkömarkkinalaissa on asetettu entistä tiukemmat vaatimukset sähkön toimitusvarmuudelle; asemakaava-alueella myrskystä tai lumikuormasta aiheutuva keskeytys saa kestää enintään kuusi tuntia ja muilla alueilla enintään 36 tuntia. Muutamia poikkeuksia lukuun ottamatta kaikkien asiakkaiden on oltava vaatimukset täyttävässä sähköverkossa viimeistään vuonna 2028.

Työ on tehty Elenia Oy:lle, joka on toiminut Suomessa pioneerina säävarman sähköverkon rakentamisessa ja ottanut esimerkiksi oma-aloitteisesti käyttöön kuuden tunnin keskeytyskorvausrajan vuonna 2009. Samasta vuodesta alkaen on myös kaikki verkon korvausinvestoinnit rakennettu maan alle suojaan sääilmiöiltä ja samaa strategiaa tullaan jatkamaan ”säävarma” brändin nimellä vuoteen 2028 asti.

Uudet määräykset kasvattavat merkittävästi vuotuisia jakeluverkkoinvestointeja. On arvioitu, että vuoteen 2028 mennessä jakeluverkkoihin tullaan investoimaan yhteensä 3,5 miljardia euroa. Merkittävät vuotuiset materiaalihankinnat ovat luoneet monia uusia mahdollisuuksia materiaalihankinnalle, mutta myös tarpeen hankintajohtamisen ja johtamismetodien tehostamiseen. Investointitasot kiinnostavat toimittajia ympäri maailmaa lisäten kiinnostusta myös tuotekehitykselle.

Projektin aikana tuli selväksi, että erityistä huomiota tarvitaan neljässä eri aihe-alueessa: toimittajan valinnassa ja -suoritustason seuraamisessa, materiaaliportfolioanalyysissa sekä kysyntäennusteen kehittämisessä. Nämä aihealueet on käyty läpi erillisissä kappaleissa ja tulokset on tuotu ryhmätöiden kautta käytäntöön Eleniassa. Työn lopputuloksena käyttöön otettiin muokattu versio Kraljicin matriisista, toimittajan tuloskortti, AHP toimittajanvalintahierarkia sekä Stevenssonin esittämä malli kysyntäennusteelle.

FOREWORDS

This Master of Science thesis is done for Elenia Oy and published by Tampere University of Technology. Topic for this thesis is formed by author, based on the experiences from the field and discussions with managers and colleagues in Elenia. The examiner of this thesis was Professor Pertti Järventausta from the University and from Elenia the supervisor was Jarkko Kohtala, head of construction and partnerships.

I wish to thank Pertti and Jarkko for a good steering during the thesis process and especially Jarkko for providing the opportunity to accomplish this thesis in Elenia. I also want to thank my foreman Henri Hovi and colleagues for sympathy and possibility to focus to the thesis process.

This thesis process was an interesting opportunity to complete my knowledge from purchasing management and implement new business aspects to the electricity distribution business. I hope that the reader can found new interesting views about this subject from this thesis.

Tampere 11th August

Turkka Kalliorinne

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ABBREVIATIONS AND NOTATION

DSO: Distribution System Operator
XLPE: Cross-linked polyethylene
RFQ: Request for tenders
OTD: On Time Delivery
MPT: Modern portfolio theory
VMI: Vendor managed inventory
BCS: Balanced Scorecard
KPI: Key performance index
NSAmp: Net Stock Amplification
HW: Holt-Winter's triple exponential smoothing method
CMA: Centered moving average
MA: Simple moving average
ARIMA: Seasonal autoregressive integrated moving average
MAUT: Multiple-criteria decision-making
DEAHP: Data envelopment analytic hierarchy process
BWE: Bullwhip Effect
RVV: Relative value vector
CR: Consistency Ratio
MAD: Mean absolute deviation
MSE: Mean squared error
MAPE: Mean absolute per cent error
PEE: Percentage forecast error

1 INTRODUCTION

Nowadays the electricity distribution system operators (DSO) are making heavy replace investments to the current electricity distribution network. Replace investments are needed because of the aging distribution network and increased demand for continuous electricity distribution due to modern life. After several harsh storms which have occurred in the past decades the public opinion has changed, and a more reliable electricity distribution is demanded by customers as well as government authors. Due these reasons the Ministry of Employment and the Economy (TEM) has composed a new, more demanding law concerning of the electricity market, which came into the effect at 1.9.2013.

The new law required a much more reliable electricity distribution network by reducing allowed outage times, which were already tighten in the last law update at 2005. Basically all customers have to be under these provisions by 2028. The law and its required investments are monitored by Energy Authority, which is operating under the TEM's administration. Energy market authority is regulating the reasonableness of the prices charged by DSO's and the cost efficiency of the network investments. The investment efficiency regulating is a critical part of the Energy market authority's response, because it is estimated that 3,5 billion Euros of investments are needed in the next 15 years for fulfilling the new requirements. (Ministry of Employment and the Economy, 2013)

Handling of these heavy network investments is requiring more sophisticated management organisations and systems for handling this development in the business environment. Traditionally the electricity distribution business has been inflexible and hardened branch of business due to the natural monopoly situation. The situation is now changing due the new regulation model, which incite to improve investment efficiency. Elenia Oy, has always been one of the forerunners in the field of business when concerning of business models and management systems. A highly sophisticated management model is already implemented to the contracting environment, and all materials used by contractors are purchased by Elenia. Currently Elenia is purchasing strategic materials directly by factory agreements and installation materials and logistics services from the wholesale and logistic partner.

Increased investments have provided many new opportunities to the global material purchasing function and in Elenia the focus is to develop more suitable material solutions. However the management challenges of the chancing situation have also created a need for a deeper insight for scientific and practice methods of the purchasing management business branch.

This thesis has been made for Elenia Oyj and the main goal is to provide deeper knowledge for the material purchasing management and create a systematic approach for purchasing function. During the process four different areas of special study were detected and performed: material portfolio analysis, supplier selection, supplier scorecard and demand forecasting. Although the term material purchasing can be understand very widely, this thesis is focused on these specific areas. Areas are selected to characterise current situation and the needs for management tools. These needs have come out to author’s knowledge by work assignment in material purchasing and also discussions with managers and colleagues.

2 INTRODUCTION TO THE DISTRIBUTION NETWORK MATERIALS

In this chapter the typical distribution network construction is characterised in purpose to answer which components are the most needed when the electricity is transferred in distribution network. Used grid components are described and one of the main goals for this chapter is to determine and limit out product areas which are focused in this thesis. For this goal in mind, a short introduction of the network structure is given before the main network components are clarified.

Electrical grid can be divided for transmission grid and distribution network. The transmission grid is used for the energy transfer from production plants to the population and consuming centers. Voltage levels in the transmission grid are typically 400 – 110 kV to maximising the transmitted energy and minimising power losses. The distribution network is used to deliver electricity from the end of the transmission grid to the customers, and nowadays also for transferring power from a distributed generation. The voltage levels in the distribution networks are typically 20 kV - 0, 4 kV. In Finland length of the transmission grid is 14 000 km and length of the distribution network is almost 400 000 km. Typically the distribution network is divided further to the medium and low voltage network which means that all grid with voltage levels 1 kV or under are low voltage and networks between 20 – 1 kV are medium voltage. (Energiateollisuus ry, 2013)

In Finland the transmission grid is operated by Fingrid Oyj and distribution companies such as Elenia Oyj are typically connected to the 110 kV connection points and after the connection point the network is on distribution company possession. Typically 110 / 20 kV substation is located directly after the main grid connection but it is also possible that there are high voltage lines before the substation in the distribution company's possession. (Fingrid Oy, 2013)

The distribution network is supplied from the transmission grid after the substation and typically voltage level in the medium voltage distribution network is 20 kV. Medium voltage distribution network is used to deliver electricity near to the customer, typically 0,5 – 1 km away. Medium voltage network ends to the secondary substation which converts voltage from 20 kV to 0,4 kV. As mention before, the 0,4 kV network is called to low voltage network and it is used to deliver electricity directly to the end-customer connection point.

In Elenia the network asset base includes 1 500 km of 110 – 45 kV high voltage (HV) lines, 22 800 km of medium voltage (MV) lines and 40 000 km of low voltage (LV) lines which means that the voltage level is 20kV or under over the 98 present of the network total length. Because of the significantly higher volumes in the MV and LV network the required management methods differs from HV material purchasing. MV and LV materials are highly standardised volume products meanwhile the HV materials are more specific and often individually designed products. Therefore the main focus in this thesis is placed on distribution network materials and the results from this thesis should not be used in HV material purchasing without consideration. However some of the presented methods in this thesis are most probably valid in all purchasing management functions.

2.1 Distribution network materials

All of the components which are needed to deliver the electricity from substation to the customer can be considered as the distribution network material. In this thesis the main focus is not on technical description or development, but basis of the most used materials is described here to give a main thread to the reader. Basic understanding from the materials is essential when managing material suppliers and it is also important to understand basic cost-breakdown structure of the products. As already discussed, Elenia is investing only for underground cable networks and therefore this chapter is valid only similar business environment.

Cost breakdown is described in general way of each category, although it has to be stated that actual cost breakdown structures are highly concealed business factors that are not publically available. General description can be however presented based on the view of the field, but is has to be kept in mind that the cost structure can be changed rapidly according to world economic situation. The main components are different metals, oils and plastics, and the prices are following for raw material exchange. However it is important to understand the main cost factors, because the supply chain is dependable for the all used components and sub-suppliers, which are not directly visible for the purchaser.

In the table 1 the distribution network materials are divided for different general product groups, which covers up to 90% of the total purchased material values. Last 10% include “oddment” construction materials. It can be said according to table that the main product groups are with high volume, but small variation. However different groups might include suppliers from large multinationals organisations to small local companies. The cost distribution can varying depending on the construction environment, different results will be obtained in the purely urban areas. In the table a suggestive percentage of the each group's volume is presented.

Table 1 Total material costs divided by groups

Group	**% of the total material costs**
Cables	40 %
Secondary substations	25 %
Distribution transformers	10 %
Distribution cabinets and fuse-switch-disconnectors	5 %
Cable accessories	5 - 10 %
Total	**85 -90 %**

In the table the distribution of total costs can be seen. These five groups are studied more deeply in the next paragraphs because of their relative importance. However it has to be notified that this list includes only main components which are used to electricity distribution. Components which are needed in network communication are left out from this thesis because it would be irrelevant to study only a material cost of the communication systems. However the same purchasing methods which are presented later on can be definitely used to the high volume communication device purchasing when needed.

2.1.1 Cables

A typically used cables in the distribution network includes MV cables and LV cables, which are also the main cables in Elenia. Structural and pricewise the MV and LV cables are deviating from each other because of the different technical requirements. Figures of the cables are presented here, the MV cable is in the figure 1 and LV cable is in the figure 2.

Figure 1 Prysmian Group AHXAMK-WP Medium voltage cable (Prysmian, 2009)

AHXAMK-W and WP are a widely used MV cable types in Finland, although the main components of the MV cables are more or less similar around the world. AHXAMK-WP cable is consisted of three one-phase cables laid-up by twisting them together and

AHXAMK–W version means that the copper center conductor is laid-up in the center of the cable. The AHXAMK-W cable was originally developed in Finland by late 80's to replace the old and expensive construction of the APYAKMM cable. The APYAKMM is an oil immersed paper insulated cable, which was the main cable type before development of XLPE insulated cables. Nowadays the APYAKMM is not anymore used in European markets.

Medium voltage cable construction from inside out is listed below (Prysmian, 2009):

1. Conductor: round, stranded and compacted aluminium, longitudinal water tight by water-swellable material in interstices of conductor.
2. Conductor screen: Semi-conducting XLPE
3. Insulation: XLPE compound
4. Insulation screen: Semi-conducting XLPE
5. Water swellable material: Longitudinal water tightness between the insulation screen and the sheath
6. Aluminium laminate bonded to the sheath: Radial water tightness
7. Sheath: Black PE

In the figure 2 a typical low voltage cable AXMK construction can be seen. This type of cable is also widely used in Finland and it is also currently the main low voltage cable in Elenia. Construction consists of four sector shaped or round stranded aluminium conductors which are insulated by XLPE layer. Conductors are bonded together by a plastic tape and the outer sheath is black PE compound. Compared to the medium voltage cable the construction is much simpler and it is not a water tight solution. (Ericsson, 2013)

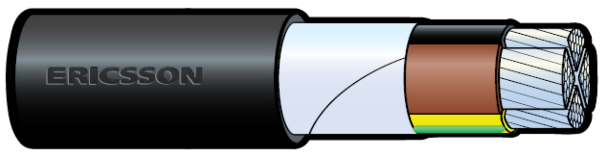

Figure 2 Ericsson N1XE-AS 3x95 0, 6- 1 kV low voltage cable (Ericsson, 2013)

The main components and cost factors in both cables are the XLPE insulator and aluminium conductor. Cost of labour is also a significant factor in the cable manufacturing and transport and drum handling costs can't be dismissed either.

2.1.2 Secondary substations

Secondary substation is the place where the voltage is transformed by the distribution transformer from the MV to the LV level. Secondary substation construction consist of both pole mounted and cabin type substation. Cabin type substations are used in cabled network meanwhile pole mounted substations are used in overhead network. However due the new outage regulations the amount pole mounted substations are decreasing and basically all new substations are cabin type solutions.

Typical substation consists of medium voltage switchgear, distribution transformer and low voltage side. Low voltage side consist of main LV- switch and fuse-switch-disconnectors for outgoing LV connections. (ABB, 2005) Because of the physical size of the substation the main cost factor consistent form labour, steel sheets, medium voltage switchgear and LV equipment. For these reasons nowadays smaller substations are used and also SF6 switchgears are becoming more used because of the smaller size and therefore a better cost efficiency.

2.1.3 Distribution transformers

In the secondary substation a distribution transformer transforms voltage level typically from 20 kV to 0,4 kV. Transformer power ratings in Finland goes from 16 kVA up to 1600 kVA, but the use of both extremities are rare, with most typical sizes in the rural area goes from 50 kV to 200 kVA. These sizes are also used as a combined distribution transformer and earth fault compensation construction, as the underground networks are increasing earth fault currents. A typical distribution transformer is presented here (Figure 3):

Figure 3 Siemens hermetically sealed oil-immersed 630 kVA TUMATIC distribution transformer (Siemens, 2010)

The transformer is hermetically sealed oil-immersed type, which is the main type used in world wide. Parts of the distribution transformer are listed below. (Siemens, 2010)

1. Core and windings
2. Core, high quality electric sheet metal.
3. Windings, copper or aluminium
4. Tap changer
5. Low voltage bushings
6. Medium voltage bushing
7. Place for thermometer
8. TUMETIC hermetically sealed tank
11. Corrosion protection

Inner parts of the transformer are oil-immersed, used oil is typically mineral oil for its good features and cost-effectiveness. Special oil such as silicone or estern oils are developed to improve e.g. self-extinguishing of fire or biodegradability. However special oil is not usually needed in new secondary substation because of its natural protection for the environment provided by the cabin.

Main cost factors of distribution transformers are core and winding materials, as high quality metals are needed for reducing power loses. Also labour and electrical oil is major cost factors when producing the distribution transformer.

2.1.4 Distribution cabinets

Distribution cabinets and fuse-switch-disconnector are used for the low voltage electricity distribution. Fuse protection is used to break of the short circuit currents and over loads.

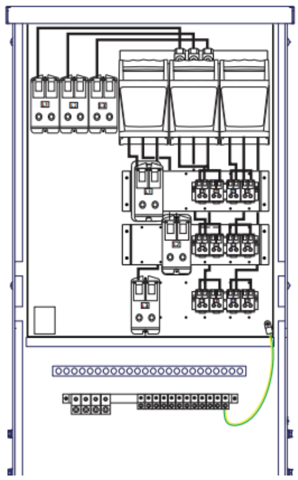

Figure 4 Modern prefabricated distribution cabinet Ensto Rapid5.3/411. (Ensto Finland Oy, 2014)

In the figure 4 the main feed line is connected to left, fuse-switches are in upper parts of the cabinets and output connection lines for the customer leaves under them. In the distribution cabinets the main cost factors are the cabinet itself and fuse-switches. Also installation cost variation might be considerable high with different cabinet solutions.

2.1.5 Cable accessories

All components which are needed for cable terminations and joints are considered as cable accessories. Cable accessories are needed for all cable types and connection points, but the cost variation for different types could be high. For low voltage cables accessories are simple and relatively cheap with small variations, unlike the medium voltage accessories which are relatively costly and price variations are high. Usually the most affordable solutions are heat shrinkable accessories without touch protection in the cable ending. However if touch protection is needed, more expensive protected endings are needed. Usually protected cable endings are needed in the SF6 switchgears and therefore cable terminations have to be taken in calculation when balancing with the total cost.

In the figure 5 two different medium voltage cable terminations are presented, a simple Raychem IXSU indoor termination and a more technical screened termination Raychem RSTI-58. Screened cable terminations are usually needed in the SF6 insulated medium voltage switchgear.

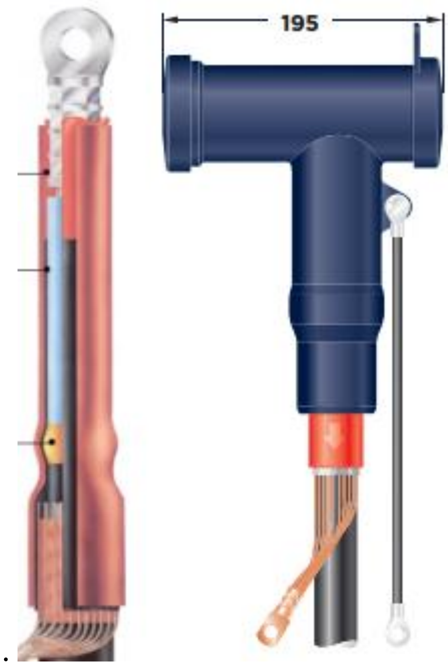

Figure 5 Left: Raychem IXSU-F (Raychem, 2013), right: Raychem RSTI-58 800 A (Raychem, 2013 b)

3 PURCHASING MANAGEMENT

The aim of this chapter is to provide a theoretical introduction and definition for material purchasing management as a part of procurement process. It is important to have even a slight understanding of the theoretical frameworks and different perspectives of the purchasing management before going to the more detailed study.

3.1 Definition of the purchasing management

One of the most famous definitions for the purchasing management is presented by purchasing management pioneer Arjan J. van Weele in the book Purchasing and Supply Chain Management:

“Purchasing management refers to all activities necessary to manage supplier relationships. It is focused on structuring and continuously improving purchasing process within the organization and its suppliers.” (Weele, 2010)

Purchasing management has developed from compulsory function to the one of the modern company’s main function and, if succeeded, one of the main advantages over the market. Development has been rapid from the 70’s until now, because of the removing of the trade barriers which were adopted after the Second World War when nationalism was at high level. It is stated that after joining to the EU a typical Finnish company’s home purchasing area has growth from the 5 million persons to the 500 million persons. Development of the communication systems will eventually include almost the whole world to the one market area. (Iloranta, et al., 2012 pp. 67-81)

According to the Finnish monetary analysis of the local public companies’ it is revealed that on average 80% of the company cost structure is formed from purchasing functions. (Kivistö, et al., 2005) Developments of the purchasing functions are caused that a purchasing networks are also more complicated than ever. Complicated purchasing networks enable high efficiency and rapid development, but on the other hand the complicacy also increases associated risks and some of them are not even controllable. Even a small bump can have a worldwide collateral effect as can be seen from the events of the last years. (Iloranta, et al., 2012 pp. 67-81)

3.2 Towards to the proactive purchasing

Traditionally the company top management have expected that purchasing department delivers right products or services to the right place and time with the best possible price. It was stated in the mid 1960 by purchasing professional and one of pioneer Bruce D. Henderson that purchasing was regarded as a negative function among the top management, which could halt the company if failed but only have a little positive effect if succeeded. (Henderson, 1975)

This classic view for purchasing function is nowadays called as a *reactive purchasing*, which adapts to the market and product changes when is necessary. Since Henderson publication much of an attention is given to the purchasing management and today's modern companies understand purchasing as the key competitive aspect for the company success. The main goal of purchasing department in the modern company is the searching of the new products and suppliers, and even chancing the market situation when needed. This modern view of the purchasing is called as the *proactive purchasing*. (Iloranta, et al., 2012 pp. 83-103; Bedley, et al., 2008 pp. 1-9)

Purchasing development trend towards to the proactive purchasing have been studied among the researchers and the main action points of the proactive purchasing organisation are listed by Iloranta, et al.(2012 pp. 83-103):

- Purchasing integration to the company strategy
- Development and strengthen of purchasing resources
- Strategic segmentation of purchased products / services
- Increasing of co-operation across the organization
- Searching of new supply sources, innovations and value-added solutions
- Searching for low cost level supply sources and geographical areas
- Development of competitive supply chains
- Integration of the product development to the supply chain.
- Development of the supply chain co-operation

It can be summarised that the proactive purchasing is one of the key elements of the modern company competitiveness and it is focused on the aggressive searching of the value-added solutions. Meanwhile the reactive purchasing is only seen as a cost factor to the top management which can only be unsuccessful.

