

INVENTORY INTERACTION WITHIN A PRODUCTION COMPANY

An attempt to model the connection between
working capital and production line

Åsmund Bratlie

Bachelor's thesis

May 2015

Degree Programme in Logistics Engineering
Technology, communication and transport





Author BRATLIE, Åsmund	Type of publication Bachelor's Thesis	Date 08.05.2015
	Pages 60	Language English
		Permission for web publication (X)
Title INVENTORY INTERACTION WITHIN A PRODUCTION COMPANY – An attempt to model the connection between working capital and production line		
Degree Programme Logistics Engineering		
Tutors SIPILÄ, Juha LEHTOLA, Pasi		
Assigned by Arctic Machine OY		
Abstract <p>The main contemplation throughout this thesis is how the different roles in a production company relate to the inventory, as there are several ways to approach the subject. The research was conducted utilizing mixed methods of sequentially qualitative and quantitative techniques, including literature review, case study surveys and model development.</p> <p>There exists a vast array of sources from many different fields where inventory is mentioned or handled. The diversity alone gives reason to find out what motivations, nuances and stresses are used by each field when referring to the concept of inventory. The findings displayed three main aspects to the inventory: an economic, a physical and a listed aspect. It also became evident that the different roles and tasks in a production company would stress one or more of these aspects over the others.</p> <p>The work then introduces a model (the Doughnut model for inventory) that can be used as a tool to communicate this situation to the involved parties. This is an attempt to achieve better quality in the finished product but also in the workers' work-related well-being.</p> <p>The results in this thesis do not represent any new information within the field of logistics engineering, but the model as a communication tool is an innovative way of building bridges for a common benefit within organizations.</p>		
Keywords Inventory, ABC analysis, XYZ analysis, Working Capital, Quality, Model development, Doughnut model for inventory		
Miscellaneous		

TABLE OF CONTENTS

Table of contents.....	1
Table of figures.....	2
Table of tables.....	3
Definitions.....	4
Preface.....	5
1. Introduction.....	7
1.1. Background information.....	7
1.2. Research, method and restrictions.....	8
1.2.1. Qualitative and quantitative research.....	8
1.2.2. Mixed methods research.....	10
1.2.3. Model development.....	11
1.2.4. Common research methods with the sequential contribution approach.....	13
1.2.5. Research method, hypotheses and research restrictions.....	15
2. Literature review.....	17
2.1. Inventory.....	17
2.1.1. Definition of Inventory.....	17
2.1.2. Types of inventory.....	18
2.1.3. Costs of inventory.....	18
2.1.4. Inventory management and control.....	19
2.1.5. Viewpoints regarding inventory.....	21
2.1.6. Tasks related to inventory.....	23
2.2. Working Capital.....	23
2.2.1. Definition of Working Capital.....	23
2.2.2. Relation between Working Capital and inventory.....	23
2.3. Production line.....	26
2.4. Quality.....	26
2.4.1. Definition of Quality.....	26
2.4.2. Quality of work environment and the workers well-being.....	29
2.4.3. Quality of assembly.....	32
2.4.4. Quality of inventory management.....	33
2.4.5. Quality of data input.....	33
2.4.6. Quality enhancement beneficiaries.....	34
2.5. Summary of the literature review.....	37
3. In search of a more complete inventory model.....	38
3.1. Introducing the model.....	38

	2
3.1. Model implications.....	42
3.2. Relation to ABXY.....	43
3.3. Relation to quality.....	43
4. Discussion	44
4.1. Grounds for discussion.....	44
4.2. Research limitations and weaknesses	45
4.3. Evaluation of the Doughnut model	45
4.4. Support beyond the presented material	46
4.5. Critique of the ABXY-analysis	47
4.6. Possible impact of item registry setup	49
5. Conclusion and further research subjects.....	50
5.1. General conclusions.....	50
5.2. Suggested research subjects	50
References.....	52
Appendices.....	57
Appendix 1. The mechanics of an ABC-analysis	57
Appendix 2. The Doughnut model complete with named positions.....	60

TABLE OF FIGURES

FIGURE 1. Venn diagram of the logistics engineer.....	6
FIGURE 2. Conflicting objectives (Arnold et al., 2012, 7).....	7
FIGURE 3. Models and theory (Hirsjärvi et al., 2009, 145).....	12
FIGURE 4. Sequential Contributions Model for Integrating Qualitative and Quantitative Methods (Morgan, 2014, 13)	13
FIGURE 5. Deducted matrix of roles, tasks, predecessors and relation to the inventory.....	22
FIGURE 6. Working capital cycle for a manufacturing or service business (Weetman, 2010, 467).....	24
FIGURE 7. Deming's PDCA-cycle.....	27
FIGURE 8. Model of a process-based quality management system (<i>SFS-EN ISO 9000:2005</i> , 2005, 3)	28
FIGURE 9. Venn illustration of cash flow.	38

	3
FIGURE 10. Initial division of the inventory aspects.....	39
FIGURE 11. The Doughnut model for inventory.....	40
FIGURE 12. Matrix extended from Figure 5 with expectations, requirements, customers and results.	41
FIGURE 13. Initial data set for the ABC analysis.	57
FIGURE 14. Data set from Figure 13 after applied ABC analysis.	58
FIGURE 15. Data set from Figure 13 after applied XYZ analysis.....	59

TABLE OF TABLES

TABLE 1. Selection of key features in qualitative and quantitative research methods.....	9
TABLE 2. Herzberg's two-factor theory (Fivelsdal & Bakka, 1998, 168)	30

DEFINITIONS

SKU – Stock Keeping Unit. Every item in the inventory is identified as a SKU. This information should include at least a name and unit of measurement (kg, m, pcs etc.) applicable to the item (Arnold et al., 2012, 218).

BOM – Bill of Material. The BOM is a hierarchical list of how many of each SKU is needed in every sub-assembly of a finished product (Arnold et al., 2012, 64–5).

Forecast – an estimate of how many of each group of finished products will be sold in a given time frame. The forecast is based on previous and current sales numbers and trends (Arnold et al., 2012, 170–1).

Demand – how many of each SKU is needed to assemble the forecasted amount of finished products (Arnold et al., 2012, 168).

TQM – Total Quality Management

PREFACE

During my studies I have become increasingly aware of the complexity in areas I once thought of as mundane and trivial. The term 'inventory' was definitely one of these. Due to skillful guidance and observations by lecturers and peers I slowly got to realize that there are several ways to understand subjects and terms without internal contradictions. For natural laws and mathematical formulas this is naturally not an issue, as they are defined and proved and expressed with numbers, but as soon as words and professional terminology is introduced, there is automatically room for interpretation. This induced a personal period of silent observations that culminated in a fairly obvious realization: *people are different*. As a result of this contemplation, I asked myself a series of questions regarding my field of studies, which ultimately led to analyzing the title I would have upon graduating: Logistics Engineer. In my opinion the words 'logistics' and 'engineering' represents very different fields of expertise.

Logistics is shortly described as being in the right place at the right time in the right condition, which is in fact a sum of estimated and forecasted values. Surely there can be connected calculations and formulas to these factors, but in the end it is a dynamic situation that demands a hands-on approach and cunning skills in mastering the obstacles and uncertainties.

Engineering, on the other hand, is all about the numbers, formulas, laws and rules within the fields of natural sciences. There are formulas for every calculation and there are mathematical proofs behind every formula. Whatever uncertainty or error margin there might be can also be calculated according to generally approved standards. The closest thing to estimating anything is trend analyzing, but this is also the result of calculations. The ability to navigate through this vast array of possible techniques demands a keen eye for the core problem at hand and a structured mindset for problem solving.

I assume it as fairly obvious that these two groups do not necessarily speak the same lingo, even though they may be talking about the same problem. As

stated above, people are different and for some it is far easier to talk about estimations, while others prefer an approach of calculations. Neither side is wrong, but the big picture might be missing. This is also the setting for a logistics engineer, who will step naturally into the middle ground and function as an interpreter between the two opposites.

The result of this contemplation can be seen in Figure 1, which is a Venn diagram to illustrate the situation described in the previous paragraphs. A logistics engineer is a person who is comfortable with both calculations and final answers, and estimations and uncertainty. This career is definitely not for everyone, but every company should acquire their own logistics engineer.