3.3 Purchasing organisation

One of the key elements of the successful purchasing function is the responsible organisation. It has to be structured correctly in order to maximize its performance and adaptation possibilities to the new situations. The main structural issues can be concluded for two aspects: *centralization* and *formalization*. Centralization means that how the purchasing organisation is divided between the different company locations or divisions and formalization is a degree of beurocracy in the purchasing organisation. (Bedley, et al., 2008 pp. 9-31)

The main activities of purchasing organisation can be divided to the three different task levels by its characters: *operational*, *tactical* and *strategic* tasks. (Weele, 2010) Operational tasks include administrative actions such as ordering, order receiving and delivery acceptance. Operational tasks are usually decentralized as near to the actual user as possible, which also releases resources from purchasing organisation to the other tasks.

Tactical level task is consisted for a longer time period activities and management decisions. The main tasks includes: (Iloranta, et al., 2012 pp. 314-339; Stevenson, 2011 pp. 663-697):

- Finding of new suppliers
- Following of supply market changes
- Supplier selection, supplier analysis and validations
- Negotiations and agreements
- Supplier performance evaluation, demand forecasting and co-operation meetings
- Supplier development

Strategic level is responsible for upper level task and strategic decisions which are affecting to the whole company. Strategic team is consisted from top managers. The main tasks in strategic level are (Iloranta, et al., 2012 pp. 314-339):

- Purchasing strategy and targets
- Sourcing decisions
- Key supplier selection
- Supply organisation structure
- Principles for performance rewards

3.3.1 Organisation structure

The purchasing organisation is always working in the interface of the company and in some cases the purchasing organisation can even include other suppliers or service providers. Therefore there are some aspects that typically differ from the manufacturing organisation structure. However the structure is highly dependent of the company and environment surrounding it, but one of the main questions are centralization and formalization which determines how purchasing organization implies with other organization. Purchasing organisation is also responsible for communication between the internal and external organisations, which has to be taking into account when designing the structural organisation. (Iloranta, et al., 2012 pp. 314-339)

Centralisation means that how purchasing is located in the company level, is there only one centralised purchasing unit which take care of all purchasing or many smaller units in different geographical or division locations. Formalization determines how bureaucracy purchasing function and its sublevels are. The key elements of the different organisation structures are clarified in the table 2: (Bedley, et al., 2008 pp. 9-31)

Table 2 Different levels of centralization and formality in purchasing organisation structure. Based on Bedley, et al. (2008)

		Centralization	
		High	**Low**
Formality	**High**	*Machine bureaucracy* +Large quantities and good bargain power - Indirect connection between purchasing and actual users	*Professional* +Purchasing has good knowledge of local organization - No clear overview of company purchasing
	Low	*Entrepreneurial* +More professional byers -Suitable only for small companies with relatively simple purchases	*Adhocracy* +Fast response -Poor overall control

However in the reality such extreme values are rarely the whole case. Most of the companies are somewhere between these corners according to current market environment and organisation structure. It should be noted that every the company is an individual and there are no one right solution model for all. (Iloranta, et al., 2012 pp. 314-339) Key factors are that the structure fits for rest of the company and that structure is continuously changing in accordance to the external and internal forces. By continuously chancing the structure even minor changes could keep structure up to date and costly major overhaul of the structure could be avoided. (Bedley, et al., 2008 pp. 9-31)

3.4 Procurement

Procurement is the acquisition of products, goods, services and other works from an external source. As the term procurement is near to the term purchasing, it is important to understand the difference between these terms. The procurement includes all actions that are needed to get the product or service from the supplier to the use, whereas the term purchasing function includes more or less all tasks that are on purchasing organisations responses. However these terms are used in many different occasions and reader has to determine the actual mean by its context. These presented meanings are used in this thesis. (Iloranta, et al., 2012 pp. 49-54; Weele, 2010)

One important aspect for energy transfer business is the public procurement which is required for public authorities and special sectors. Public procurement process, although intended to reduce corruption and open market areas, set out some restraint for purchasing with truly competition focused purchasing.

3.4.1 Public procurement

In the electricity distribution business one important factor in the purchasing management is Public procurement is the procurement process of services and material for a public authority. The main focus is to prevent waste, corruption and protectionism of a local part of the market. In the all EU area energy business belongs under to the "Act on public contracts by contracting authorities in the water, energy, transport and postal services sectors" (349/2007), also called as the *special sector*. This directive is valid for all material supply agreements with higher value than 414 000 € at the time of writing (HILMA, 2014). (Iloranta, et al., 2012 pp. 379-388)

The key reason for the acts of public procurement is to provide fair and equal chance for all tenderers, when the market competition doesn't force the company to reach for competitive advantage. This is usually the case when purchasing entity is a public authority or the business environment is a natural monopoly, such as in the electricity distribution business. Public procurement process is based on regulations of tendering process and public display of contract notices. Contract notices have to be published in an open access database, which is in Finland called as HILMA and in European Union wide TED electronic information delivery system. After publishing contract notices are accessible for everyone. (Iloranta, et al., 2012 pp. 379-388; HILMA, 2014).

The main acquisition methods in the public procurement are open, limited and negotiation procedure. In a limited procedure the numbers of tenderers is limited in the first phase of the procurement process by predetermined conditions for participation which have to be fulfilled by tenderer in order to receive invitation to tender. In the open process there are no predetermined conditions and anyone can participate to invitation of tenders. In the special sector the limited procedure can be used and therefore the limited procedure is studied in more detailed. (Iloranta, et al., 2012 pp. 379-388)

After the invitations of tenders are sent according to the first paragraph, the negotiation process can be used for material purchasing. In the negotiation process the technical and contractual terms could be negotiated and specified for all parties and several negotiation rotations could be used if it is necessary. All changes that occurred during the negotiation process have to be informed to all participants who are selected to negotiation round and tenders much have enough time to update the final tender after the last evaluation round. After the negotiation process the final tender comparing calculation and project or framework agreement can be made with one or several most feasible suppliers. The tender comparing have be performed by using the predetermined evaluation criterions, which are clarified to all parties during the negotiation round.(Iloranta, et al., 2012 pp. 379-388)

However these strict acts can also be problematic for purchasing organisation. In Finland almost 19 000 contract notice was left in HILMA and over 500 complain was left to the market court in 2011. Complain usually interrupt procurement process and causes excessive cost for purchaser. Complaint processing time is typically from several months up to one year and during that time the purchaser is not allowed to make the final agreement. However the threshold for complaining might be low for tenderer; in the same year only 39% of complains was approved by the court. (Iloranta, et al., 2012 pp. 379-388)

4 PUCHASING PORTFOLIO MODEL

Purchasing has become one of the most critical functions in today's organizations and the scope for different material and service purchases can be broad. Therefore purchasing portfolio models have been in the great interests of researcher during the last decades and many different models have been presented. (Iloranta, et al., 2012 pp. 105-130; Bedley, et al., 2008 pp. 40-68) Originally the portfolio theory has its roots in financial investments especially in a means of expected rate of return and balancing the risk of investment. First modern portfolio theory (MPT) for investment purposes was developed and introduced by Markowitz in the early 1950. That model is generally seen as the origin of the portfolio theory. (Gelderman, 2003 pp. 35-61)

Markowitz model is based on assumptions of investors' behaviour and that decisions are based purely on the expected returns of the investments. The main idea is that all decisions are based purely on the combination of the expected returns and risks. So for a given risk level the investor will always select the most profitable one and other way around with given return level investor will select the least risky opinion. Although the Markowitz model is based on the financial investment, it has the same base idea with all different portfolio models after that: its main focus is to efficiently allocate limited resources for the most profitable actions. In a general way this problem is very relevant for purchasing management and the most famous purchasing portfolio model, called as a Kraljic (1983) model, have a general objective to minimize a supply risks. (Gelderman, 2003 pp. 35-61)

It is stated by Bedley, et al. that the Kraljic's model is, although 30 years old, still valid and that many resent models published by other authors are not able to add any advance to the original model. Some authors have elaborated with Kraljic's work and focused on more advanced strategic recommendation, which can however be very useful supplements. (Gelderman, 2003) Original model has also been criticised that the supplier side of the relationship is not taken into account and therefore authors such as Håkansson & Persson (2006) and Olsen & Ellram have focused for development of interdependencies and relatioships between the company and the supplier. (Bedley, et al., 2008 pp. 40-68)

4.1 The Kraljic purchasing portfolio

As already discussed, purchasing portfolio that has published by Kraljic is the basis for all purchasing portfolio analysis and it is still the most cited article in the field of business. For these reasons it is studied in this thesis with deep insight and it is also the red line in this chapter. The portfolio became famous when it was presented in the Purchasing conference in Copenhagen at 1983 by Peter Kraljic, who was at that time office director of McKinsey Company at Dusseldorf. Later on that conference paper was published by The Harvard Business Review with topic "Purchasing must become supply management". In the paper Kraljic proposed a four phase framework for analysing the supply strategy. These four phases will be studied more carefully in this chapter, the four presented phases were: (Kraljic, 1983; Gelderman, 2003 pp. 63-95)

1. Classification
2. Market analysis
3. Strategic positioning
4. Action plans.

4.1.1 Classification

In the first phase all purchased products or product categories are divided to a four different area depending on the total purchased volume or importance of the purchase and associated supply risks. These four areas and dimensions are presented in the figure 6 below, where is also the formed 2x2 matrix. This famous matrix is used for visualising the results from the classification phase. (Kraljic, 1983)

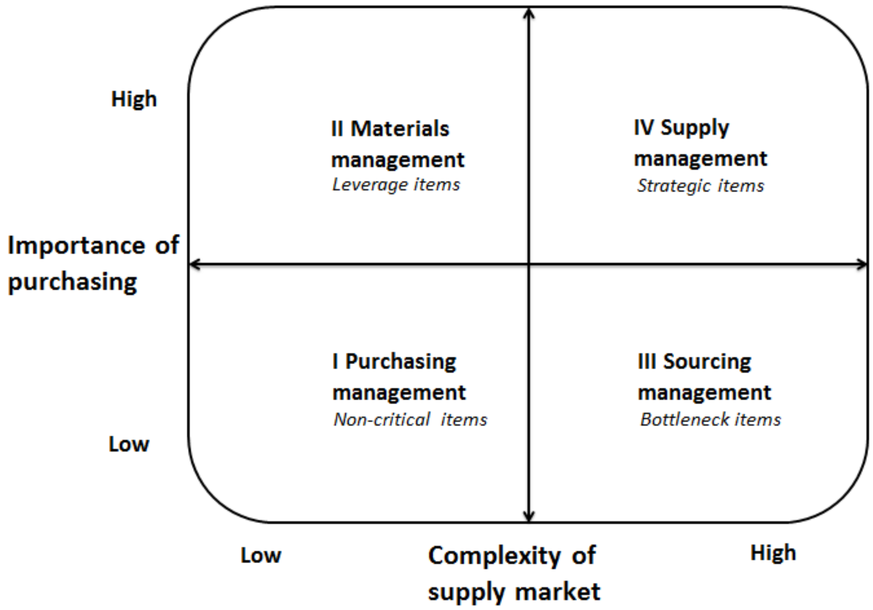

Figure 6 Stages of purchasing management, based on Kraljic (1983)

Importance of the purchasing can be ranked for example by its relative weight from company’s total purchased value and, if a further consideration is needed, the impact of the overall profitably can be added. However the simplest and least speculating way is to add purchasing values to the vertical axis without any correlation and therefore the importance of purchasing is a relatively simple dimension. Complexity of supply market is meanwhile a broader dimension and it is consisted for example by product availability, number of possible suppliers, competitive demand, substitution possibilities and storage risks. (Iloranta, et al., 2012 pp. 105-130; Kraljic, 1983)

Low complexity of the supply market means that there are many available suppliers in the market which are willing to supply the product. These situations are usually called as a buyer’s market. On the other end of the axis there might be only one possible supplier in a monopoly position, when the market complexity is considered high. It is stated that when making the portfolio analysis at the first time the supply managers easily position many products to the right side. This is because of long partnerships and high level of trust for supplier. However these situations are called as a “virtual monopoly” which should be detected and avoided, but not to be confused with beneficial partnerships. (Iloranta, et al., 2012 pp. 105-130)

As a result of that analysing, 2x2 matrix is formed from four different areas: I *purchasing management* for noncritical items, II *material management* for leverage items, III *sourcing management* for bottleneck items and IV *supply management* for strategic items. Kraljic has also presented basic purchasing strategies for all of these areas, although the main focus in the original paper was in the supply management area. (Gelderman, 2003 pp. 63-95) Strategic recommendations for all areas are presented in the below: (Table 3) (Kraljic, 1983)

Table 3 Purchasing requirements for different purchasing functions, based on Kraljic (1983)

Procurement focus			
	Main tasks	**Required information**	**Decision level**
Strategic items	-Accurate demand forecasting -Detailed market research -Development of long-term supply relationships -Make or buy decisions -Contract staggering -Risk analysis -Contingency planning -Logistic, inventory and vendor control	-Highly detailed market data -Long-term supply and demand trend information -Good competitive intelligence -Industry cost curves	-Top level
Bottleneck items	-Volume insurance (with cost premium if necessary) -Control of vendors -Security of inventories -Backup plans	-Medium-term supply/demand forecasts -Very good market data -Inventory costs -Maintenance plans	-Higher level
Leverage items	-Exploitation of full purchasing power -Vendor selection -Product substitution -Targeted pricing strategies / negotiations -Contract / spot purchasing mix -Order volume optimization	-Good market data -Short- to medium-term demand planning -Accurate vendor data -Price / transport rate forecast	-Medium level
Noncritical items	-Product standardization -Order volume monitoring/ optimization -Efficient processing -Inventory optimization	-Good market overview -Short term demand forecast -Economic order quantity and inventory levels	-lower level

Strategy recommendations for each category

The Kraljic portfolio model is criticised by Gelderman (2003) for the fact that it focuses only for strategic items henceforth and left other categories without further consideration. However, in practice all categories should be considered and strategies for all categories have to be made during the portfolio process. (Gelderman, 2003 p. 70) Strategic recommendations for all categories are presented, for example, by Iloranta et al. (2011. pp. 105-130) and these strategic recommendations for other categories are presented here as an addition to the original Kraljic model.

Leverage items are purchased in a high volume from a market from many possible suppliers. Usually this category is the company's highest value category, but amount of different products might be small.

In this category all purchases offers a good opportunities for the company purchasing organisation for price reductions and tough price competition. Usually the competition is fierce and the cost of supplier change is small. Therefore all traditional methods for price competition are available and even a small percentage reduction in prices offers a high real cost reduction. Purchasing in this category might be performed by electronic bidding or auction process. However disadvantages of the traditional purchasing process should be under consideration and continuous price reduction should not be done with the cost of a beneficial supplier partnership.

Noncritical items or *routine items* are low-cost items with a small total value and a very broad supplier base. Daily office supplies such as pens or gloves in a construction site are listed to this category. Because of the low total value of products, it is typical that purchasing management cost can be significant when comparing to the total purchase value.

Automatic purchasing channels and delegation of purchasing tasks for the end users are emphasised actions in this category. For example available internet catalogues or predetermined and automatic purchase orders can be used. Large frame agreements are one way to increase the interesting from supplier point of view. If many small purchases can be combined, the company can create more competition when using frame agreements in the purchasing process. One example of the highly sophisticated business model has been developed by Würth Oyj, where they monitor and fill customer stock levels in the customer's worksite without any specific purchase order. Customer makes only a frame agreement and pay invoices according to use of these items. This kind of service is called as a vendor managed inventory (VMI) and it is commonly used service in these days.

Bottleneck items are purchased in small volumes from very narrow supplier base, usually only from one supplier. Although the purchasing value is small, the bottleneck items are critical for the company success, as those items are critical for the company's main functions success. Very often a bottleneck is formed around spare parts or repair service of the critical production machine. It is also possible that the company creates its own bottleneck product, when making a product development project closely only with one supplier, which is especially typical in IT-software projects.

The main short-term strategy is to ensure the availability of the bottleneck products and reducing damages of stock outs. As a long-term strategy the company should try to reduce its dependency from the bottleneck items or suppliers. This can be done by searching of alternative suppliers or product solutions, when the usage of bottleneck products can be minimized or avoided. In some cases the company should start a product development project to reduce its dependency of the specific product.

4.1.2 Market analysis

The second phase is the market analysis, where the company weights its own strengths and weakness in terms of bargain power against its own suppliers. This market analysis has to be performed regularly and it is important to detect possible changes in the market area. Especially a comparing of the company's demand against the supplier capacity and market capacity is an important factor. (Kraljic, 1983)

Kraljic has suggested a list to the company to weight different market aspects against suppliers. This list is however only suggestive, it is stated that every company should evaluate the list corresponding on current situation. Adaption of the list is presented here (Table 4): (Kraljic, 1983)

Table 4 Purchasing portfolio evaluation criterions, based on Kraljic (1983)

Supplier strengths	**Company strengths**
Market size versus supplier capacity	Purchasing volume versus capacity of main units
Market growth versus capacity growth	Demand growth versus capacity growth *If a company is planning a major extension of the production, it might be forced to pay a price premium for suppliers because of their capacity extensions.*
Capacity utilization or bottleneck risk *If a supplier is running near its full capacity, in a upswing situation it creates a high risk of bottleneck product*	Capacity utilization of main units
Competitive structure	Market share vis-à-vis main competition
ROI and/or ROC	Profitability of main end products
Cost and price structure	Cost and price structure
Break-even stability *A supplier that archives break-even at a lower production level than other has usually more bargain power.*	Cost of non-delivery *If the non-delivery cost is high a company have to use safety stocks or other suppliers if avalable to ensure the availability of the product.*
Uniqueness of product and technological stability *Unique or sophisticated products have less alternative sources and cost competition might be minimal or not existent*	Own production capability or integration depth stability
Entry barrier (capital and know-how requirements)	Entry cost for new sources versus cost of own production
Logistic situation	Logistics

4.1.3 Strategic positioning

In the third phase the company positions all materials that are identified to belong in the area "I supply management" in the figure 6. These strategic items can be then identified as areas of opportunities and vulnerabilities and develop basic strategies for these items. The table, which is called as "The purchasing portfolio matrix", is presented here (Table 5): (Kraljic, 1983)

Table 5 The purchasing portfolio matrix (Kraljic, 1983)

Company strength			
High	Exploit	Exploit	Balance
Medium	Exploit	Balance	Diversify
Low	Balance	Diversify	Diversify
	Low	**Medium**	**High**
			Supply market strength

In the purchasing portfolio matrix strategic items are divided to the three different strategy categories: *exploit*, *balance* and *diversify* category. The company is in exploit category when it has a dominant share of the market and supplier strength is low or medium. In the exploit category an aggressive strategy can be used because the supply risks are slight and generally availability of the items is good. In that situation a tough price competition is usually beneficial, but it has to take care that beneficial long-term supplier relationships are not jeopardized. (Kraljic, 1983)

On the other hand if the supply market strength is high and company strength is low the company have to have defensive. In that category the new suppliers have to be searched and the goal is to diversify supplier base with a new material solutions. If necessary the new material solutions should be searched by increasing of R&D budget. (Kraljic, 1983) A short-term strategy in that category is to increase volumes by aggregating purchases and purchase quantities for increasing the purchase strength. (Iloranta, et al., 2012 pp. 105-130)

When the company is between of exploit and diversify category the price competition might be harmful for the supplier relationships meanwhile researching costs for the new material solutions or suppliers might be excessive. This category is called as a balancing category, where the company has to try to find the happy medium. (Kraljic, 1983)

Many authors have later named the first 2x2 matrix (Figure 6) to the purchasing portfolio matrix, but it is important to notify that originally the second categorisation

(Table 5) was the actual purchasing portfolio matrix. Therefore many authors are only using the first matrix and the actual portfolio matrix is fairly unknown within practitioners. In the literature the term ”Kraljic matrix” usually refers to the first matrix and therefore the meaning of the term have to be determined from its context. Some authors are also implemented the second matrix and its recommendations to the first matrix. However the second matrix is also very usefully tool for strategic items and therefore it should not be forgotten. (Gelderman, 2003 pp. 63-95)

4.1.4 Action plans

In the fourth phase the company should determine a correct action plan for each different identified purchasing category that was detected in the third phase. Individual elements for each areas include factors, such as volume, price, supplier selection, material substitution and inventory policy. Strategies have to be considered for different time periods and as a result, the long and short-term strategies are formed. (Kraljic, 1983)

Kraljic has also defined examples for portfolio implementation strategy, although it is stated that it is not possible to cover all needs and every company’s has to determine its own purchasing strategy. (Table 6) (Kraljic, 1983)

Table 6 Strategic implications of purchasing portfolio positioning (Kraljic, 1983)

Policy issues			
	Exploit	**Balance**	**Diversify**
Volume	Spread	Keep or shift carefully	Centralize
Price	Press for reductions	Negotiate opportunistically	Keep low profile
Contractual coverage	Buy spot	Balance contracts and spot	Ensure supply through contracts
New suppliers	Stay in touch	Selected vendors	Search vigorously
Inventories	Keep low	Use stocks as "buffer"	Boister stocks
Own production	Reduce or don't enter	Decide selectively	Build up or enter
Substitution	Stay in touch	Pursue good opportunities	Search actively
Value engineering	Enforce supplier	Perform selectively	Start own program
Logistics	Minimize cost	Optimize selectively	Secure sufficient stocks

It should be noted that in the *diversify* area volume should be centralized according to table, but it is also stated that as a long-term strategy new suppliers and material solutions should be exploited.

As a result from this phase and the whole purchasing portfolio process, the purchasing organization should explore a range of different supply scenarios and secure the long-term supply strategy. Strategy should be well defined and documented with approval of the top management. (Kraljic, 1983)

4.2 Other purchasing portfolio approaches

As already discussed, most of the other portfolio approaches are based on Kraljic methods and many of them merely change labels of the axis. These approaches include authors such as Elliot-Shircore & Steele (1985) and Van Weele (1992, 1994) (Gelderman, 2003 p. 95). Therefore it is not meaningful to have a closer look for these approaches in this thesis.

However there are some beneficial additions to the original model: a power dependence perspective is implemented to the Kraljic model by Gelderman (2003) and supplier relationships are highlighted by Olsen & Ellram (1997). (Bedley, et al., 2008 pp. 40-69). Iloranta, et al. (2011) also presented shortly different strategies for moving to one category to other, a feature which is missing from Kraljic's and Gelderman approach (Bedley, et al., 2008 pp. 40-69). These approaches are shortly presented in this chapter.

4.2.1 Power-dependence approach

Gelderman (2003) has implemented two more perspectives to the original Kraljic model: *power* and *importance* by adding these to the diagonal axis. The y-axis in the Kraljic matrix was named as the *importance of purchasing*, but the name is changed by Gelderman to *profit impact* which is more explanatory term for the initial meaning. This is also done to x-axis, which were originally *complexity of supply market* and is changed to *supply risk*. (Gelderman, 2003 pp. 110-143)

The main idea of this modification is to add two key elements to the Kraljic approach from the resource dependence theory (RDT). It is stated that RDT is crucial element for purchasing management, for understanding of the supplier relationships and supply markets. In the Kraljic approach the supplier power and dependence is not considered at all, which is one of the most criticised aspect of the original model. Gelderman has solved this by adding those two elements from RDT to Kraljic's first matrix and then rotating the matrix. The formed matrix is therefore called as *the rotated Kraljic matrix*, which is presented here (Figure 7): (Gelderman, 2003 pp. 110-143)

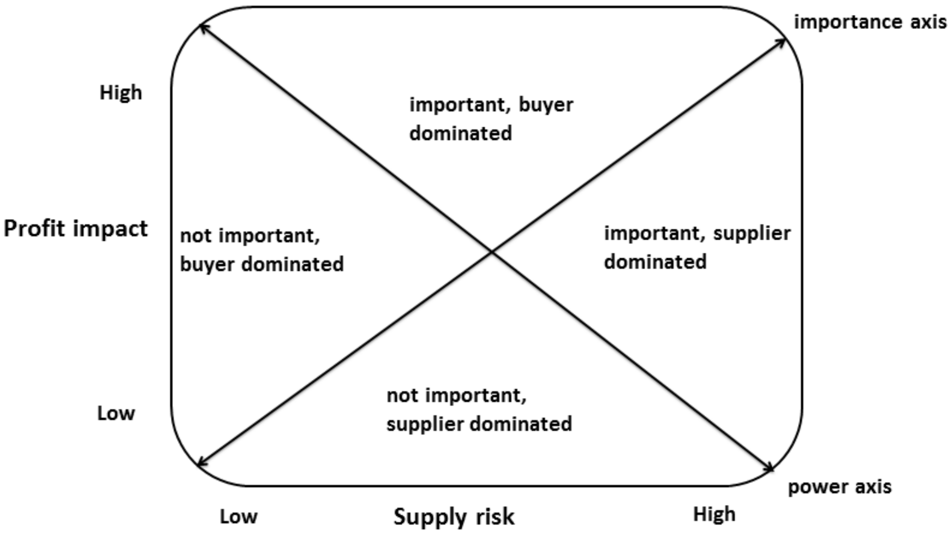

Figure 7 The rotated Kraljic matrix. (Gelderman, 2003 pp. 110-143)

The advantage of the adding the new perspectives are that the original model is now connected directly to the RDT. It is also stated that the Kraljic matrix can be over-simplistic in some situations and adding these new perspectives reflects more closely to the complex nature of the supply market. It is important to understand that the four categories from the initial model are still existed, but following additions to these categories can be made: (Gelderman, 2003 pp. 110-143)

- *Strategic items* are important and either buyer or supplier dominated the relationships
- *Leverage items* are either important or not important and buyer dominated the relationship
- *Bottleneck items* are supplier dominated and either important or not important
- *Non-critical items* are not important and relationship is either supplier or buyer dominated. (Gelderman, 2003 pp. 110-143)

However, this model has also some drawbacks, it is stated that the matrix doesn't work well when there are balanced power between the supplier and buyer. Balanced power is a typical situation between relationships, so it is major lack for the model. Furthermore the model is limited because of its dependency of supply risk and profit impact. It is stated that power dependency between supplier and buyer would be a more generic model. Geldermand also doesn't provide any generic strategic recommendations beyond of recommendations presented by Kraljic and especially recommendations of how to move from one category to other is missing. It is only stated by Gelderman that every purchasing department should try to find the best strategy for moving to a better position in the matrix (Bedley, et al., 2008 pp. 110-143)

4.2.2 Supplier relationship approach

The Kraljic matrix is a criticised for the fact that it is not focused interdependent relationships between the buyer and the supplier as already discussed. Therefore Olsen & Ellram (1997) have researched of different supplier relationships and their effect for the portfolio analysis. As a result of the research the portfolio analysis was divided to different steps:

1. Analysis of the company's purchases
2. Analysis of the supplier relationships
3. Development of action plans.

The result of the research is based on the Kraljic model with the addition of the supplier relationship consideration. It is stated that when only considering product markets without the supplier relationship, it will lead to too simplistic view from the real situation. (Olsen, et al., 1997) The results from this research are studied more carefully in this thesis.

Step 1: Analysis of the company's purchases

In this step the main idea is to categorise purchases to the Kraljic matrix. Although this is done also in the initial model, the difference is that supplier relationships should also take in consideration in this model. Idealized description and normative suggestion of supplier relations are provided by authors. The provided category description is basically same in the Kraljic model, but suggestions for supplier relationships management are added and these suggestions for relationship management are descripted in the below. (Olsen, et al., 1997)

- *Leverage category* the goal is to create mutual respect and good two way relationship with suppliers and should be managed by system contracting.
- *Noncritical items* should manage as simplistic as possible and administrative cost should be minimized.
- *Strategic items* should be handled by close relationships between suppliers. Early supplier involvement and joint operations of product development with long-term value are important factors. Supplier in this category should be a natural extension of the company.
- *Bottleneck items* should be managed by having suppliers involved to concurrent engineering and involving of product value analysing for increasing the supplier interest to further development. (Olsen, et al., 1997)

Step 2: Analyse the supplier relationships

The Kraljic matrix is focused on power between the actors in the strategic item category and how this power relationship should be managed. This is however considered dangerous by Olson, et al. (1997) because of the rapid changes in today's market conditions. Therefore they presented that power and risks are only two additional factors when managing the purchasing strategies. Meanwhile they presented a new second matrix, where the suppliers are segmented by means of their *relative supplier attractiveness* against the *strength of the actual relationship*. Supplier attractiveness is presented in the research by dividing it to five main key points: financial and economic, performance, technological, organizational, cultural and strategic factors. However it is stated that only the general points are presented and the company has to consider the most important factors of the supplier attractiveness depending on the market situation. Determined key points have to be weighted individually and each supplier is ranked based on its relative attractiveness. (Olsen, et al., 1997)

Meanwhile the strength of relationship is consisted for example by amount of financial and social exchange or knowledge exchange. Also factors such as amount of personal contacts, duration of existing relationships and time spent on interaction are considered as relationship strength factors. (Olsen, et al., 1997)

As a result the new matrix is formed (Figure 8), where suppliers are placed according to descripted criterions and decisions made by purchasing managers. The area of the circle reflects current allocation of resources to relationship management of each supplier. (Olsen, et al., 1997) The area of the circle could be also used for reflecting the total purchased volume of the supplier. (Iloranta, et al., 2012 pp. 105-130)

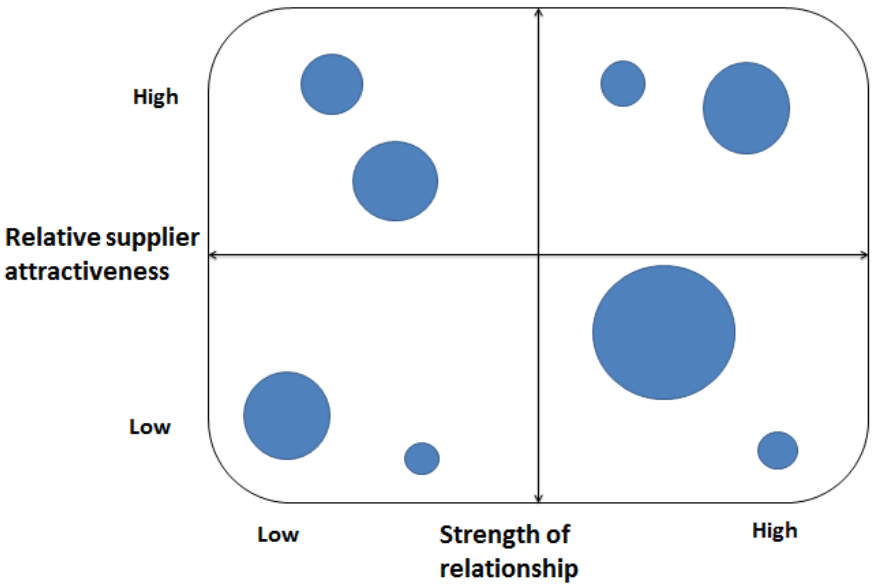

Figure 8 Analysis of supplier relationships, based on Olsen, et al. (1997)

Step 3: Develop action plans

The last step is to develop action plans. Three generic approaches are descripted according of the supplier placement in the matrix. The first one is considering of the upper left corner where relationships should be strengthened for example by increasing of volumes or communication. The second suggestion is for upper right corner where supplier relationships should be maintained by using enough resources for relationships management. The last area is lower row of the matrix where relative supplier attractiveness is low and the company should do it best to change these suppliers to more attractive ones. (Olsen, et al., 1997)

4.2.3 Strategic moving directions

After the Kraljic matrix is formed, one of the main questions is to consider how to move to the better position in the matrix. The purchasing managers should be able to create strategies for the each area in the matrix, but also strategies for moving to different area. However many authors, including Kraljic and Geldermand, have not provide any recommendation for changing the area. (Gelderman, 2003; Kraljic, 1983)

Some general strategies are recommended by Iloranta, et. al (2011) and the advantageous movement directions to the company are presented here (Figure 9) as an addition to the initial matrix. These advantageous moving directions should be considered when making purchasing strategies. (Iloranta, et al., 2012 pp. 105-130)

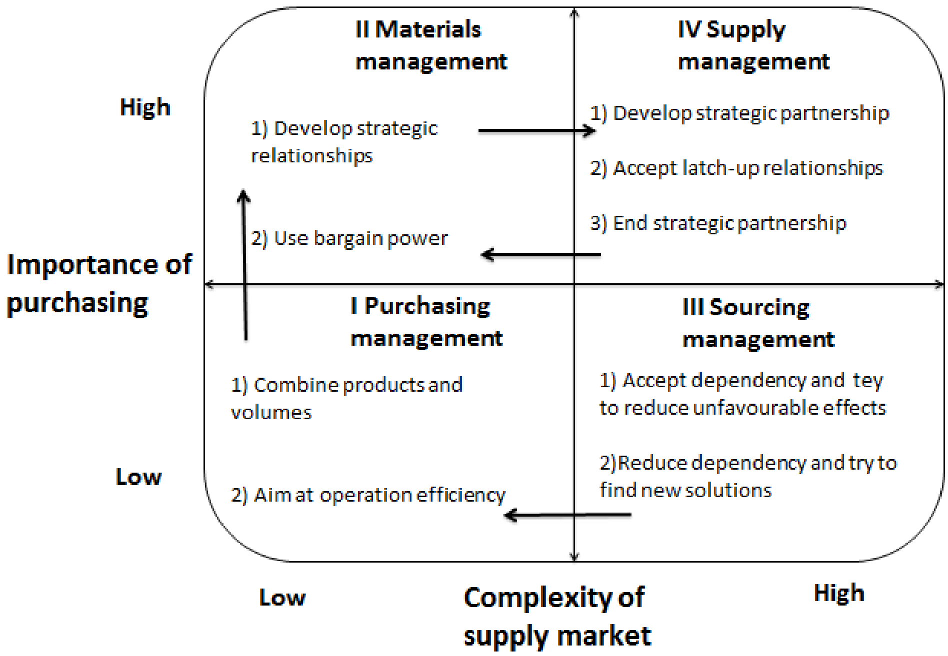

Figure 9 Basic strategies and movement directions (Iloranta, et al., 2012 pp. 114-130)

It is summarised that most of the new insights are discovered when fulfilling the Kraljic matrix. This matrix can be used as a tool for consideration when fulfilling the matrix and then the basic strategy for each group can be determined and feasible moving directions have to be considered during the strategy planning phase. (Iloranta, et al., 2012 pp. 114-130)

5 SUPPLIER SELECTION

Supplier selection is one of the most challenging decisions for purchasing managers and it is one of the main steps in the purchasing management process. The selection decision has an extensive impact for the company success; the right supplier selection will be the vital component to the company's competitiveness and success in future. (Weele, 2010; Bedley, et al., 2008 pp. 105-114) However the supplier selection process is a complex multi criteria decision, where different selection criterions are hard to combine because of both quantitative and qualitative nature of the criterions (Saaty, 2008).

In this chapter a broad vision of different problems and used selection criterions will be presented and studied. One part of the supplier selection is a specification determination, the purchaser has to determine the specification that have to be fulfilled by suppliers and also fulfil the company's actual needs. After that the selection methods and specification determination are presented, different methods for selection are presented with closer look to the a*dvanced hierarchy process* (AHP), as it turns out that it is widely used among researchers and industrial managers.

5.1 Selection criterions

One of the first steps in the supplier selection process is to choose the right selection criterions. Correct selection criterions are a key to the successful supplier selection as it assures that suppliers are compared equally and with relevant success factors. Selection criterions have to be defined before the supplier selection and defined criterions have to be implemented correctly to the selection process by using predetermined selection method. (Bedley, et al., 2008) Importance of the criterions is emphasised in the public procurement process, as unclear selection criterions might increase possibilities for complaints.

5.1.1 Dickson's criterions

Selection criterions have been studied and focused by researchers and purchasing managers actively since 1960's, when one of the first comprehensive researches was presented in 1966 by Dickson. (Benyoucef, et al., 2003) Dickson's study was based on an enquiry sent for professionals of the National Association of Purchasing Managers, were top level purchasing managers ranked 23 of predetermined supplier selection criteria in order of their importance. Results from the study are relevant even today, as can be seen from table 7, where the Dickson's score are compared to a more recent research presented by Thiruchelvam, et al (2011).

Research from Thiruchelvam, et al., (2011) different criterions was studied based on their appearances in publications from 1966 to 2001 and 2001 to 2010. Result from the study can be seen in the below (Table 7), where the findings from the both research, Thiruchelvam, et al (2011) and Dickson (1966) are combined. The table is in order of overall appearances of publications, based on Thiruchelvam research. The Dickson's scores and rank are presented in the two last columns.

Table 7 Top ten criterions in order of overall appearance compared with score and rank from Dickson study. Based on Dickson (1966) and Thiruchelvam, et al., (2011).

Criterion	**1966-2001**	**2001-2010**	**Overall**	**Dickson's score**	**Dickson's rank**
Price	81	37	118	2,758	6
Delivery	75	36	111	3,417	2
Quality	71	37	108	3,508	1
Production facilities and capacity	35	20	55	2,775	5
Technical capability	30	24	54	2,545	7
Management and organization	17	22	39	2,216	13
Financial position	15	17	32	2,514	8
Repair service	18	11	29	2,187	15
Geographical location	17	12	29	1,872	20
Performance history	11	10	21	2,998	3

The research made by Thiruchelvam, et al. (2011), shows that Dicson's criterions are still presented in the literature today and the Dickson's study is the base for most of the resent studies (Benyoucef, et al., 2003). More recent comprehensive researches have been made in last decades including authors such as Roa, Ellram and Stamm. The research of Ellram is studied in more detail below, as it is widely referred research in the branch of business. (Bedley, et al., 2008)

5.1.2 Ellram criterions

Research presented by Ellram (1990), the selection criterions where studied in a broader scope and criterions where divided to a hierarchy structure. Structure was based on criterions reported by case studies. In the uppermost level the four main supplier selection criterions were: *financial issues, organizational culture and strategy issues, technology issues* and *other issues*. (Ellram, 1990) The hierarchy structure is presented in the table 8:

Table 8 Supplier partnership selection criteria (Ellram, 1990)

Supplier selection criteria
Financial issues
Economical performance
Financial stability
Organizational culture and strategy issues
Feeling of trust
Management attitude for the future
Strategic fit
Top management compatibility
Compatibility across levels and functions of buyer and supplier
Supplier's organizational structure and personnel
Technology issues
Assessment of current manufacturing facilities/capabilities
Assessment of future manufacturing capabilities
Supplier's design capabilities
Supplier's speed in development
Other factors
Safety record of the supplier
Business references
Supplier's customer base

Financial issues include factors such as performance and stability of the company based on an historical data available on public sources or a review of suppliers records if available. It is stated that the poor financial stability of the supplier will reduce possibilities for the development of strategic partnerships, as the supplier has to concentrate to its own survival. Organizational culture is mostly based on intangible factors such as feeling of trust, management attitude, outlook and functions between supplier and purchaser. These criterions are mostly based on a judgmental raking by purchasing managers. It can be summarised that organisational culture describes how the two firms are able to work together. (Ellram, 1990)

Technology factors include the supplier capability to design new innovations, development and speed for product changes. As a result of the research is it stated that the most usable method for ensure the technical development capabilities is a reviewing of suppliers production and development facilities. A good estimate can also be obtained by using availability and amount of technical staff into consideration when evaluating technical development capabilities. Other factors include related factors that can be used in selection criterions, such as safety record and references. (Ellram, 1990)

5.1.3 Katsikeas criterions

After the studies of Roa, Ellram, Stamm and others, a professor from Leeds University, Constanttine Katsikeas grouped criterions to more general conclusion on 2004, based on reviews of the literature in the field. (Figure 10) Criterions were: *competitive pricing*, *reliability*, *service* and *technological capability*. Although Katsikeas study was focused for the IT supplier selection, are these fundamental criterions fully relevant for all supplier selection. These criterions are presented in the figure below and all also selected for approach point of this thesis. (Katsikeas, et al., 2004)

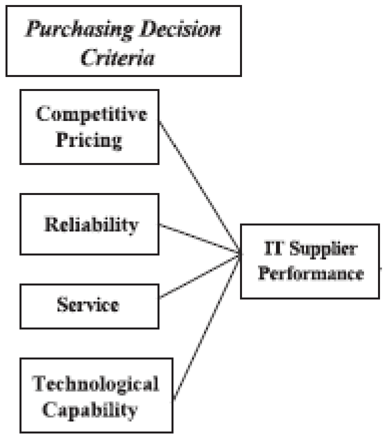

Figure 10 The conceptual framework for purchasing decision criterions. (Katsikeas, et al., 2004)

Competitive pricing

Competitive pricing is the most common and the most citied element for traditional approaches to purchasing. "Lowest prices" has been usually the most important determinant of the purchasing decision process, especially when purchasing routine products. However resent studies have shown that more and more weight is given for other cost factors, such as quality and services. Therefore the competitive pricing is nowadays representing more overall cost than just the purchasing price. (Piercy, 1997; Katsikeas, et al., 2004)

Reliability

Reliability has been devoted by particular attention in the field. In the research different aspects of the reliability is clarified according to the supplier situation. When selecting multi-sourcing suppliers the most critical aspect is right time deliveries and production reliability, meanwhile when selecting a single-source supplier the most important aspects is the product reliability. (Katsikeas, et al., 2004)

Scope for reliability is also broadened by authors such as Swift (1995) for including deliveries, fulfilment of agreements and distribution. Even supplier honestly and regular communication are often counted as part of the reliability.