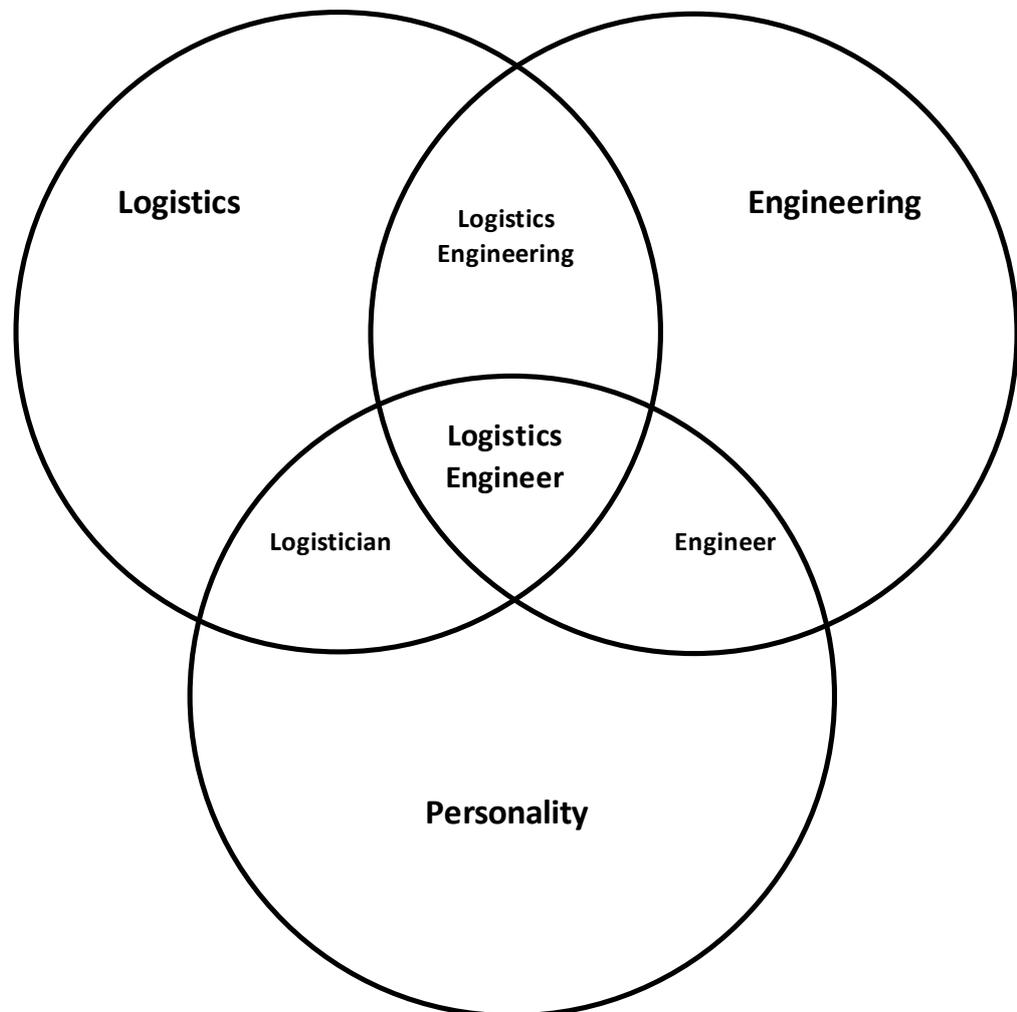


FIGURE 1. Venn diagram of the logistics engineer.

1. INTRODUCTION

1.1. Background information

Inventories are everywhere. In a production environment everyone will at some point be in contact with an inventory. The understanding of the concept of inventory, however, varies depending on experience, knowledge and objectives. For the financial department the inventory represents a cost that is always too high, while a production line worker will be interrupted when the inventory is too small, also known as shortage. This continuous conflict is illustrated in Figure 2 below. Marketing will strive for the best possible customer service, which includes holding high amounts of products in the inventory and tailor each order according to the customers' demands. Finance aims to lower the costs in order to increase profitability, which is partially done by reducing inventory levels and maintaining a steady pace in production. High inventory levels will also benefit production by securing a steady supply of needed materials. Naturally other roles and groups within an organization also relate to the same inventory, each with their own agendas. (Arnold et al., 2012, 7–9; Silver et al., 1998, 15–8; Waters, 2003, 35–6; Muckstadt & Sapra, 2009, 1.)

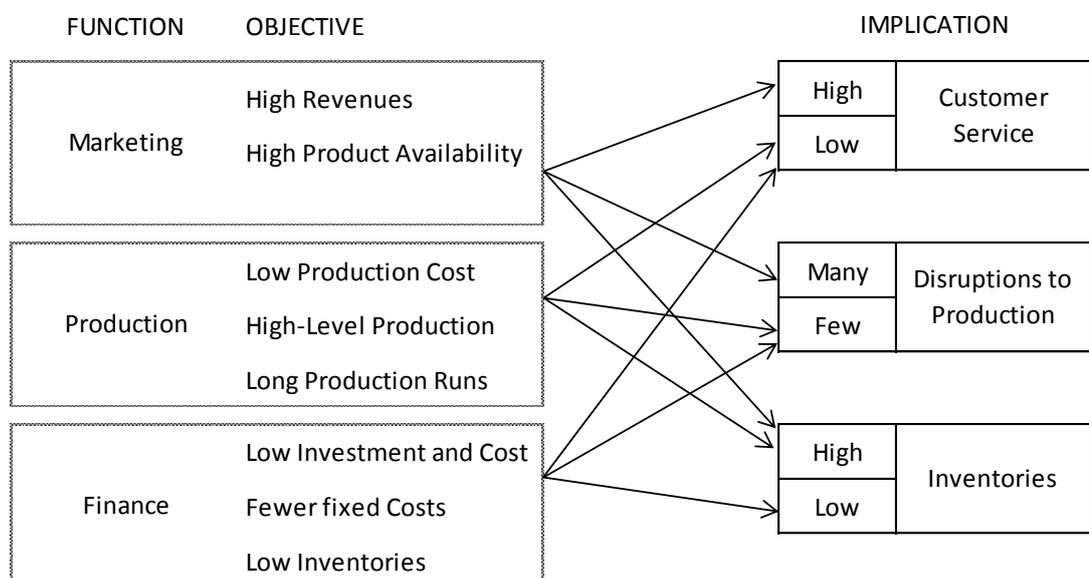


FIGURE 2. Conflicting objectives (Arnold et al., 2012, 7)

Whatever hovers beneath the term 'inventory' beyond one's own understanding and expectation might seem difficult to grasp. This thesis will seek to unbox the inventory and deal with its different aspects leading to discover how the production line can be enhanced, regarding both the quality of the product and the well-being of its workers. This thesis will start with a clarification of the research methods and the research subject, including its boundaries, followed by a literature review and basic explanation of the main concepts and themes. The work will introduce a general model for understanding inventory in a complete setting, which will lead to a contemplative discussion and conclusion.

Although the general focus is directed towards a production environment, the main achievement for this thesis is showing that the different roles and tasks within a company will link to each other through the inventory. This allows the model presented here to be a useful tool in communication and creation of a deeper understanding, regarding both the importance and the effect of each role towards a common benefit. The target group of this thesis thus includes anyone interacting with an inventory. The aim is to educate and the goal is to induce communication between the different roles in an organization as well as inspire more research on the related subjects.

1.2. Research, method and restrictions

1.2.1. Qualitative and quantitative research

According to Hirsjärvi, Remes and Sajavaara (2009, 135–6) there are two main types of research: qualitative and quantitative. The former is usually connected to a deeper study of some selected sources while the latter leans more towards the areas of statistics and number analysis. Even though it is tempting to handle these two research types as competing, they should rather

be considered as completing. The distinction between the two methods is established, however, and any attempt to merge them is assumed futile.

There are yet those who, despite the establishment, seek to at least level the two approaches, as the 'qualitative' method tends to be associated with a higher quality of research, even though the etymology does not support such assumptions. Töttö (2004, 11–3) suggests that when researchers are selecting their preferred method, they should assume that qualitative research will act as a life boat that is always available, while the path in striving for excellence through quantitative research is far more narrow, thus making it a method of higher ambitions.

TABLE 1. Selection of key features in qualitative and quantitative research methods

Method	Qualitative	Quantitative
Sources	Gathered from naturally occurring situations	Conclusions from earlier researches
Research basis	Observations and experience is regarded highly	Previous theories and formulation of new hypothesis
Goal	Seek to reveal new and unexpected information	Seek to prove a hypothesis true or false
Target group	Specific target group	Not conclusive
Result	Incidents are considered unique in the interpretation of the material	Forming and developing a general model

As stated above, the two methods exist and they are differentiated by some key features (Hirsjärvi et al., 2009, 136–7, 140, 164), of which a selection is presented in Table 1. Yet again, it is important to keep in mind that these features are not supposed to compete against or oppose each other. Hirsjärvi et al. (2009, 137) points out that there are several examples of studies where one method proceeds the other to present a more complete research

conclusion. This is also supported by other researchers (See Morgan, 2014; Teddlie & Tashakkori, 2009; Creswell & Plano Clark, 2011) and is handled more specifically in the next section.

An important part of the quantitative research method is to form one or more hypotheses based on existing theory and to define the key elements and concepts. For qualitative research, the stress is more towards gathering information about a much narrower subject. While the validity and proof of the hypothesis is in focus in the quantitative approach, the qualitative method tries to reveal something that is not yet described in the area of interest. The quantitative research might try to form a model to simplify and perceive a reality issue on a relatively general scale. The qualitative research could lead to the study of a particular phenomenon¹, which is used to describe how a group experiences or thinks about a particular issue. (Hirsjärvi et al., 2009, 139–66).