Service

Reliability and price have been reported as the most important decision criterion but it is stated by Katsiekas, et al. (2004) that many studies have also raised service attributes as a principal determinant in decision making process. Service offerings are emphasised especially in studies where the main focus is in performance and quality management, from where it is implemented also to the purchasing management. (Katsikeas, et al., 2004)

Service can include factors such as maintenance, installation or training etc. Also advanced delivery systems or customer service are counted as the service, where the company can archive cost reductions from other cost factors. (Katsikeas, et al., 2004)

Technological capability

The technological capability includes assessment of supplier design abilities and the speed for taking the new design into production. Supplier's ability to move fast in the market or long term development will add value to the purchaser as technical innovations and long-term development projects can be successfully performed. On the other hand supplier without the technological capabilities may become to a burden, if the development speed is slower than market average. (Ellram, 1990)

5.2 Determining specifications

One of the most critical point of the supplier selection process is determining specifications for the request for tenders (RFQ). Although this might sounds as an obvious detail, determining a good specification will be the base for the successful supplier selection process. Poorly made specification could cause a quality decrease or limit different suppliers' ability to tender the most suitable or lowest overall cost solution. (Morledge, et al., 2013)

Quality decreasing is based on aggressive price competition which will lead suppliers to fulfil exactly the minimum requirements which are defined in the specification. In aggressive price competition specification will become the minimum requirement and all additions will affect negatively to the tenders comparison. By going to aggressive price competition the customer will increases its own risk and also the importance of the specification. (Morledge, et al., 2013)

On the other hand if the customer uses strict specifications it might decrease the possibility for the supplier to offer different solution and it might limit new innovations in the field of business. Strict specification is also typically made in close cooperation with current supplier, the situation where the supplier could use its position to make the specification most suitable for its own business model. To prevent the most typical problems in the procurement process, called as *pitfall*, ten basic steps of are listed by Iloranta et. al. (2012) and four of those steps are preventable in the specification determining process. These four steps are studied more closely in the below. (Iloranta, et al., 2012 pp. 245-255)

Determining of the acquisition is a process of determining needs and targets of the future procurement. In this phase customer should get to know of different possibilities in the field and possible suppliers. Also in phase the scope of the procurement should be determined and how many of different pieces the acquisition should be divided.

Finding of the potentially suppliers can be made after the needs is determined and one of this phases main goals is also to find potential new suppliers and to got wide perspective of different possibilities for the specific market area.

Request for suppliers to make open proposals is a phase where the chosen suppliers can make a proposal for their solutions to fulfil the requested needs. Usually in this phase the specification can also be clarified and chanced according to the proposals.

Supplier's methods for minimizing the risks should be made in the same phase or after the requesting of proposals. Suppliers are asked to estimate major risks concerning of the supply chain and life time of the offered product. Suppliers should also make a proposal how risks can be avoided or minimized.

To summarise it is important to have good relations with manufacturers and suppliers to have a view for changes in the field and the possibility of new innovations. To do that a constant dialogue between the purchaser and suppliers should happen. (Iloranta, et al., 2012 pp. 245-255)

5.3 Methods for supplier selection

As earlier discussed, the supplier selection is a complex multi-criteria decision and a successfully supplier selection have major impact in the company's future success. After the selection criterions are determined one question remains: how to compare each criterion between each other and against others suppliers? To do that a systematic method for criterion comparing is a much needed tool for archiving the desirable result. (Benyoucef, et al., 2003)

Different supplier selection methods and tools have been into great interest of researchers and practitioners in the field of purchasing management. Broad investigations of those methods is performed, for example, by De Boer (2001), Bedley et al.(2008) and Sonmez (2006). The research performed by Bedley et al.(2008) is very board and comprehensive, and therefore the result of the study is presented below (Table 9). In the research four different category of selection methods are presented, based on the used methods.

Table 9 Different methods for supplier selection (Bedley, et al., 2008)

Multi criteria decision making	**Mathematical programing**	**Multivariate statistical analysis**	**Artificial intelligence**
AHP, outranking, judgemental modelling, multiple attribute theory	Total cost based approaches, non-linear programing, mixed integer programing, linear programing, goal programing	Structural equation modelling, principle concept analysis, confidential interval approach	Neutral network, case based reasoning, Bayesian belief network

In a research performed by Huang (2007) a different methods from business universities and engineering universities were analysed and compared. The main focus in the research was to compare different approaches from different universities. Publications from engineering schools were criticized for overemphasising the need of quantitative optimisation and overlooking the importance of qualitative factors such as business strategy integration, meanwhile business researchers were emphasising philosophical issues and supplier selection was only based on qualitative methods. It was stated that the best result could be achieved by integrating both qualitative and mathematical optimisation. (Huang, 2007)

As a result in Huang’s study it was concluded that multi-criteria methods are good for integrating qualitative and mathematical optimization methods together and such methods are already widely used in practice. Different variations of widely used multi-criteria methods such as AHP, multiple-criteria decision-making (MAUT) or multivariate outranging methods are based on structured decisions problems and both qualitative and quantitative criterions could be used similarly. It was stated by Huang that any one of these methods could be effective when used criterions are correct. (Huang, 2007)

One of the most popular methods among researchers is the AHP, which is developed by Saaty in the 1970s (Benyoucef, et al., 2003). It is a robust multi criteria decision making tool and it is also widely used among supplier selection in an industrial business.

(Bedley, et al., 2008) For these reasons, and keeping in mind the fact that the most important factor in successful decision method implementation is to have the correct decision criterions, the AHP model is selected for further studying and will be used as the selection decision tool in this thesis. (Huang, 2007)

5.3.1 AHP

As discussed earlier the AHP is widely used method among the researchers and supply managers as a tool for making the best overall decision. AHP is a multi-functional decision tool and it can be used in all decision making problems. There are examples like project selection, product formulation and microprocessor selections performed by AHP model. (Bedley, et al., 2008) Even a place for a new city is once decided with AHP method. (Saaty, 2008) It is based on pairwise comparison in a hierarchy structure assembled from selection criterions of the decision problem. (Benyoucef, et al., 2003)

The AHP model is consisted from four steps. Steps are listed here according to Saaty (2008):

1. Define the problem and determine what information is needed or available.
2. Structure decision hierarchy from top to down, when the goal is the uppermost part of the hierarchy. Each level after that should in more detail than the upper one and lowest level should be alternatives, e.g. different suppliers.
3. Pairwise matrices have to be assembled according to previous steps. Each level before alternatives should be compared pairwise by all elements on that same level.
4. Weighting of the different elements in each level will be formed from pairwise comparisons. When pairwise comparisons are made for all levels and lastly on down-most level the best alternative could be calculated mathematically.

The AHP method’s main advantage is an ability to relatively rank choices and combine all separate decisions together. It is also hard to fiddle judgements in means to archive predetermined results, because the AHP will detect if judgements are inconsistent. (Coyle, 2004) However, the AHP method has some drawback, as like every other method. It only works in special type of matrix, called as a *positive reciprocal matrix* and because if its nature it will only show relatively ranking of different selection alternatives. (Coyle, 2004)

5.3.2 Structure decision problem

The first step in the actual AHP process is to structure decision problem from top to down so that the *main goal* is the uppermost level. Although the problem could be divided to as many levels as desired, it is usually divided to four levels because of easier handling with still enough comprehensive criterions. (Saaty, 2008; Sevkli, et al., 2007)

As the main goal is the most uppermost level, the second level is the *main criterions*, which should be determined every time separately depending on goal and available information from the selection problem. After the second level there is a last hierarchy level before alternatives. These criterions are called as a *covering criterion*, which connect the main criterions to the covering criterions and from there to the alternatives, in this thesis to the suppliers. (Saaty, 2008)

After the levels are determined, the weighting of each criterion of every level can be calculated by using the pairwise comparison. After the pairwise comparison is performed for each level, from top level to the bottom, it is possible to calculate the best alternatives from given criterions. The pairwise comparison and the calculation based on the comparison results are presented in the next chapter. However the main idea is that each comparison is made separately and results of these comparisons are combined by the calculation. When the comparison are made separately and also documented it will also help to notify possible areas of development. It also improves purchasing managers' possibilities to understand all the available information and helps to understand the real importance of specific part of the information. It is said that understanding the importance of available information is one the biggest challenge when making the decision. (Saaty, 2008)

One example of structured selection problem is shown in the below (figure 11). Structure is made by Sevkli et al. (2007), when performing a case study to Turkish television maker Beko concerning the supplier selection problem. Although Sevkli's main study was to compare two different methods, AHP and data envelopment analytic hierarchy process (DEAHP), the main structure are exactly the same in both models. From this picture the main idea can also be clarified, the goal is supplier evaluation, the main criterions are after the goal and covering criterions are before the alternatives. By using the pairwise comparison from top to bottom priorities can be calculated based on judgement in each level. (Sevkli, et al., 2007)

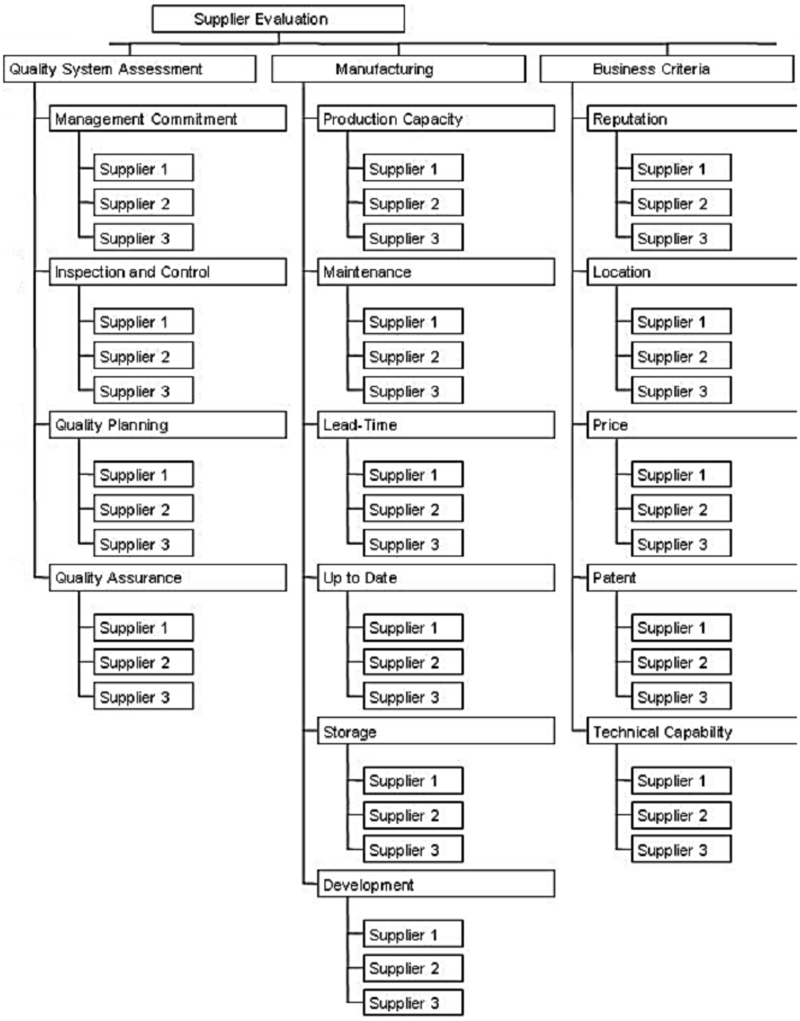

Figure 11 Structured selection problem criterions (Sevkli, et al., 2007)

5.3.3 Pairwise comparison

For using the structured selection hierarchy in the most successfully way, the pairwise comparison has to be made by a standardized numerical way for each judgement. To do that, Saaty has presented a framework for the pairwise comparison ranking, which was developed to be used in the AHP method as a judgement tool. (Bedley, et al., 2008)

In the framework of the pairwise comparison a scale of absolute numbers is determined by Saaty (2008). The scale and its meanings are presented in below (Table 10). As can be seen from the table, Saaty has determined the scale from 1-9, where 1 is equally importance and 9 is the most important or better solution than compared alternative. If the importance is opposite, the reciprocals numbers are used. (Saaty, 2008)

Table 10 The fundamental scale of absolute numbers (Saaty, 2008)

Intensity of importance	**Definition**	**Explanation**
1	Equal Importance	Two activities contribute equally to the objective
2	Weak or slight	
3	Moderate importance	Experience and judgement slightly favour one activity over another
4	Moderate plus	
5	Strong importance	Experience and judgement strongly favour one activity over another
6	Strong plus	
7	Very strong or demonstrated importance	An activity is favoured very strongly over another; its dominance demonstrated in practice
8	Very, very strong	
9	Extreme importance	The evidence favouring one activity over another is of the highest possible order of affirmation
Reciprocals of above	If activity *i* has one of the above non-zero numbers assigned to it when compared with activity *j*, then j has the reciprocal value when compared with *i*	A reasonable assumption
1.1–1.9	If the activities are very close	May be difficult to assign the best value but when compared with other contrasting activities the size of the small numbers would not be too noticeable, yet they can still indicate the relative importance of the activities.

When making the pairwise comparison, it should be noted that if the subject of the criterion is objective, their interpretation is always subjective. However it could be validated that using judgments to derive values with a good credence can be done. Example of this validation is made for example by Saaty (2008). The test was performed by using a group of 30 persons where they have to obtain a consensus of judgements for different drink consuming in the USA. Consumed drinks in the USA are provided also by official statistical data sources, so result obtained by AHP method could be compared to official statistic. (Saaty, 2008)

In the test study group have to have consensus judgements in the most typical drinks consumption compared to each other, for example coffee vs. wine. The group judged that coffee is consumed nine times more than wine. By doing likewise pair comparisons to all drinks and calculating result from all judgements it can be noted that results derived from AHP model are actually very close to official figures. (Saaty, 2008) Whole result from study group can be seen in the table 11 below. From this picture in could be noted that when making the pairwise comparison the opposite result is always inversed from first comparison, for example like coffee – wine is 9 and wine – coffee is 1/9.

Table 11 Result from group study. (Saaty, 2008)

Drink consumption in US							
	Coffee	Wine	Tea	Beer	Soda	Milk	Water
Coffee	1	9	5	2	1	1	1/2
Wine	1/9	1	1/3	1/9	1/9	1/9	1/9
Tea	1/5	2	1	1/3	1/4	1/3	1/9
Beer	1/2	9	3	1	1/2	1	1/3
Soda	1	9	4	2	1	2	1/2
Milk	1	9	3	1	1/2	1	1/3
Water	2	9	9	3	2	3	1

The same kind of validation test was also performed in the thesis seminar by author. In the test a consumption of different alcohol types in Finland were compared by the seminar group. Seminar group was consisted from 20 persons. After the pairwise comparisons the result was compared to the official report from National Institute of Health and Welfare. The result was similar than official report, taken into account the fact that consumption of alcohol is always person dependable.

5.3.4 Priority calculation

When the pairwise comparison table is fulfilled by judgements, the priority of each criterion or alternative can be calculated. Calculation is based on an eigenvector of each matrix, which is called as a *relative value vector* (RVV). To measure reliability or consistent of the judgements, the *Consistency ratio* (CR) should also be calculated. The CR will indicate the consistent of judgements and it should always be less than 0,1. If CR is more than 0,1 judgements are untrustworthy and judgements should be made again. It indicates that judgments are not consistent, which might be caused by lack of information, comprehension difference or confusion with criterions. The 0,1 limit is based on experiences from the field. (Coyle, 2004)

A theory behind the eigenvector calculation is based on the fact that AHP matrix is always a reciprocal matrix, because the following conditions are valid in each time:

$a_{ii} = 1$, $a_{ij} = 1/a_{ji}$, $i \neq j$ and the fact that matrix is always a square matrix. For such matrix there is always a vector ω that fulfils the following equation:

$$A\omega = \lambda\omega. \qquad 1.$$

Vector ω is called as the RVV and λ is an eigenvalue. For the consistent matrix $\lambda = n$ where n is an order of the matrix, because of the fact that consistent matrix fulfil following statement for all values of i, j and k.

$$a_{ik} = a_{ij}a_{jk} \qquad 2.$$

RVV (ω) can be calculated by a standard approximation method as shown in below. Approximation from the eigenvector could be calculated by many different methods, but the following approximation method gives good approximation results with reasonable amount of calculation. (Coyle, 2004)

First step in the approximation process is to calculate a product of each row and take an *n*th root from every one of those products, where the *n* is a dimension of the matrix. After that the result should be normalized to achieve the eigenvector ω. An example of AHP calculation can be seen in the below (Table 12) and it will be used also in further AHP calculation examples in this thesis.

Table 12 Example of AHP matrix (Coyle, 2004)

	A	**B**	**C**	**D**	**n^{th} roof of product values**	**Eigenvector**
A	1	1/3	1/9	1/5	0,293	0,058
B	3	1	1	1	1,316	0,262
C	9	1	1	3	2,279	0,454
D	5	1	1/3	1	1,136	0,226
Totals					5,024	1

After calculating the eigenvector, also the eigenvalue λ could be calculated by multiplication of $A \times \omega$, which gives a vector Vnx1. Because of the definition of the eigenvector, $A\omega = \lambda\omega$, an approximation of λ could be calculated by dividing each value of $V_n \times 1$ by corresponding eigenvector value $\omega_{n\times1}$. It gives $n\lambda$ values and an average of those results is an estimate for λ. After that the consistency ratio could be calculated by using the equation below.

$$CR = \frac{\lambda - n}{n - 1} \qquad 3.$$

The result can be seen in the table 13, where the eigenvector ω is already calculated in the table 12 and the eigenvalue λ is calculated in the table 13, where calculation results are visible. (Coyle, 2004)

Table 13, calculated average λ, based on Coyle (2004)

AHP Vector		Eigenvector [ω]		V	Each value divided by corresponding eigenvector value	λ
[A]	x	0,0584	=	0,241	=	4,133
		0,2619		1,117		4,264
		0,4536		1,919		4,231
		0,2261		0,931		4,118
	Sum	1,0000			Average	4,19

In the table 13 the average of the eigenvalue is calculated, and the consistency ration is also calculated by using given the equation 3. The result in this example is (when n=4) $\mathrm{CR} = 0{,}062$ which is well under the critical limit 0,1. (Coyle, 2004)

6 SUPPLIER PERFORMANCE EVALUATION

One of the key elements for creating and especially maintaining an effective supplier relationship is a supplier performance evaluation. Performance evaluation tools are necessary for confirming that suppliers are functioning as agreed and pointing out potential problems and points for possible efficiency improvements. In a research made by Gunasekaran, et al. (2004) supply managers where asked about the impact of return of investment (ROI) rate when additional efforts were put to supply chain management. Result from the survey shows that 76% of responses agreed that the efficient performance evaluation system has increased ROI and also 66% of responses noted that the effective supplier performance management has improved the market share growth.

In this thesis the metrics will be studied from the literature and the most efficient metrics will be pointed out, when keeping on mind the needs and available supplier performance data in this thesis case. After the literature review of the different methods and metrics, the results will be pointed out to the organisations key persons and an internal group work will be kept. Purpose of the group study is to archive an understanding of an appropriate performance measures and metrics, which will most efficiently fulfil organisations requirements.

After the group study has been performed, the chosen metrics will be tested by using the available purchasing data and the test results will be reviewed internally and further tested. The most appropriate metrics will be taken implemented into use after that, but the implementing process will take some time. The same principle has been used in a research made by Cormican, et al. (2007) at a research where large multinational organisation supplier performance evaluation was accomplished. (Stevenson, 2011 pp. 689-691; Iloranta, et al., 2012 pp. 311-316)

6.1 Measurements

Traditionally the supply chain measures have been focused for the cost and customer response measured by a single performance measurement. In the single performance system the supply chain is measured only from one aspect, typically because of its simplicity. However single performance measurement doesn’t measure the supply chain performance inclusively and therefore a more advanced framework is recommended. In order to create an effective performance metrics framework a four main questions are presented by Beamon (1999). These questions should be considered at the beginning of the measurement process.

- What to measure?
- How to integrate different metrics into measurement system?
- How often measurements should be performed?
- When re-evaluate the metrics?

Literature study from the field reveals that many researches have been made from this subject and some companies (e.g. Rotek) even publish their supplier performance evaluation boards. Comprehensive theoretical researches are made for example by Beamon (1999) and Gunasekaran, et al. (2001; 2004) about a theoretical framework of supplier performance evaluation. (Iloranta, et al., 2012 pp. 297-312) These two publications are comprehensive studies from the branch of business and two different concepts are presented. For these reasons are these two papers selected for further studying in this thesis.

The main difference between researches is that Gunasekaran, et al. (2004) emphasise the importance of measurement in every hierarchy level and also in each supply chain activity level. In the research performance metrics were divided to the three different hierarchy level: operational, tactical and strategic level and activities were divided to four: plan, source, make / assemble, deliver. Beamon (1999) meanwhile emphasise the need for supplier measurement in three different aspects but does not divide measurements in different hierarchy levels. Aspects in the Beamon research are: resource, output and flexibility measures. Both of the researches have been chosen for more detailed study in this thesis.

6.1.1 Beamon's research

Beamon emphasises the importance of the right and coverage measurements to archive effective performance measurement model. According to Beamon the main weakness of single or not fully coverage measurements is that it does not adequately describe the whole system performance. For example if only measurement is focused to the cost level, it might cause severe harm to other functions, such as customer service or quality. Therefore the effective measurement metrics should fulfil certain characteristics. Characteristics of effective performance measurement system are researched by Beamon (1999) and these characteristics are listed in the below. (Table 14)

Table 14 characteristic of an effective performance measurement (Beamon, 1999)

Characteristic	**Description**
Inclusiveness	Measurement of all pertinent aspects
Universality	Allow for comparison under various operation conditions
Measurability	Data enquired are measurable
Consistency	Measures consistent with organisations goals

In the same research the inclusiveness measurement were categorized by the type in three measurement categories: *resource*, *output* and *flexibility* measures. (Table 15) Each of these categories has been identified as a vital component of the supply chain success and at least one measurement should be in use from every category. It is noted that many of practitioners are only relying for resource measurements because it is the most direct measures. Meanwhile the output and especially the flexibility measurements are left out from evaluation system because of the limited availability of the quantitative data and an indirect effect to the purchasing performance department. However both of these measurements are a major advantage to the company and supply chain performance from those areas should be measured (Beamon, 1999).

Table 15 Inclusiveness measurements types (Beamon, 1999)

Performance measurement type	**Goal**	**Purpose**
Resources	High level of efficiency	Efficient resource management is critical to profitability
Output	High level of customer service	Without acceptable output customers will turn to other supply chains
Flexibility	Ability to respond to a changing environment	In an uncertain environment, supply chains must be able to respond to change

These three categories fulfil the inclusiveness characteristic according to Beamon, which was the main focus of the research. More detailed comprehensive study of each category and examples of different usable metrics are studied in chapters below.

Resources

Resource measures can include a wide variety of different metrics such as costs, inventory and energy usage. Resources could be measured by quantity as a minimum requirement or composite resource efficiency. It is noted that the resource minimisation is often used as a general goal of the supply chain analysis with the cost of reduced flexibility, because it is often left out from evaluation. The most typical performance measures are listed in table 16.

Table 16 Resource metrics. (Beamon, 1999)

Metrics	Clarification and examples
Total cost	Total cost when using purchased product
Distribution cost	Cost of logistics and order handling
Manufacturing cost	Cost from labour and machine hours
Inventory	Capital cost of obsolete inventory or finished goods
Return on investment (ROI)	Profitability of the organisation

Output

Output of the supplier could be understand in the most simplest to output from the supplier factory or deliveries. Both of these measures are usually easily measurable from order handling system and therefore these are most used output measurement criterions. However output metric category also includes more complicated measures such as quality or customer satisfaction. (Beamon, 1999)

Minimum level of output is often specified by the frame agreement, meanwhile the added value of the better output level is rarely considered, although it might be a crucial benefit for example when production capacity is increased. Output measures are also usually based on past ordering data; while managers are truly interested from the future output performance level. Examples of output metrics stated by Beamon are listed in here (table 17). (Beamon, 1999)

Table 17 The most used output metrics (Beamon, 1999)

Metrics	Clarification and examples
Sales	Total revenue
Profit	Profit rate
Fill ratio	Amount of directly delivered orders or fill in per cent for ordered amount
On-time deliveries,	How many deliveries differs from order confirmation due date (+/- days) or from agreed delivery time.
Backorder / stock out	The possibility to stock out
Customer response time	Time between the order and the delivery
Manufacturing lead time	Total amount of time required to manufacture a particular order.
Shipping errors	Amount of defective shipments
Customer or users complaints	Number of customer reclamations.

When comparing these metrics to the other literature, it can be noted that output metrics are the most emphasised measurement after the costs. Almost all presented metrics belong to output category, for example by Stevenson (2011), and it can be summarised that after the resource metrics these are most used in performance evaluation. Metrics are measurable and the needed data is usually available which makes these metrics easily to adopt. (Cormican, et al., 2007)

Flexibility

Flexibility metrics measures how effectively system can withstand the market fluctuations and changes ftom manufacturers, suppliers and customer point of view. System has always some uncertainties and development needs, so the supplier's ability to respond to changes will give a major competitive advantage for flexible supply chain. If the supply chain flexibility is actively developed, it will increase variation withstand ability and variations can be handled more efficiently. However the drawback of the flexibility measurement is that there are rarely suitable data for flexibility measurement. Usually the qualitative measurements are used, but however there are also numerical measurements developed (Beamon, 1999)

Flexibility measures differ significantly from resource and output measures, because flexibility is always the potential of the system. The flexibility measurement is therefore measurement of the supplier's future potential. Future potential flexibility is also divided to the two different dimensions: *range* and *response* flexibility. Range can be seen as in what extent the operation can be changed and response as how easily operation changes can be adapted. (Beamon, 1999)

To solve this problem the flexibility measurement system (FMS) have been developed and studied for manufacturing organisation. Flexibility measurements include meters dependency to the type of the flexibility such as: *volume*, *delivery*, *product mix* and *new product flexibility*. However volume and delivery flexibility measurements requires relatively simple supply chain and an accurate order handling system, so those are usable only in production factories etc. where the order handling system is highly automatized. (Beamon, 1999; Taylor, 2003, pp. 76-83)

The new product flexibility measurement is based on the time that supplier has to spend before the product change can be taken in the production. The measurement is by itself very simple, but no specific as the concept of the product change is wide. Because of that it is more or less the qualitative metrics. However it can be expressed with given equation: (Beamon, 1999)

$$\mathrm{F}_n = T \tag{4.}$$

Where F_n is the flexibility and T is require time for the change.

6.1.2 Gunasekaran's research

When Beamon is focused for the flexibility measurement for scorecard purpose, is Gunasekaran et al. (2001; 2004) meanwhile emphasising an importance of supplier performance measurements for internal aspects. In the research the performance measurements are divided to the three different management hierarchy levels: *strategic*, *tactical* and *operational level*. The main idea in the research is that when the correct performance indicators are available in different management levels the company can more easily maintain its management over the suppliers.

In the research the metrics are also divided to four supply chain activities: *plan*, *source*, *make*/*assemble* and *delivery*/*customer* and requirements for each level are presented in the research. Conclusion of the different measurement in each level is presented in the table 18. The table is completed by enquiry for British companies supply managers, but used sampling distribution was small. However it is stated that each company have to decide the most important metric to its own purposes. (Gunasekaran, et al., 2004)

In the research it is stated that one of the common problems within the practitioners is that the amount and complexity of measurements are increasing and additional measurements are added when requested by other employees. Complex measurement systems however may mislead managers and in the worst case include irrelevant information. Therefore it is recommended that only the most trivial measurements are used, which are also the most critical factors for the company's success. Despite of different measurements it was pointed out that all participants in all hierarchy levels should be aware and understand all measurements. It was noted that the strategic level measurements are often reflected to the board and could affect corporate financial and competition plans so it is important that all hierarchy levels can approve correct metrics. (Gunasekaran, et al., 2004)

Table 18 Performance metrics categorized by hierarchy levels and goal of measurements in each level. Based on (Gunasekaran, et al., 2004)

	Hierarchy level		
	Strategic	**Tactical**	**Operational**
Purpose	Top management tool for decision making and supplier controlling.	Measuring performance against targets and company goals	Metrics required for low level managers and workers to archive required goals
Supply chain activity			
Plan	Value gained by customer, total cash flow, variances against budget, information processing cost, total cycle time, total cash flow time, product development cycle time	Customer query time, product development cycle time, accuracy of forecasting, planning process cycle time, human resource productivity	Order entry method, human resource productivity
Source		Supplier delivery performance, supplier lead time against the industry, supplier pricing against the market, efficiency of cash flow method, efficiency of purchase order cycle time, supplier booking in procedures	Supplier pricing against the market, efficiency of purchase order cycle time
Make / Assemble	Product range	Percentage of defects, cost per operation hour, capacity utilization, utilization of economic order quantity.	Percentage of defects, cost per operation hour, human resource productivity index
Deliver / Customer	Flexibility of service system to meet customer needs, effectiveness of enterprise distribution planning schedule	Flexibility of service system to meet customer needs, effectiveness of enterprise distribution planning schedule, delivery reliability performance,	Quality of delivered goods, on time delivery of goods, effectiveness of delivery invoice method, number of faultless delivery notes invoiced, percentage of urgent deliveries, information richness in carrying out delivery, reliability performance.

6.2 Performance metrics

When analysing the supplier performance metrics, qualitative grading scale such as “good” or “fair” is rarely a meaningful evaluation, because of difficulties to utilize these metrics and therefore the quantitative measurements are usually preferred. However when using quantitative numerical methods there are always a risk that chosen numerical performance measurement does not adequately describe supplier performance and therefore special attention have to be given for performance metrics valuation. (Beamon, 1999)

One comprehensive study is performed by Gunasekaran, et al., (2004) where the most important evaluation metrics was raked by their importance in each supply chain activity function. In the research the most common evaluation metrics where firstly studied from the literature and after that ranked by professionals. The complete result from the study is presented here: (Table 19)

Table 19 The most common evaluation metrics, based on Gunasekaran, et al., (2004)

Assessment	Planning metrics	Percentage rating %	Importance of supplier metrics	Percentage rating %	Importance of production metrics	Percentage rating %	Importance of delivery performance measures	Percentage rating %
Highly important	Level of customer perceived value of product	16.42	Supplier delivery performance	23.20	Percentage of defects	24.27	Quality of delivered goods	12.34
			Supplier lead-time against industry norm	19.69	Cost per operation hour	22.51	On time delivery of goods	12.20
			Supplier pricing against market	18.30	Capacity utilization	21.61	Flexibility of service systems to meet customer needs	11.43
Moderately important	Variances against budget	14.23	Efficiency of purchase order cycle time	15.42	Range of products and services	18.01	Effectiveness of enterprise distribution planning schedule	10.31
	Order lead time	13.50					Effectiveness of delivery invoice methods	10.23
	Information processing cost	12.68					Number of faultless delivery notes invoiced	10.05
	Net profit Vs productivity ratio	12.46					Percentage of urgent deliveries	9.32
	Total cycle time	11.80					Information richness in carrying out delivery	8.76
Less important	Total cash flow time	10.27	Efficiency of cashflow method	12.38	Utilization of economic order quantity	13.60	Percentage of finished goods in transit	7.76
	Level of energy utilisation	8.64	Supplier booking in procedures	11.01			Delivery reliability performance	7.70

Variation of different researches and tables can be found from the literature concerning about supplier selection and evaluation criterions and metrics. Many of the literature sources are however similar and key measurements are more or less based on same evaluation criterions. Also selection criterions which are presented earlier in the table 7 are naturally valid in performance evaluations. (Stevenson, 2011 pp. 633-694; Beamon, 1999; Gunasekaran, et al., 2004)

6.3 Supplier scorecard

After the evaluation criterions are selected the framework for the scorecard has to be selected. The scoreboard has to combine different measures and keep the development focus on the right track. The development needs have to be also handled according of their importance to the company. The most well know framework for combining the different qualitative and quantitative metrics is the balanced scorecard. (Salomäki, 2009) However many different scorecards can be found from the literature which combines the hard key point indices to the strategic measurements. (Nguyen, 2013)

Balances scoreboard (BSC) is a performance management tool which is based on structured report that can be used by managers to control and monitor the system. (2GC, 2009) BSC is developed from the late 1980s to the early 1990s and most popularly published, though not first, by Robert S. Kaplan in 1992 after a study made by co-operationally with US management consultancy Nolan-Norton. (Lawrie, et al., 2002)

The BSC was developed for combining the financial and non-financial measurement to the one single measurement report. The aim for combining the financial and non-financial, or so called soft factors, measurement was to create the measurement system that can be used for a long-term strategy development. It was stated in the further research also made by Kaplan, et al., 1993 that one of the first successful company that introduce the BSC was Apple Computer where it was used as the long-term development tool by senior managers in a small high level steering group. Although used only in the small steering group the BSC greatly improved communication of the company's strategic goals to lower organization levels by attention given by top level managers. (Kaplan, et al., 1993)

As in Apple Computers, the BSC was originally used on internal organization performance improvement tool with four different measurement perspective: *financial, customer, internal process* and *learning & growth*. (Kaplan, et al., 1992) However the first generation BSC did get a lot of criticism about the fact that it could be only used as an organization internal performance measurement and development tool and it did not have perspective for example to supplier performance measurement. Over the years many different method and implementation model has been made to fulfil these gaps from the relative simplistic Kaplan's first publication. (Lawrie, et al., 2002)

However as the BSC model was originally developed to organization internal strategy development tool it has to be modified for supplier performance evaluation. The BSC is still much more sophisticated performance measurement tool, because it combines the hard and soft measurements together. Traditionally a key performance index (KPI) measurement is used, which is consisted only for hard measurements. The main weakness of the KPI system is that it only measures numerical values, which doesn't usually represent the company’s strategy. Therefore, when implementing BSC to the supplier environment it should be noted that it is important to absorb the most important strategic measurements from the company’s strategy. (Salomäki, 2009)

Different modifications of balanced scorecard are widely used in studies and real-life cases of different companies, although the line between the KPI and BSC measurement can be sometimes faltering. Implementation of the BSC and KPI can be found in example from thesis by Salomäki (2009) where the BSC was developed for service supplier environment of electricity distribution business or Nguyen (2013) where KPI was developed for textile and manufacturing industry suppliers. Some companies, such as Bell Helicopter Textron and Rotek, also openly publish their supplier KPI’s evaluation scorecards.

6.4 Case studies

In this chapter two different models are presented, one of them is publicly available by Rotek Incorporated and other is based on real-life research performed by Kathryn Cormican and Michael Cunningham in 2007.

6.4.1 Rotek Incorporated

The model used by Rotek is descripted in very detailed way and it is also used by Nguyen (2013) when implementing supplier performance scorecard to the textile technology industry. Rotek has divided the supplier evaluation to three categories and seven sub-categories with following weights: (Rotek, 2014)

- Delivery performance 100
  - On-Time delivery performance 60%
  - Quantity reliability 40%
- Quality performance 100
  - Quantity rejected v. total quantity received 50%
  - Required documentation 30%
  - Quality management system 20%
- Price performance 100
  - Price level 60%
  - Price trend 40%

As can be noted, each of three main categories is weighted to 100 points, so they are valued equally important to Rotek. Points of each subcategory are calculated by pre-determined scorecards, for example OTD is calculated by using the table 20:

Table 20 ODT scorecard, based on Rotek (2014)

Points	Deviation in days late	Deviation days early
100	0	0
90	+1	-3
80	+3	-7
70	+5	-10
60	+7	-14
50	+10	-17
40	+14	-21
30	+18	-24
20	+21	-28
1	+28 ->	-36 ->

6.4.2 Large multinational organisation

In a case study from Cormican, et al. (2007) the supplier performance evaluation is implemented to the large multi-national organisation with excellent results. Purpose of the study was to present an approach that helps to evaluate supplier performance and identify the best performing suppliers and eliminate those who not add any value. Result of the presented method was that the company reduced its inventory value from 15$ million to 5$ million and amount of suppliers per products were reduced from 23 to 8. (Cormican, et al., 2007)

In the study supplier rating tool was developed with co-operation of company stakeholders and following metrics was chosen: on-time delivery, quality and total cost. Total performances of supplier were calculated by weighted sum, on-time delivery and quality had weighting of 40% and total cost had weighting of 20%. (Cormican, et al., 2007)

6.4.3 Total cost measurement

Total cost measurement was used based on the price of the product divided with the cost of quality. Total quality cost includes all relevant expenses such as products defects and also preventive measures including audits, sample and part inspections, third party audits and preventive maintenance. Calculation was based on total dollars used on quality divided by total worth of received goods on particular time period. Result was a per cent figure which can be compared with all suppliers. (Cormican, et al., 2007)

6.4.4 Quality measurement

In the study the quality was measured as an amount of parts returned to supplier (RTS) or any other supplier corrective actions (SCAR) needed divided with the total amount of delivered products and scaled to part per million. After that a scale table with predetermined values was used to convert PPM figure to the actual performance evaluation score. (Cormican, et al., 2007)

6.4.5 On time delivery

On-time delivery metrics based on calculation of total amount of parts received on-time divided by total amount of expected parts on that particular time period as can be seen from the equation below. Time period was formed according to each product accepted delivery time tolerance and the delivery was expected to happen when promised by supplier. Overall result is thus an average of each individual purchase order. (Cormican, et al., 2007)

$$\text{OTD} = \frac{\text{number of parts recived on time}}{\text{number of total parts excepted}} 100\% \qquad 5.$$

7 DEMAND FORECASTING

Supply chains are always dependable for the upper level demand and the forecasts are a way to distribute the information to the suppliers about the future demand before the actual purchasing order. The forecast allows suppliers to plan future actions and make needed decisions before it is too late to correspond to demand changes. Missing or inaccurate forecast will lead to resource shortages or excess through the supply chain which will eventually cause work disruptions and cost increases among the supply chain. The accurate forecast will help operation management along the supply chain and it is therefore forecast are an important part of supply chain management. (Stevenson, 2011 pp. 74-109; Bedley, et al., 2008 pp. 113-151)

Forecasting in a broad scope can mean many different type of the forecast, and the two main types are: forecast used for planning the system and forecast used for planning the use of the system. In supply chain business forecast are mainly used for system usage planning, which can mean for example budgeting, production planning and scheduling. In this thesis the main focus is on demand forecasting, which purpose is to be used for system usage planning. (Stevenson, 2011 pp. 74-109)

Demand forecasts are a way to share the demand information to the supply chain and therefore improve supplier’s possibilities to more precise production and logistics planning. Improved planning possibilities will reduce the cost of excess workload, over stocks, stock outs etc. caused by demand variations. One of the most famous and the most researched phenomenon’s which are caused by lacking of communication is called as a *bullwhip effect* (BWE). Reducing of BWE can be made directly by implementing accurate and effective demand forecast, which will lead to direct supplier cost savings. (Jaipuria, et al., 2014)

7.1 Bullwhip effect

One of the most typical and severe phenomenon caused by improper demand forecast is called as a bullwhip effect (BWE) and its means that demand variations in the beginning of the supply chain will gain along the supply chain and cause major disturbances in the end of the supply chain. For example, if a customer order typically one order quantity of specified products in weekly and then suddenly increased weekly orders to order two quantity it will be seen as a major percentage increase in the supply chain. Without any shared demand information the reason for increased order quantity is not visible to the suppliers. The demand can keep the same trend and the next week order might be four order quantities, or if there is no real demand change there is one extra quantitate in the stock and there will be no order in the next week at all. This lack of the actual information is the key element of the BWE (Iloranta, et al., 2012 pp. 351-356)

Effects of the BWE to the supply chain was firstly analysed by Forerster in 1961 and then famously demonstrated by Sterman (1989) in the Beer Distribution Game. (Jaipuria, et al., 2014) In the research made by Forrester (1961) the supply chain was demonstrated by the computer analysis where supply chain was consisted from customer, retail store stock, delivery stock, factory stock and factory. Every one of these activators worked independently and was based to inventory related ordering. Inventory related ordering means that order were sent when the need for predetermined order quantity limit were reached. For this reason the origin of the product, the factory, received information from the demand changes greatly distorted and late. Therefore the production has to increase its capacity rapidly and for higher demand than actual customer need was. According to the research the amount of gain is depended to a slowness of the supply chain. This gain effect is nowadays called as a Forrester phenomenon. (Iloranta, et al., 2012 pp. 351-356)

Other notable phenomenon which causes BWE is the Burbridge and Houlihan phenomenon. The Burbridge phenomenon means that orders are made in larger quantities by summing up smaller orders. In that case the point of order as well as quantity of order is unknown for the supplier. Therefore the supply chain has to be prepared to large order quantities at uncertain time. Best practise for avoiding Burbridge phenomenon is to predetermine approved order quantity and order points which are optimised by both parties. (Iloranta, et al., 2012 pp. 351-356)

Houlihan phenomenon meanwhile is caused by shortage speculations and it is also called as a vicious circle of the supply chain. It is caused by rumours of shortages and it causes that customers will order larger quantities to the warehouse, which actually causes the real shortage. In that case some customers have oversized stocks meanwhile others are facing real shortages, which increases shortage speculations even more. Same effect can also occur, if the demand forecasts are made wrongly by over estimating the near future demand. This can especially happen if the forecasts are adjusted based on a short time period demand increasing, when suppliers thought that overall demand will increase in the future. (Iloranta, et al., 2012 pp. 351-356)

7.2 Requirements of good forecast

When producing the forecast it has to fulfil certain characteristics, because it is important factor that the supplier can really trust to the forecast. The basic requirements for forecasts is that it have to be usable and enough reliable. Without fulfilling these characteristics it will lose its confidence among the suppliers. To make a usable forecast there are general steps and requirements which should be taking under consideration when starting the new forecasting process. The steps during the forecasting process are presented by Stevenson (2011 pp. 72-131) and these steps are in the below: (table 21)

Table 21 Steps during the forecast process. (Stevenson, 2011 pp. 72-131)

Step	**Action**
1.	Determine the purpose of the forecast
2.	Establish a time horizon
3.	Obtain, clean and analyse appropriate data
4.	Select forecasting technique
5.	Make the forecast
6.	Monitor the forecast

Along with these process steps there are also requirements for the forecast, which are presented by Stevenson. (Table 22) These technical requirements have to be fulfilled to create the useful and reliable forecast. Technical requirements are listed in the table below and these should be taken under consideration parallel with steps during the forecasting process to create useful and reliable forecast. (Stevenson, 2011 pp. 72-131)

Table 22 Requirements of a good forecast. (Stevenson, 2011 pp. 72-131)

Point	**Requirement**
1.	Forecast should be timely; changes in the forecast could not be taken in the action over night.
2.	Forecast should be accurate and level of accuracy should be stated.
3.	Forecast should be reliable, otherwise confidence for the forecast could be lost among the suppliers
4.	Forecasting unit should be correct, Euros or units depending on needs.
5.	Forecast should be in writing form
6.	Forecasting technique should be easy to understand
7.	Forecast should be cost effective

These steps and requirements presented by Stevenson are generally presented in the forecasting literature. Some other points of view for good forecast requirements are however presented by Armstrong (2001). These upper level requirements are useful addition to the Stevenson’s publication, because of the more general point of view. Additions from the Amstrong research are presented here:

- Forecast method should be structured
- Quantitative method should be always used if possible
- Use assosiative method rather than naive if possible
- Always use simple method if there are no evidence that complex method will gave benefits.

In conclusion in can be stated that both sources are emphasising the accuracy and formal form of the forecast. It is important that suppliers can really trust to the forecast and a professional appearance is one important part of that.

7.3 Forecasting methods

Before making an actual forecast a right forecast method have to be chosen, which fulfil requirements which were discussed and is usable with available information. In this chapter different method for forecasting are studied based on literature review. Comprehensive literature publications from different methods can be found for example by Stevenson (2011) and Charles (1997) and methods presented in these are studied more detailed in this thesis.

In a broad scope there are two different ways to create the forecast, either a *qualitative* or a *quantitative* forecasting method. The qualitative method is based on subjective views and inputs whereas the quantitative method is based on the available data. The data can be obtained from the past behaviour, such as purchasing data, or explanatory data available such as weather or oil price. The qualitative forecasts are called as a *judgemental forecast* and quantitative forecasts are called as a *time-series forecast* or *associate model* depending if the explanatory data is used. Time-series forecasts are based on available past purchasing data meanwhile associate model is based on explanatory data. The most typical forecast is based on time-series forecasting method, but managers often use their knowledge to modify the forecast based on intuition and therefore the actual forecasts are typically combination of quantitate and qualitative method. (Stevenson, 2011 pp. 72-131)

Besides of the qualitative or quantitative there are also other types of methods which can be apprehend as the forecasting method such as a goal setting. In the goal-setting firms’ managers set goals for the organization which are also used as a forecast. This method however requires that goals are realistic and reachable by the organization. (Charles , 1997)

7.3.1 Quantitative forecasts

Quantitative forecast are typically divided for time-series data based and associative based forecast, as already discussed. Time-series forecasts are based on available historical data and therefore predict the future demand from history behaviour. Time-series forecast are the most widely used because of their easy implementing and relatively low system requirements, usually with fairly good results in the stable market. However the simplest models adjust slowly on market changes and may therefore be unusable in some market situations. (Charles , 1997)

An associative method relies on the factors which have causal effects on the demand. Such factors include changes for example in prices, weather or marketing campaign which can all be considered causal demand factors. (Stevenson, 2011 pp. 72-131) Therefore the associative methods can be also called as the *causal methods*. (Charles , 1997)

Forecasts based on time-series data

Time-series forecast is based on a past observation from the relevant measurements, such as demand, earnings, accident etc. Forecasting techniques are based on an assumption that the past behaviour could be projected to the future by analysing the underlying behaviour. One of the critical factors is to detect past behaviour patterns, which can be made by plotting the available data and visually examining the plot. Many different variations or patterns might appear on the plot and it is important to determine all correct patterns from the plot. The typical patterns are presented by Stevenson (2011) and those are listed in the below: (table 23)

Table 23, Notable patterns in demand time-series based on Stevenson (2011)

Pattern	**Description**
Trend	Long term upward or downward movement caused by major changes
Seasonality	Seasonal variations such as summer or evening
Cycle	More long term changes than Seasonality, cycle more than one year. Caused by economic or political conditions
Irregular variation	Irregular variations are caused by unexpected event, such as catastrophe or strike.
Random variation	Random variation is leftovers from other patterns.

These patterns are visualized in the figure below (figure 12) and key elements of different patterns are also described in more detailed here. In the figure the first pattern is the trend factor, where long-term upward movement is notable from the history. The long-term upward movement is usually caused by technical innovations, cultural changes or population movements.

In the same picture also an irregular variation could be noted which is caused by unusual circumstance like a strike or technical error in the ordering systems. When making the forecast, these irregular variations should be removed, because these events are not expected to happen again. Therefore it is very important to detect irregular variations and eliminate them correctly. (Stevenson, 2011 pp. 72-131)

The second pattern in the figure is the variation cycle, which is a long-term cycle. The variation cycle differs from the seasonality in the last pattern by a longer time period, which is always longer than one year. Variation cycles are caused by long-term variations for example in economic or political situation. (Stevenson, 2011 pp. 72-131)

In the last pattern seasonal variations can be seen which are caused by different seasonal factors such as time of the year, week or even in day. For example in a restaurant daily season can include breakfast, lunch and dinner rush hours as well as weekly variations like weekend which all are seasonal variations and could be forecasted. In this picture the random variations are also easiest to notify, which is variation caused by uncertainties of the surrounding nature. However it is important that random variations are not affecting to forecast as it is not predictable by its nature. (Stevenson, 2011 pp. 72-131)

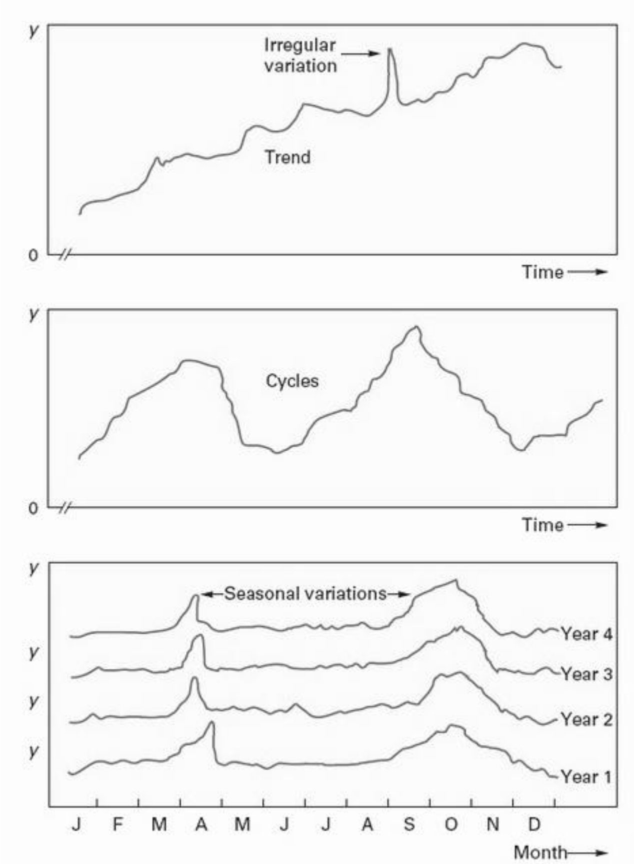

Figure 12, Different variations of time-series demand (Stevenson, 2011)

Methods for forecast based on time-series data

The time-series forecast are widely used and usually also with sufficient accuracy. Because of the quantitative nature of the forecast many different calculation methods are developed by the researchers. The simplest method is call as a *naive* method, which means that that the past time-series data, for example from the last year, are presented as a forecast for the next year. Naive forecasts can be accurate in very stable market and it is very simple to use and basically has no development costs. (Stevenson, 2011 pp. 72-131) However naive method is not usually relevant forecasting because of the natural changes of marketplace and therefore a more advanced forecasting method is needed. (Charles , 1997)

More advanced, but still relative simple and commonly used, methods for time series are called as *averaging methods* and the main idea of these methods is that they adjust to the current demand development. However adjusting can also be harmful if the random fluctuation is not properly levelled out. Random fluctuation can be levelled out by using enough long adjustment periods, which have also a clear disadvantage: if the adjustment period is too long the forecast will always lack behind. Adjustment period have to be selected by balancing with these reductions. However these methods are based only for current situation, and therefore it is not possible to forecast any determined demand pattern. If the demand is not steady these methods cannot be used. (Charles , 1997)

Averaging methods are relatively easy to understand and use without the need of advanced software systems, usually with satisfactory results if the forecast is correctly used. However if there are detected patterns in the past demand even more advanced forecasting technique is needed.(Stevenson, 2011 pp. 72-131)

The most sophisticated techniques for time series forecasting are called as an exponential smoothing techniques. Exponential smoothing techniques include an array of different techniques and sophistication levels such as Brown single exponential smoothing, Holt’s double parameter exponential smoothing and Winter’s three parameter smoothing. (Charles , 1997) Single and double parameter techniques are relatively easy to understand and use, but forecasting software is highly recommended and mandatory for more complex forecasting techniques such as three parameter smoothing. (NIST, 2014 6.4.3.)

The most advanced smoothing techniques, such as Box-Jenkins or seasonal autoregressive integrated moving average (ARIMA) methods, which have major advantage as they combine time-series and causal (associate) models. However comprehensive casual relation models have to be known before these methods can be used and advanced forecasting software is also required. Because of these reasons such advanced forecasting methods are rarely used in the branch of business. (Charles , 1997)

Simple moving average

The simplest method for averaging is called as a simple moving averaging, where predetermined amount of past observations of forecasting periods F_{t-n} is used for forecasting the next forecasting period F_t (Charles , 1997). Equations for calculating the moving average is illustrated in the below. (Stevenson, 2011 pp. 72-131)

$$F_t = MA_n = \frac{\sum_{i=1}^{n} A_{t-i}}{n} = \frac{A_{t-n} + \cdots + A_{t-1}}{n} \qquad 6.$$

Where

$F_t = Forecast\ time\ period\ t$
$MA_n = n\ period\ moving\ average$
$A_{t-i} = Actual\ value\ in\ period\ t - i$
$n = Number\ of\ periods\ in\ the\ moving\ average$

The moving average method is simple to understand and use, but it is very dependable of the factor *n*, the number of periods in the moving average. If the *n* is big the forecast adjust slowly, for example if n = 10 months the forecast adjust slowly for demand changes. On the other hand, if *n* is small, for example two months, the random variation could affect to the forecast, which is critical factor for increasing the BWE. (Stevenson, 2011 pp. 72-131)

Weighted moving average

Another version of moving average is called as a weighted moving average, which basically means that the more recent months are more heavily weighted. The main idea of the weighted moving average is that it adjusts to changes more rapidly than long-term moving average but is less vulnerable to random variations than short-term moving average. Equation for weighted moving average is presented below. (Stevenson, 2011 pp. 72-131)

$$F_t = w_t(A_t) + w_{t-1}(A_{t-1}) + \cdots + w_{t-n}(A_{t-n}) \qquad 7.$$

Where
$F_t = Forecast\ time\ period\ t$
$w_t = \ weight\ for\ the\ period\ t$
$(A_t) = \ actual\ value\ in\ period$ t
It has to be notified that the total sum of $\mathrm{w_t}$ has to be one or otherwise total amount will not be correct.

Single exponential smoothing

Brown exponential smoothing is the simplest smoothing technique and it is based on the last forecast plus forecast error multiplied by smoothing constant. It is developed by Robert Goodwell Brown in 1956 (NIST, 2014 6.4.3.) and the formula is presented below. (Brown, 1956 s. 15)

$$S_{t+1} = S_t + \alpha(A_{t-1} - S_{t-1}) \qquad 8.$$
$$0 < \ \alpha \leq 1, t > 0$$

Where
$S_{t+1} = Forecast\ for\ the\ next\ time\ period\ t$
$S_{t-1} = Forecast\ for\ the\ previus\ period$
$\alpha = Smoothing\ constant$
$A_{t-1} = Actual\ demand\ for\ the\ previous\ period$

However this technique does not work well when there is the demand trend, because forecast made by the single exponential smoothing are always lacking behind the actual values in these situations. Therefore it should be noted that when any trend can be determined, the single exponential smoothing is not suitable technique. In those cases the double exponential smoothing should be used, such as Holt-Winters double parameter exponential smoothing. (Kalekar, 2004)

Double exponential smoothing

Double exponential smoothing, such as Holt's double parameter exponential smoothing, is consisted from two different parameter, level and trend which have to be separately updated. Equation for double exponential smoothing forecast is presented below (NIST, 2014 6.4.3.):

$$\mathrm{F_{t+1}} = \mathrm{S_t} + b_t \qquad 9.$$

Forecasting equation for *r* periods ahead can be given in the following way:

$$\mathrm{F_{t+1}} = \mathrm{S_t} + rb_t \qquad 10.$$

Where $\mathrm{S_t}$ is the level and b_t is the trend, equations for these are presented here:

$$\mathrm{S_t} = \mathrm{\alpha A_{t-1}} + (1-\alpha)(S_{t-1} + b_{t-1}) \qquad 11.$$

$$0 < \alpha \leq 1, t > 0$$

$$\mathrm{b_t} = \mathrm{\gamma(S_t} - S_{t-1}) + (1-\gamma)b_{t-1} \qquad 12.$$

$$0 < \gamma \leq 1, t > 0$$

Where:

$\mathrm{S_{t-1}}$ *is previous trend forecast*
$\mathrm{b_{t-1}}$ *is previous level forecast*
α *and* γ *are smoothing constants*
Initial values of these can be determined by several different ways, but Kalekar (2004) suggest that $S_1 = A_1$and for the $b_1$two following ways to be used depending on the situation:

$$\mathrm{b_1} = A_2 - A_1 \qquad 13.$$

$$b_1 = \frac{(A_2 - A_1) + (A_3 - A_2) + (A_4 - A_3)}{3} \qquad 14.$$

Initial values for smoothing constants α and γ can be determined by variety of ways. Stevenson (2011) states that values can be selected as a trial and error and determine the values that fits best on past demand variations. More sophisticated methods called as Marquardt algorithm non-linear optimization technique is suggested by NIST (2014). However the main idea is to choose constants that cause minimal mean square error (MSE), which is presented on later in this thesis. (NIST, 2014 6.4.3.).

Forecast of these two techniques are calculated in the table 24 below and also with two presented averaging methods for comparing. (Table 24) Data set is available from period one to ten and periods from 11 to 15 are forecasted to shown the main differences in the reality.

Original data set is based on the book “Engineering statistics handbook”, where also Brown and Holt’s methods are calculated in similar ways with values for α and γ calculated by Marquardt algorithm. (NIST, 2014 6.4.3.). Values for b_1 can be calculated by given equations with the result of b_1= 0,8 and $S_1 = A_1 = 6{,}4$.

Table 24 Calculated results for different time-series forecasting methods

	Time series forecasting			**Exponential smoothing**	
Period	**Data set**	**Moving average (3 months)**	**Weighted average (0,7, 0,2, 0,1)**	**Brown (α=0,23)**	**Holt (α=0,3623, γ=1)**
1	6,4				6,4
2	5,6			6,4	7,2
3	7,8			5,6	6,8
4	8,8	6,6	7,2	7,9	7,8
5	11,0	7,4	8,3	8,8	9,1
6	11,6	9,2	10,2	11,1	11,4
7	16,7	10,5	11,2	11,6	13,2
8	15,3	13,1	15,1	16,8	17,4
9	21,6	14,5	15,2	15,3	18,9
10	22,4	17,9	19,9	21,7	23,1
11		19,8	20,0	22,4	25,8
12		17,4	21,5	22,4	28,7
13		18,3	23,0	22,4	31,7
14		18,5	24,5	22,4	34,6
15		18,1	26,2	22,4	37,6

Results from different forecasting methods are plotted in the below. (Figure 13) It can be noted that differences are clearly visible and the best results can be obtained by using Holt’s double smoothing technique. Double smoothing technique follows the data set more closely than any other presented methods.

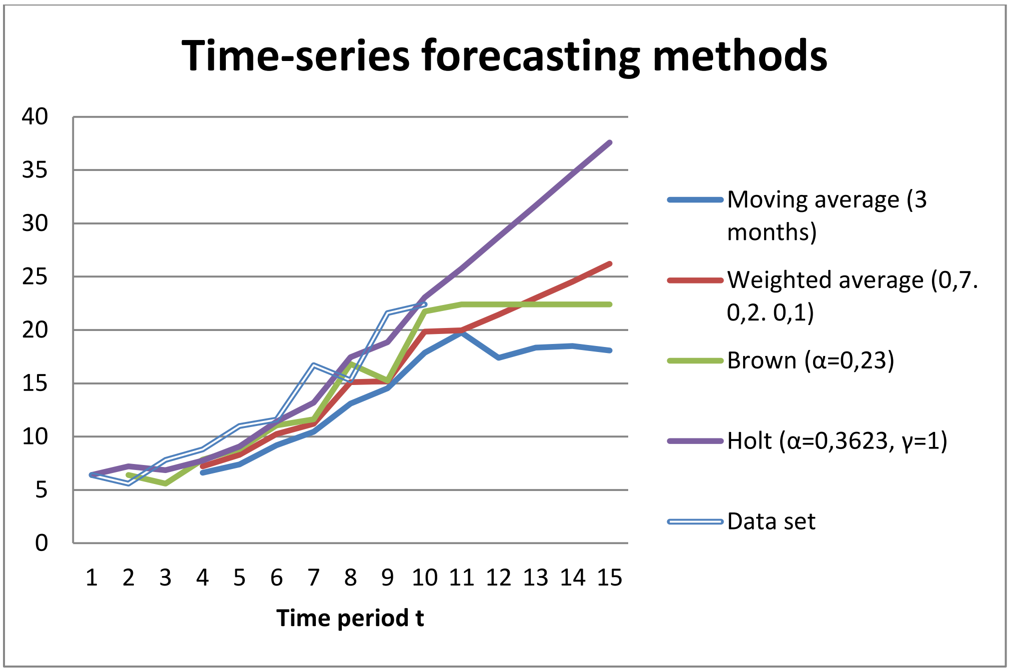

Figure 13

It could be also noted, that all forecasting methods without trend factor are lacking behind of the actual data set. Moving average and Brown's method are also totally unable to predict longer periods ahead as can be seen from the figure. (NIST, 2014 6.4.3.).

Triple exponential smoothing

Seasonality is a typical phenomenon in most of the demand trends as it caused by typical markets variations such as holiday or weather season. However any of the previously presented forecasting methods is not able to forecast seasonality and therefore technique for seasonality is very much needed. (Kalekar, 2004)

In this thesis two different methods for seasonality will be studied, one is triple exponential smoothing called as Winters or Holt-Winters (HW) method (1960) as Winter was Holt's student and the other is Stevenson method (2011). However both methods are relaying on same basis, but Stevenson method is simpler to use without advanced software system.

Seasonal forecasting methods can be divided to two different approaches: additive or multiplicative seasonality. Difference of these methods is that how seasonality is presented: additive means that seasonality is expressed in quantity, for example that seasonality of the June is 20 pcs above normal. Multiplicative seasonality is expressed as a percentage of above normal, for example it can be stated that sales in June are 20% above normal. This differences means that in additive method the seasonality is known in quantity which is not related to current trend, meanwhile in the multiplicative method seasonal sales are related to whole year sales. (Kalekar, 2004) However in business the multiplicative model is much more widely used because it is usually more closely to reality. (Stevenson, 2011 pp. 72-131) Therefore only the multiplicative model will be studied in this thesis.

The triple exponential smoothing method is first introduced by Peter Winter in 1960. Originally Winter was Holt's student who developed the double exponential smoothing method. The method is based on the three different equations (NIST, 2014 6.4.3.):

$$\mathrm{F}_{\mathrm{t+1}} = (\mathrm{S}_{\mathrm{t}} + rb_t)I_{t-L+m} \quad 15.$$

Where values of S_{t}, b_t and $I_t$can be calculated by equations given here:

$$S_t = \propto \frac{y_t}{I_{t-L}} + (1-\propto)(S_{t-1})(S_{t-1} + b_{t-1}) \quad 16.$$

$$b_t = \gamma(S_t - S_{t-1}) + (1-\gamma)b_{t-1} \quad 17.$$

$$I_t = \beta \frac{y_t}{S_t} + (1-\beta)I_{t-L} \quad 18.$$

Where
$y = observation$
$S = smoothed\ observation$
$b = trend\ factor$
$I = seasonal\ index$
$F_{t+m} = forecast\ for\ m\ periods\ ahead$
$t = time\ period\ index$
$L = number\ of\ periods\ in\ complete\ season\ (for\ example\ 12\ months)$
$\propto, \gamma, \beta = constant, have\ to\ be\ estimated\ so\ that\ MSE\ is\ minimized$

When using the HW method the minimum requirement is that demand data is available at least from the one season behind and for seasonal trend calculation at least from two seasons is recommended. (NIST, 2014 6.4.3.)

First step in the actual forecasting process is to calculate parameters for the trend factor and the seasonality indices. The general equation for the trend factor is following:

$$b = \frac{1}{L}\left(\frac{y_{L+1} - y_1}{L} + \frac{y_{L+2} - y_2}{L} + \cdots + \frac{y_{L+L} - y_L}{L}\right) \qquad 19.$$

Seasonality indices can be calculated by first calculating average for each period in season by using available demand data. First step is to calculate averages of each season:

$$A_p = \frac{\sum_{i=1}^{L} y_i}{L} \qquad 20.$$

And then calculate the initial seasonal indices by dividing each observation on relative season's average:

$$I_1 = \left(\frac{y_1}{A_1} + \frac{y_{L+1}}{A_2} + \cdots + \frac{y_{nL+1}}{A_n}\right)/n \qquad 21.$$

After calculating parameters the constant values $\propto, \gamma, \beta$ should be calculated by using past demand data in a way that amount of the MSE is minimized. This is however a complicated optimization problem and it could only solved by using advanced software system. Calculation of these advanced forecasting methods is not meaningfully anyhow without the computer software, because of the complexity of needed calculations. (NIST, 2014 6.4.3.) Because such software is not available at the moment further calculation of triple exponential smoothing is left out from this thesis. Different methods are however compared in the figure 14 below:

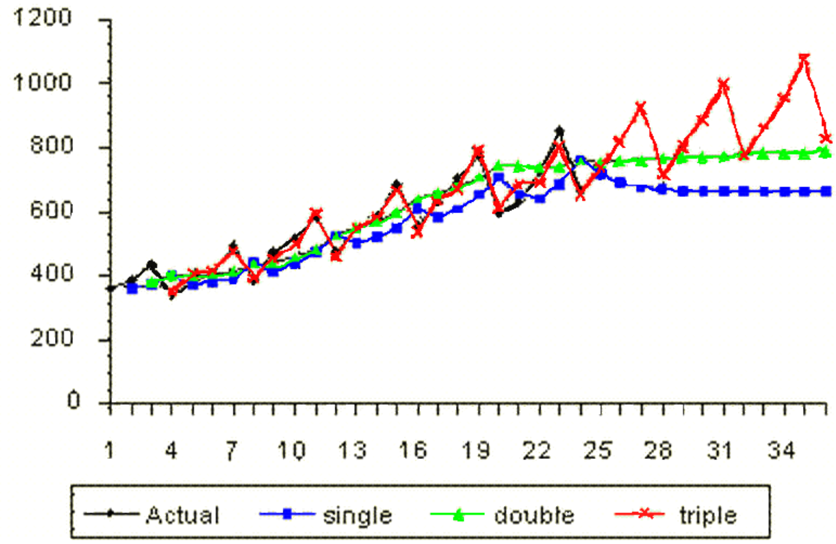

Figure 14, Comparison of single, double and triple smoothing methods when seasonality is present (NIST, 2014 6.4.3.).

From the plotted patterns, (figure 14) it can be noted that the triple smoothed exponential, the red line is the only one which efficiently follows the seasonality that is presented in the actual data. When forecasting r period in the future it can be noted that single and double methods are totally unable to predict seasonality and single exponential smoothing is also unable to forecast the trend factor as already stated. In conclusion it can be stated that triple smoothing method is by far the most capable smoothing method, but also the most complicated to use and the need for advanced software system is essential.

Stevenson's method for seasonality

Simpler method is presented by Stevenson (2011) which is based on *seasonal relatives*. Seasonal relatives are a percentage of the particular season's demand compared to all season average demand. For example if the seasonal relative for January is 1.2 it means that the demand in January is 20% higher than in average season. After the data is decentralised other variation can be forecasted by using simpler methods such as averaging. (Stevenson, 2011 pp. 72-131)

A computing of the seasonal relatives is usually made by using centralized moving average (CMA) method because it effectively accounts all possible trends that might be in the data. The computing of the seasonal relatives is a bit tricky when calculating the CMA for even number of periods, such as months in a year. In such situations a second moving average has to be calculated, because otherwise there is no actual centred value. (Stevenson, 2011 pp. 72-131)

Other option for computing the seasonal relatives is a simple MA where each period demand is divided by season total demand. However MA method should be used only when variations are large compared to the trend factor in the pattern. This is because the trend factor is not working properly in MA method. (Stevenson, 2011 pp. 72-131)

Associative forecasting methods

Associative forecasting methods rely on identified related variables that can be used for demand forecasting for original products or services. For example price can be used to forecast the demand for product, such as beef, and consumption of beef can be substituted by chicken if price for beef is high. So price of beef can be used to forecast the demand of beef as well as demand for chicken. (Stevenson, 2011 pp. 72-131)

When making groundwork for associative methods it is important to have all associations quantified. Associative variables can include factors such as price, advertising campaign, sale promotions. The most used associative techniques are simple and multiple regressions which are simple to use and understand. Also a more complicated technique called as a robust regression is used, but it needs advanced software to have it effectively used. (Charles , 1997)

Simple linear regression is the simples and most widely used regression model that involves a linear relationship between two variables. If more than two variables are needed for forecasting, multiple regression technique has to be chosen. In simple regression model it is assumed that two different variables have linear relation between each other. Equation of simple linear regression is presented here (Stevenson, 2011 pp. 72-131):

$$y_c = a + bx \qquad 22.$$

Where
$y_c = Predicted\ variable$
$x = Predictor\ variable$
$b = Slope\ of\ the\ line$
$a = Value\ of\ y_c\ when\ x = 0$

The major advantages of the associative methods are that provide an accurate sort and medium-term forecast and these methods are usually capable of supporting “What-if” analysis. Associative forecast are also usually easily understandable because of used statistic methods are widely known to public and therefore needed development expenses are limited. (Charles , 1997)

However associative techniques have also disadvantages as all techniques: The forecasting accuracy depends on consistent relationship of predictor and predicted variable which is crucial. Also all major independent variables have to be identified and therefore some managers view it as a “black box” technique. These methods are also very dependable of available data, because relationship has to be established with two or more variable. (Stevenson, 2011 pp. 72-131)

7.3.2 Qualitative forecasting

Qualitative forecast, also called as a judgemental method are subjectively derived forecasts which are based on intuitive or feeling of people who has understanding of present situation of the marketplace and has also strong feeling what is likely to occur. Often these judgemental forecasts are used as a last resort technique when there are not any demand or association data available. Despite that qualitative forecast can be very accurate if executives have a good understanding from the marketplace, but on the other hand qualitative forecast are always based on subjective view from development team or persons. These forecasts are not typically suitable for firms with a large number of units. (Charles , 1997)

Qualitative forecast are typically divided to four different methods: Executive opinions, salesforce opinions, consumer surveys and other methods. Executive opinions are based on upper-level manager’s view of future situation. This method is especially efficient when planning long-range forecasts with possibility of new development ideas available. The main advantage is that the amount of knowledge is very high in the upper-level managers. (Stevenson, 2011 pp. 72-131)

Salesforce opinions are good source for information because they are in direct connection with customer. Therefore salesforce are usually best aware of the customer future plans. However salesforce may have problems to see what customers would like to do or actual will do which could drives to over estimations of the future. Salesforce are also often influenced with current situation, future changes might be hard to see beforehand. (Stevenson, 2011 pp. 72-131)

Consumer surveys are way to get demand information from actual users who eventually create the demand. If the amount of customers are limited this method could be efficient and the most accurate method. However if there are too many customers it is impossible to contact with all customers and therefore only a sample consumer opinions can be collected. When doing so there are always a risk that all potential customer groups are not identified or contacted. Also when using this method when launching new products which are only presented in high-flown advertising campaigns consumer might not be able to form a real picture from the new product. Beyond of these factors consumer surveys are usually expensive and require lot of administration. (Stevenson, 2011 pp. 72-131)

Other approach includes such as the Delphi method, where series of questionnaires are circulated through the organisation and responses are taken anonymously so that all participants are able to answer honestly. Delphi method is useful when making a technological forecast, especially when some new technology can be taken into use. Such forecast could be, for example, usable when forecasting when the new vaccine can be ready for mass distribution. (Stevenson, 2011 pp. 72-131).

7.4 Selecting the forecasting method

After introducing the most common methodologies for the forecasting in the field of business one important questions remains: what is the correct forecasting method? Earlier in this thesis seven different requirements were listed which is the basis for selecting the forecasting method, but however more detailed study is needed for selecting the appropriate forecasting method. Comprehensive research from the subject is made for example by Charles (1997), Armstrong (2001) and Stevenson (2011). Case study is meanwhile performed for example by Pilinkienė (2008) where forecasting method was selected for furniture manufacturer.

Most of these researchers are underlying the fact that most companies are using simple methods which are easy to use and understand. (Charles , 1997; Stevenson, 2011 pp. 72-131; Armstrong, 2001) Simple forecasting methods are also low-cost solution, but however this is typically made at the expense of an accuracy. It is stated that typically the higher accuracy means also higher costs, so benefits from the accurate forecast have to be balanced with forecasting costs. (Stevenson, 2011 pp. 72-131).

When selecting the forecasting method also available historical data and availability and need for forecasting software have to be considered. This is especially important when selecting the forecasting time period; usually the simplest forecasting techniques such as moving average or singe parameter exponential smoothing are suitable only for short-term forecasting. Double or triple exponential smoothing methods are suitable for medium-term forecasting meanwhile Delphi or executives opinions should be used for long-range planning. (Stevenson, 2011 pp. 72-131)

In a research made by Armstrong (2001) the most popular methods are listed based on literary study. It is stated that most common qualitative methods are salesforce and executive opinion; meanwhile the most used quantitative methods are naive method and moving average. More sophisticated methods such as exponential smoothing and box-Jenkins are rather rarely used, about 10-15% of firms. However it is stated that awareness and ability to perform quantitative methods are increasing because of more advanced software and increasing sales history data.

7.4.1 Forecast product portfolio

In a research made by Charles (1997), Forecast Process Manager of The Coca-Cola Company, the need for product portfolio analysis when selecting correct method was emphasised. It was stated that all forecast should not use the same method, because the selected method might cause poor results in some product segment while working in analysed segment. Appropriate method should be instead select for all product segments according to separate analysing. It is also important to detect the situations where forecasting method should be changed, for example if there are major changes in the marketplace (Charles , 1997; Stevenson, 2011 pp. 72-131).

In the research made by Charles the product portfolio is divided to two intersecting values: either complete or incomplete and stable or unstable. Incomplete or complete refers to available history data. Complete means that all relevant data is available, including causal variables, meanwhile incomplete means that available data is limited or not existing at all. (Charles , 1997)

Stable or unstable refers to data variations and patterns. Unstable means that data has not any distinct pattern which could be detected. In the stable end the data has clear seasonality or trend pattern. This forecasting portfolio is illustrated in the figure 15, which can be used to categorise different methods (Charles , 1997):

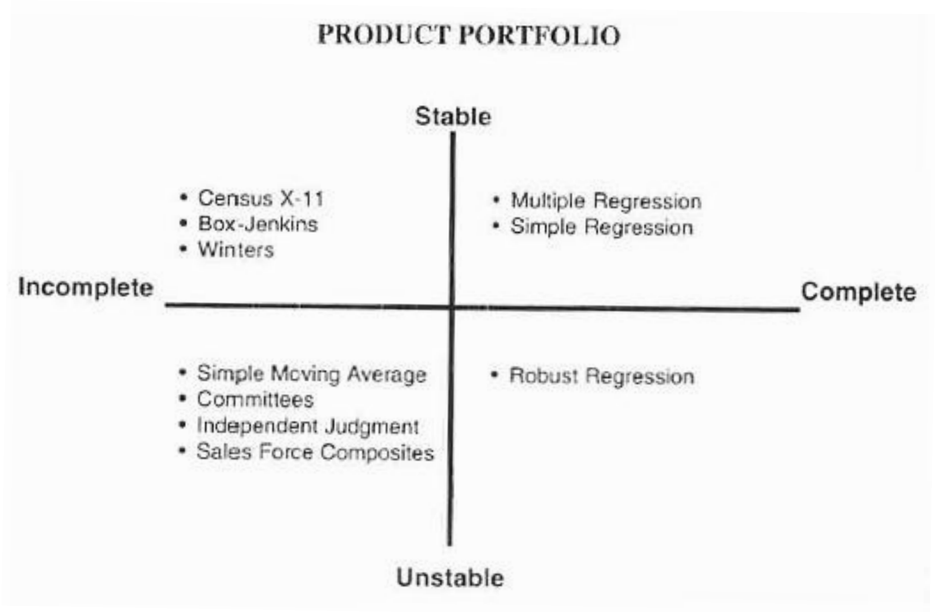

Figure 15, Forecasting portfolio (Charles , 1997)

From the picture it could be determined that qualitative or simple short-term forecasting method has to be used when available data is incomplete and demand is unstable. Methods such as simple moving average, judgment or salesforce opinion are valid forecasting methods in these cases. When the available data is incomplete but demand is stable, the forecast have to be made by using time series method such as HW, ARIMA or winter’s double exponential smoothing. Usually it means that sales data is available and causal data is not. However if the sales and causal data are both available with stable market it is possible to use associative methods such as simple and multiple regression. (Charles , 1997)

It is stated that when reviewing a typical product portfolio about 50% of products belong to upper left category. Second category is upper right with about 35% of products, when 10% of products fall in lower left and 5% to lower right corners. As a conclusion quantitative methods, either time series or associative, can be used in 85% of cases. (Charles , 1997)

In overall the usage of quantitative method if needed data is available is always recommendable, (Armstrong, 2001) although the qualitative methods are the most used in firms because of their simplicity (Charles , 1997). However simple methods should always be used if there is no evidence that more complex forecasting methods can bring benefits as already stated. (Armstrong, 2001)

7.5 Forecast performance measurement

Producing of good forecast can have a major impact on the internal and external organization by means of production efficiency and customer satisfaction. However forecast error will always be presented due the complex real world events and random variation. It is important to follow forecast performance and indicate of the extent that forecast can deviate. (Klimberg, et al., 2010)

Forecast performance measures can be divided to two broad scopes: directional and size. Directional measurement measures direction of the forecast and size measurement measures deviation from the forecast. Both measurements can also be combined in same measurement. In the simples forecast error can be presented as $F_e = Y_t - F_t$where $Y_t$is actual value and $F_t$is the forecast for the period t. However most used measurements are the mean absolute deviation (MAD), the mean squared error (MSE) and the mean absolute per cent error (MAPE). Also more complicated method is presented such as the percentage forecast error (PEE). (Klimberg, et al., 2010; Stevenson, 2011 pp. 72-131)

MAD is one of the most popular forecast performance measurement and its measures the size of the absolute deviation. Equation for MAD is presented here (Stevenson, 2011 pp. 72-131):

$$MAD = \frac{\sum|Y_t - F_t|}{n} \tag{23.}$$

Where

$Y_t = Actual\ value\ of\ time\ period\ t$
$F_t = Forecasted\ value\ for\ time\ period\ t$
$n = number\ of\ time\ periods\ t$

Another very popular measurement is MSE, which measures dispersion of the forecasting errors. Equation for MSE is presented here (Stevenson, 2011 pp. 72-131):

$$MSE = \frac{\sum(Y_t - F_t)^2}{n} \tag{24.}$$

In both MAD and MSE measurements the smaller value is better and 0 is the perfect accurate. One other variation from MSE is the root mean square error (RMSE) which is square root of the MSE. It is typically used to estimate a standard deviation when MAD or MSE is expected to follow normal distribution with a mean of zero. The major drawback of both MSE and MAD is that they only measures real deviation without consideration of the magnitude of the actual values. For example deviation of ten units has same MAD and MSE regardless of the total amount. Therefore these methods are not suitable to use without contexts.

The MAPE is a widely used method which takes magnitude in a consideration, MAPE measure was developed by Lewis in 1982. Equation for MAPE is presented here (Klimberg, et al., 2010):

$$MAPE = \frac{\sum(|Y_t - F_t|)/Y_t}{n} \tag{25.}$$

As previous models the lower MAPE means the more accurate forecast. Lewis also developed a basic framework for the MAPE, which can be seen from the below. (Table 25) However the framework has be to adjusted each time separately depending on the needed forecasting accuracy. (Klimberg, et al., 2010)

Table 25 MAPE accuracy framework (Klimberg, et al., 2010)

MAPE	**Judgemental forecast accuracy**
Less than 10%	Highly accurate
11% to 20%	Good forecast
21-50%	Reasonable forecast
51% or more	Inaccurate forecast

PEE is the newest forecast performance measurement model developed by Klimberg and Ratick in 2000. The main idea of PEE is that two or more data set are easily comparable between their relative variations regardless of the measurement units. Equation for PEE is presented here (Klimberg, et al., 2010):

$$PEE = \frac{2RMSE}{Y_{t+1}} \tag{26.}$$

Where

$Y_{t+1} = forecasted\ value\ for\ next\ period$

In the equation the multiplier of 2 for RMSE is based on empirical rule, and as a result of that analysis has shown that next forecast will be within the range of PEE% in the probability of 95%. However PEE is most complicated to use and it follows forecast performance basically as well as MAPE. PEE has been utilized in extremely critical cases such as clinical study. (Klimberg, et al., 2010)

8 IMPLEMENTATION ANALYSIS AND RESULTS

In this chapter the main results of this thesis is presented and analysed. Presented results are based mainly on literature researches that were made in this thesis and internal group studies. Main theoretical frameworks were presented to participating group before the group studies were performed. After the group studies the selected methods were implemented. Participating group was Elenia's material and logistic team (Hovi, et al., 2014), which is responsible for distribution network material purchasing and logistics.

8.1 Purchasing portfolio analysis

Purchasing portfolio analysis was made by using the given theory in this thesis. Theory was used for preparation of the material to the group study, and the best suitable method was selected and modified by author. As the material and logistic team is responsible only for distribution network materials, was the study focused only for this specific material group. Because all of the distribution network materials are more or less strategic items in the DSO business, a need for some modifications was detected to the original methods during the portfolio process.

The Kraljic original model was used as a starting point for portfolio analysis. Decision was based on the fact that the Kraljic model is the most used portfolio matrix and it is relatively simple model. Because some modifications were needed it was important that the original model was simple enough for modifications. Although the Kraljic model was used, the theory from other portfolio analysis was used as background information when making the actual portfolio analysis.

Analysis was started from classification phase as stated by Kraljic. Purchased material products are divided to the few main products or product groups (Table 1) with very high percentage value and many groups with small overall value. Because of that, the purchased materials were divided to 15 different product groups. These groups cover over 90% of total the purchased value, and other products were left in "oddments" group. If the oddments group would be divided to the product groups, it would increase the amount of product groups rapidly. Increased product groups would make the handling of the portfolio analysis more complicated, and therefore it was decided that this product categorisation performs well. However, if there would be a detected bottleneck item in the oddment group it could be handled separately. Couple of these products were founded during the process.

Product groups consisted of different products with a very similar construction, such as different cross sections of cables, because there were no detected differences in the supply market situation. The situation might be different if the product group include a non-standard product. These special products were considered and one was also founded; a product which was developed with close co-operation only with one supplier.

Purchasing importance classification was mainly made according to purchased value of the product, as suggested by Iloranta, et al. (2012). However some consideration was also used based on knowledge from the past practice experiences. Complexity of the supply market was classified based on the qualitative view from the team, because no other considerable method was presented in the literature.

After the classification, the second phase was performed, called as the market analysis. The analysis was performed according to table 4, purchasing portfolio evaluation criterions. The market analysis was performed to the main suppliers, which were selected based on the total purchased value or existent supply agreements. However during the process it was notified that some of the criterions were too complicated to compare, because of all needed information was not available. It was anyhow clear that further analysing is needed for market factors, such as power dependency and supplier relationships.

The method for the supplier relationships approach, presented in the chapter 4.2.2 was considered as a good method and addition to the Kraljic matrix, and therefore the second market analysis was performed by using the presented method. The chosen matrix is presented in the figure 8. In the original model the area of the supplier circle was used for clarifying the efforts that were placed for the supplier relationship, but it was decided that it would be more beneficial if the area is presenting the total purchased value. It was considered that the supplier relationship axis already, at least partly, include the used efforts. The same modification was also used in other literature sources.

The supplier relationship approach was chosen instead of the Gelderman's rotated Kraljic matrix because of the fact that the rotated matrix doesn't perform well when the dominance is balanced. The rotation also increased the complexity of the matrix and therefore reduces the readability.

The third part of the portfolio process is the strategic positioning. Originally the strategic positioning, presented in the figure 6, was meant only for items that were selected to the area “IV purchasing management” in the table 5, which were strategic items. However as discussed earlier, the purchasing team is only responsible for materials which can be more or less considered as strategic in distribution network business. Because of that, the scale of the first matrix is obliviously changed to respond the team’s view so that all areas are used.

Therefore it was decided that all materials which were selected to the first matrix are also placed to the second matrix, or in other words the second matrix was placed on top of the first matrix to give an idea of the strategy directions. This new formed figure can be called as a “strategic material portfolio matrix” (Figure 16). It was also notified that the advantageous moving directions, given by Iloranta, et. al.(2012), was a helpful tool when the feasible moving directions were considered.

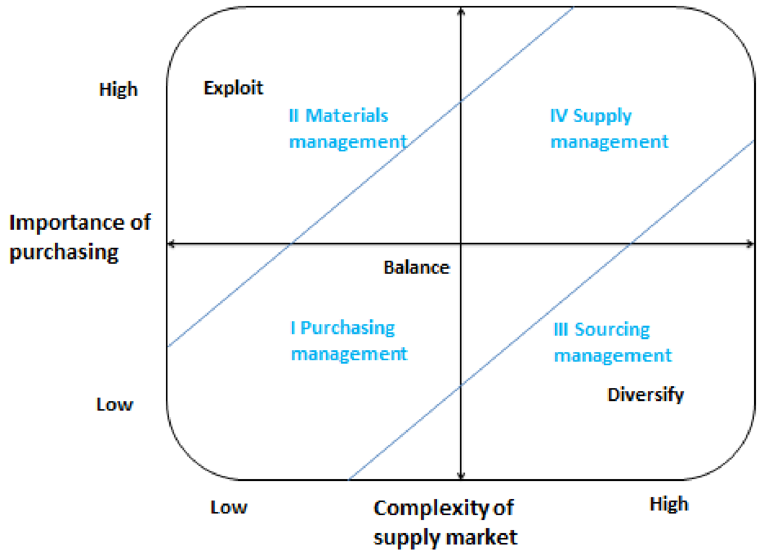

Figure 16 Strategic material portfolio analysis

The most important part of the portfolio analysis, action plans, was performed only shortly at this phase, but it was stated that the action strategy for each supplier shall be performed. The strategies will be based on the findings from the portfolio analysis, and it was decided that the strategies are implemented beginning of the next year, because of the yearly strategies are already in use at Elenia. It is also natural that strategies are made for yearly basis.

As a drawback of the research, it can be said that the implementation of the action plans will take years to archive and during that time many market aspects will change. It is not meaningful to implement all the findings at once and hope for a miracle, because of the limited resources of the real world. For these reasons it is important to regularly monitor the market situation and update the portfolio analysis. It was decided that at this phase material portfolio analysis will be updated yearly by the purchasing team and the actions based on the strategic plans will be monitored regularly. It was also stated that, although some of the action will take a good deal of time and resources, it is a great deal of daily working that the best possible strategy is determined and the right moving direction is in our knowledge. It was overall opinion that even this quite sketchy cross section analysis gave many new and interesting views from supplier base.

It can be summarised that the methods presented in this thesis was a very helpful for the purchasing portfolio process, and with the help of the modifications made during process a correct method for Elenia's needs was founded. The used method was a combination of the methods presented by Kraljic's and Ollsen, et al. The first matrix from the Kraljic's model was used because of its simplicity and therefore a manageable method. However the Kraljic's model presented a relatively complex and insufficient method for the market analysis, and therefore it was substituted by a method presented by Ollsen et al., where supplier relationships were categorised in a similar matrix than the Kraljic's first matrix. The used matrix also visualised the situation, which helps to comprehend the real situation.

8.2 Supplier selection

The supplier selection is, as already stated, one of the most difficulty decisions among the purchasing managers. Therefore it was clear that more studying from the subject was needed. After the literature research the AHP selection method was selected for further studied and tested. The AHP method was selected because of the facts that it performs well when quantitative and qualitative criterions are combined and the hierarchy process is a good tool for structuring the decision problem to smaller parts which are easily to handle and understand by decision makers.

At the first phase the AHP method was presented to the purchasing team and it was decided that the method will be tested during the next purchasing process. However at the test phase the actual supplier selection decision will be made by foregoing method. It was also stated that the public procurement process might cause some reduction to the model, which was one of the reasons why the AHP method could not be used in the actual purchasing process at this phase. Nevertheless the AHP model will be used in parallel with the purchasing process and the result will be compared to the actual purchasing decision. The parallel AHP process however gave some different perspectives to the purchasing process, which were considered as helpful and some implementations to the actual purchasing process were made.

At the beginning of the process the selection hierarchy was made by using the selection criterions presented in the literature. Because of the limited available information, the hierarchy model was kept simple enough. The AHP method limited the CR ratio and it is important that there are enough data for coherent judgements, which is of anyhow an important factor. The selection hierarchy is presented in here:

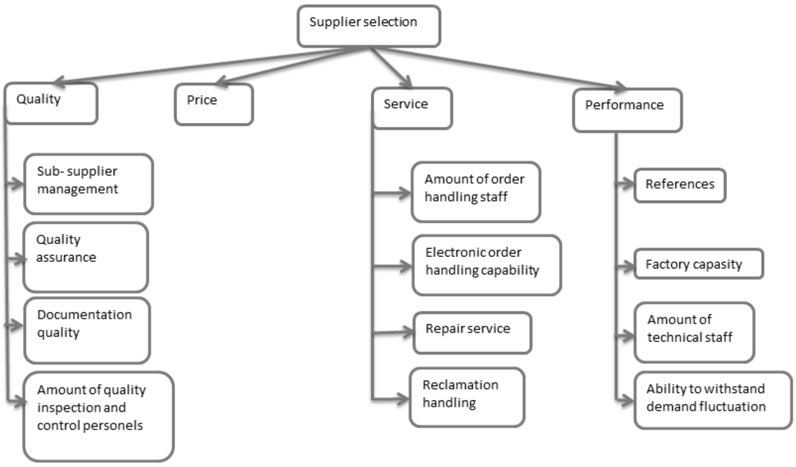

Figure 17 The selection hierarchy model

One of the key notifications was made when the selection criterions were selected to the AHP model. It was notified that when using the foregoing method the available information from the tenderers was limited. Limited information caused uncertainties in the process and appraisal of potential development need was hard to detect. To solve this problem a separately “Supplier Self-Assessment” form was implemented to the purchasing process. (Kalliorinne, 2014)

In conclusion the AHP model helps to make a correct decision and for pointing out aspects where development is needed before the supplier relationship beginning. This is a great deal when making the selection or working with less-know suppliers. However the last comparing between the foregoing methods versus the AHP method was not performed in this thesis due the time schedule of the purchasing process. Therefore further studies are needed for implementing the AHP method to the supplier selection method, especially because the requirements of the public procurement process have to be considered carefully.

8.3 Supplier performance evaluation

After the best suppliers are selected, the next step is to evaluate selected suppliers performance during the agreement period. Therefore the supplier performance scorecard is a needed tool for Elenia. The scorecard is already implemented in contracting environment and for some material suppliers, but it is a natural extension to include all strategic material suppliers to the scorecard evaluation process. However, it was a known fact that at the moment the available purchasing data will cause some reductions to the available performance evaluation metric. For that reason the supplier scorecard is only implemented to the test phase, and further development of combining the scorecard and business models is required later on. Nevertheless it is important that the most basic measurement are taken into use and developed.

When selecting the metrics the two presented case studies and research was studied and the metrics was chosen to corresponding to the current situation. It was stated that at the first phase the most important goal is the supplier scorecard, but dividing the measurement results to the internal organisation according to Gunasekaran's research would gave a major benefits. It was decided that internal measurement system will be developed after the supplier scorecard is presented.

In that phase the scorecards have to be presented to all suppliers and correct evaluation scales have to be developed and selected. However, the scorecard can be used as a management tool even before that and, as already stated, the process have to be started somewhere. For full-size utilization of the scorecard it was also considered that electronic ordering system such as EDI should be implemented at least with all strategic suppliers and further research for the possibilities for ITC integration is needed.

The developed measurement system was based on basic metrics, because of the confidence of the available data and reliable results. The usage of the most basic metric was also recommended in the literature. The selected metric are presented in the table below: (Table 26)

Table 16 The supplier scorecard

Supplier scorecard	**Value**	**Weight (90)**	**Score**
Resources		30	
Total cost *Additional resource cost divided by the total purchased cost (%)*			
Output		30	
OTD *On-time deliveries divided by total deliveries (%)*		15	
SCAR *Amount of supplier corrective actions divided by the deliveries*		15	
Flexibility		30	
Development projects *Success of the development projects, at least two projects in a year (0-30/project)*		*Average of the total results*	
Overall score			

Scores for the evaluation are predetermined in own scale scoring tables, for example the total cost scores are based on the presented scale. One important factor for the test phase is to confirm that scales (Table 27) are determined correctly.

Table 27 The additional cost score table

Additional cost	Score
0-2%	30
3-5%	26
6-8%	20
9-12%	10
13%->	0

As the result of this thesis the framework for supplier scorecard is determined, and this framework will be tested and presented to the suppliers during the next supplier meetings. Therefore the aim of this thesis is reached, although further development might be needed in the future.

8.4 Demand forecasting

When managing the supply chain the demand forecasting is an important way to distribute demand information along the supply chain as already discussed. In Elenia the current forecasting method is developed in couple years ago and it is based more or less to the naive method with additions of manager's intuition. However the forecasting accuracy has been problematic in some occasions when demand variations have occurred. Due these reasons several stock outs have been occurred during the last years and therefore a more advanced method is needed.

At the beginning of the forecasting development process, a closer look for the six basic steps presented in the thesis (Table 21). Although some of the steps are trivial as forecasting process is already on going are all steps considered separately. The purpose of the forecast is clear based on the needs stated by managers, colleagues and suppliers; it is needed for quantity demand forecasting and it is updated monthly. Monthly updating period is selected because it is notified from the past experiences that quarterly forecasting period is too long to respond timely demand changes. The accuracy of the demand forecast have to be developed, and no more stock outs should occur because of inaccurate demand forecast.

Time horizon for the forecast is a one year and time interval is one month as already stated. Time horizon for the forecast is naturally selected because of the nature of the business environment. Demand for the next year can be forecasted with satisfactory accuracy, but it is known that timely changes are much more unpredictable, which is the main reason why the monthly forecast interval is needed.

The needed data and its weakness are already known as it is used in the current forecasting process and the available data can be plotted. Plotting of the data reveals the behaviour of the demand patterns (Figure 18), which are known to be similar in all product groups, although the timing of the high season is dependable of the product group.

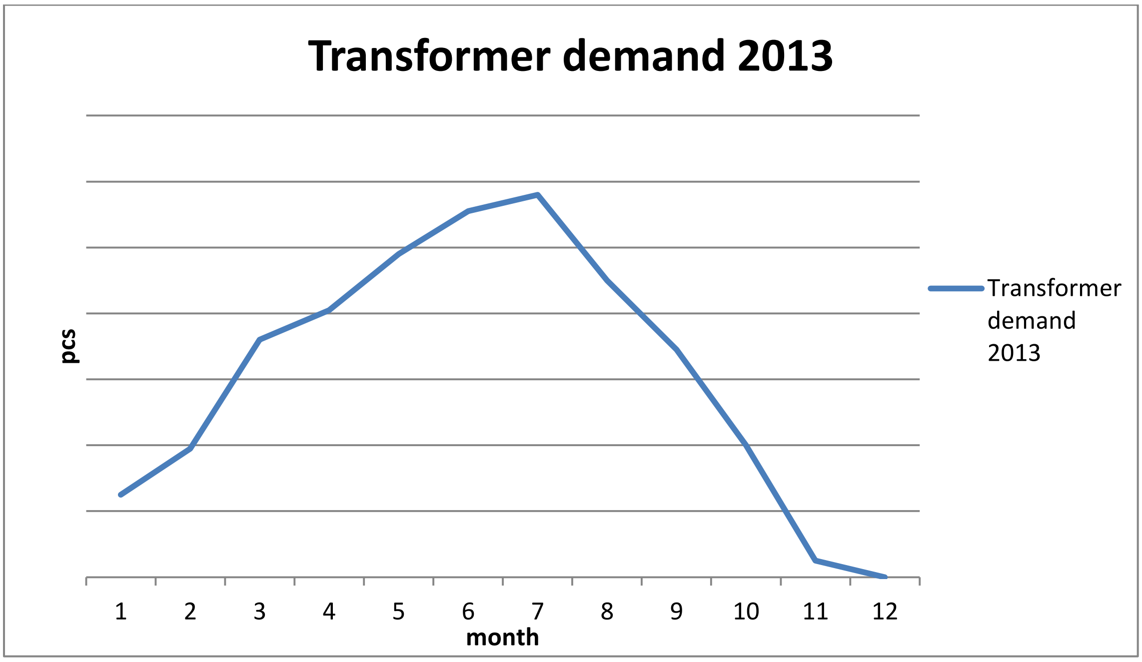

Figure 18 An example of typical demand pattern

From the figure 18 a typical demand pattern can be seen. It is clear that the demand pattern is highly season dependable and the forecasting method has to be suitable for seasonal patterns.

When selecting the forecasting method it was clear that the data is available and already used, which means that the quantitative forecasting method is the most suitable. However, the seasonal pattern will limit the number of available forecasting techniques and from the studied techniques the triple smoothing technique or Stevenson method should be used. Both of these techniques are multiple regression models, which are categorised in the Charles forecasting portfolio (Figure 23) to the stable and complete product area. As already stated the products are highly standardised and markets are also stable, so the usable forecasting methods are also backwards combatable to the Charles research.

Currently there isn't any available forecasting software, which basically limits the triple exponential smoothing out. It was stated that the triple exponential smoothing is dependable for constant values and the computing of the values is a multi-criterion optimisation problem. As a conclusion it is not meaningful to solve the optimisation problem without the advanced software system and therefore the Stevenson's forecasting technique is selected for forecasting method in this thesis. Different models have to be considered, if the accuracy that can be reached by Stevenson method is not adequate.

The first step in the Stevenson's method is to calculate seasonal relatives. As already stated the season demand is dependable for product groups, so seasonal relatives have to be calculated separately to each group. As the amount of months is uneven number the calculation of the centered moving average is bit tricky and values have to be smoothed two times. Seasonal relatives are used for smoothing out random fluctuations of the one season and the amount of smoothing is dependable for amount of past seasons used in calculation. Currently the ordering data is available from the two past years.

After the calculation of the seasonal relatives, it was notified that in some product groups the random fluctuation is not smoothed out because of the limited availability of the past ordering data. Two years of data doesn't smooth all variations that were clearly caused by irrelevant factors. Some of the variations are caused by problems at the start-up phase of the current ordering system and other can be meanwhile explained by changes in the environment. However in these cases an intuition has to be used and unrealistic variations are levelled out. In the figure 19 shows seasonal relatives for medium voltage cables and transformers without any additional smoothing.

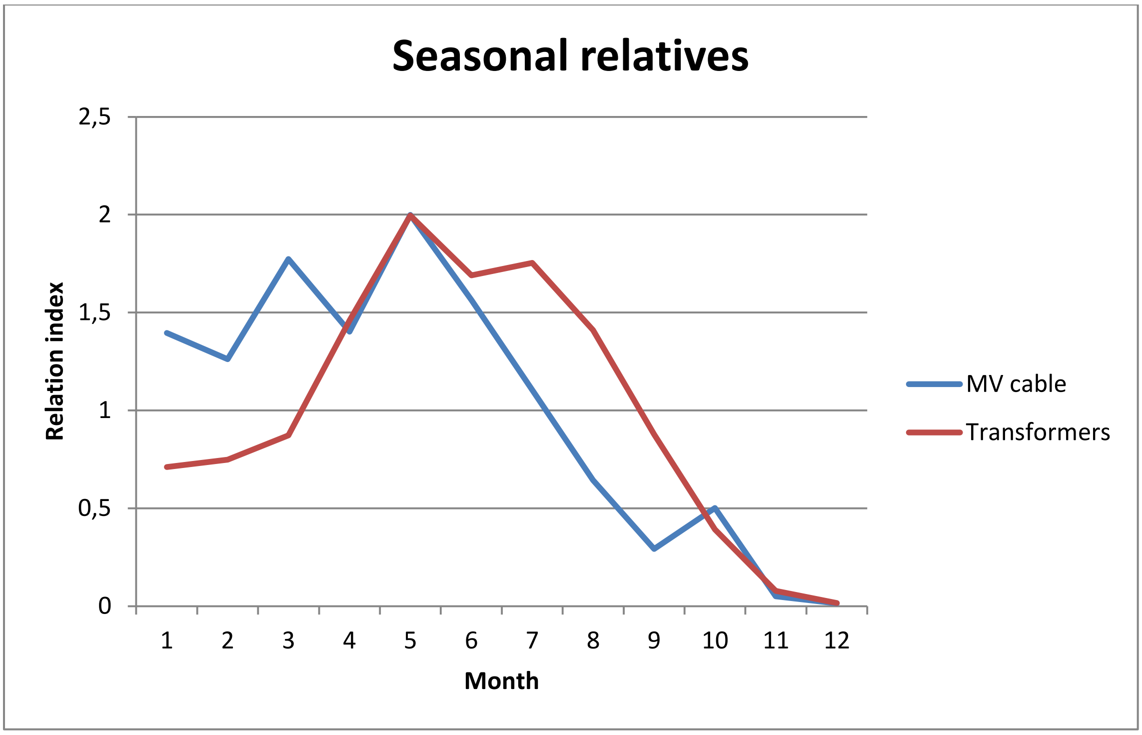

Figure 19

From the figure it can be noted that a saw toothed beginning of the MV cable pattern is not realistic prediction to the future and therefore is has to be smoothed based on intuition. Transformers meanwhile have a much more realistic seasonal variation pattern, which shows that there are no such irregular demand variations in the past data. Both of the patterns show a high seasonal peak, but demand for MV cables starts couple months earlier than transformers. This is however caused by the nature of the investment projects and it is a known fact.

After the seasonal relatives are calculated a correct method for forecasting the deviations has to be selected. As already stated, the yearly volumes of the each product group can be forecasted with a decent accuracy because of the project planning schedule. However this causes some differences to the typical forecasting models, where the yearly volumes are forecasted by the trend factors.

The forecast accuracy has to be monitored, which is also stated by Stevenson as the last step in the forecasting process. For that reason the MAPE method was selected due the fact that it is one of the most used methods for forecasting error calculation and still simple enough not to increase a workload significantly. After that the MAPE is calculated from the two previous months and results are distributed to the suppliers with next material forecast.

As a conclusion, in can be said after the literature study that Stevenson’s method is the most suitable to fulfil the requirements, without the need of advanced computing software. The accuracy of the Stevenson’s method will most certainly be must better as it is a more advanced forecasting method. The forecast is calculated already calculated by using this method to the year 2015, but the current forecasting season last to the end of the year 2014. Therefore the accuracy can be calculated at the beginning of the year 2015. If it turn out that the accuracy of this method is not enough, then the software based forecasting system is highly recommended.

9 CONCLUSION

The goal of this thesis was to improve the knowledge of purchasing management in Elenia Oy and implement key aspects used by researchers and practitioners in the business branch. The need for the improved management methods was created by increased investment level. During the thesis project it comes clear that special attention was needed to four areas of purchasing: purchasing portfolio analysis, supplier selection, supplier performance evaluation and demand forecasting. These special areas were further studied in this thesis based on literature review in the field of business.

The material purchasing portfolio analysis was based on the Kraljic's portfolio model, which is the most famous publication in the field. However, based on criticisms from other authors, it was noted that the Kraljic's model doesn't fully fulfil the needs for modern purchasing portfolio. The main weakness in the Kraljic's model was a lack of supplier relationship and power dependency analysing. Also based on the studies in Elenia it was noted that market analysis phase was descripted insufficiently. Therefore the second method was combined to the Kraljic's approach, presented by Olson, et al. (1997). In this approach the supplier relationships was taken into account, and the supplier relationship matrix was presented. This supplier relationship matrix was implemented to the Kraljic's model as an additional matrix. After the modification the supplier portfolio analysis was performed in Elenia with good results. It was stated that many new interesting notifications was made during the process and it was decided that the portfolio analysis will be performed yearly.

The supplier selection was studied from the literature in the business branch. Studies were divided to two parts: firstly different selection criterions were studied and the most common were detected. Secondly, different selection methods were studied and the analytic hierarchy process was selected, as it turns out to be the most suitable structured method available. The AHP requires a selection hierarchy, which criterions were selected by using the findings from the first part. As a result the AHP method was implemented to the test phase for current procurement process and the results of this test will be completed at the end of this year.

The supplier evaluation is an important part of developing the supplier relationship, and therefore it was one of the main goals of this thesis. Literature research was performed and two important perspectives were founded: supplier scorecard and supplier measurement used as management tool. It was founded that the supplier scorecard is the most important at the first phase, and the developed supplier scorecard is presented in this thesis. The supplier scorecard is based on Beamon's approach, where the need for measurements from all aspects was emphasised. In the Beamon's paper it was stated that three different measurement groups are needed for fully coverage: resources, output and flexibility. These three measurement aspects were used in the developed scorecard. At the time of writing the presented scorecard is in implementation phase.

The last studied area was the demand forecasting. It is important tool for distributing demand information along the supply chain, with the goal of reducing the BWE and possibilities to costly stock outs. In Elenia a naïve forecasting method was already in use, but it has turn out to be inaccurate in some situations. Due the inaccurate forecast stock outs have been experienced during the last years. After the literature view it found out that a triple exponential smoothing technique have to used, because of high seasonal variation in the demand. However, it also found out that the triple exponential smoothing method requires an advanced software system. However Stevensson has presented a simpler version of seasonal forecasting, which is partly modified from the triple exponential smoothing. Because there is no software available at the moment, the Stevenson's method was selected. It improves the forecast accuracy and it will be used in the future.

As a conclusion of this thesis it can be said that it is was an interesting, thought demanding process, because of the topic which was related to author's daily work assignment. The broad scope of this thesis however complicated the process, but after all the goals was achieved with a good out coming. All the main goals were studied with results that are implemented to the use in Elenia. However it has to be said that the material purchasing process is never ready and constant improvement will be needed in the future, but this thesis is a good starting point.

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