The feature division presented in Table 1 is supported by Morgan (2014, 9, 47–51), when he summarizes the qualitative research as an emphasis on own observations to form theory, interpret the social world and describe specific settings, and quantitative research as an emphasis on observations to test theories, to deduct own opinions and having a generally valid result. He goes on to confront the common opinion that there are only two categories – qualitative and quantitative – and upholds that there are several researchers who have tried to mix the two approaches, albeit with varying success (Morgan, 2014, 4–7).

1.2.2. Mixed methods research

The term ‘mixed methods research’ is more than just combining research methods in a the-more-the-merrier fashion, but rather the integration of qualitative and quantitative research methods to form an effective middle

¹ Phenomenography is about how a researched group of people relate to a phenomenon, while phenomenology also includes the researchers own views (*Fenomenografia*, 2014)

ground. This means that each of the base research methods needs to be applied effectively and that the integration needs to effectively extract and combine the core elements of each method. Perhaps the most deceiving trench in this approach is to include more data and more observations than are necessary (Morgan, 2014, 4–5). It is also important to note that there is still no concise consensus within the mixed method community about the exact definitions and constitutions of typology and methodology, despite its wide range of usage (Teddlie & Tashakkori, 2009, 21).

Morgan (2014, 66–8) shows three main motivations for choosing the mixed method: convergent, additional and sequential contributions. The *convergent contribution* is basically to use both qualitative and quantitative approaches to research the same question, thus achieving a higher grade of certainty when ending up with similar results. The core idea of *additional contribution* is to assign different methods to each task in the research material, in order to make use of the strongest method in each aspect. The *sequential contribution* motivation is different from the additional contribution method in the way that each pair of task and method is used to induce and enhance the next pair, thus building up a stronger argument.

While Morgan is satisfied with three motivations, Creswell and Plano Clark (2011, 109) introduce several other combinations that are all confined within the mixed methods. Teddlie and Tashakkori (2009, 151) also utilize more than three motivations, or designs as they call them. However, the three motivations introduced by Morgan are endorsed by all three sources and will cover the most basic versions, leaving the other possibilities for more seasoned researchers. This thesis will utilize what Morgan described as a sequential contribution approach.

1.2.3. Model development

Hirsjärvi et al. (2009, 145–6) describes the development process of a model as a natural part of the formulation of hypotheses and theories. Figure 3

shows how they place the different stages in connection to each other, which suggests that the process is continuous, thus letting the created model serve as a basis for development of new hypotheses and research and, ultimately, the creation of new theory and models.

Hirsjärvi et al. (2009, 145–6) continue to state that the purpose of a model is to describe an abstract concept as a complimentary explanation of the theory connected to that concept, which will form the basis of new hypotheses.

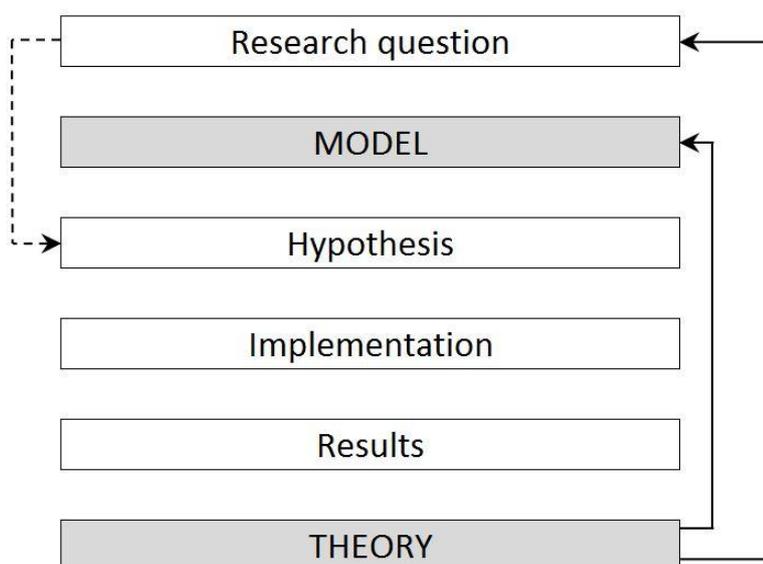


FIGURE 3. Models and theory (Hirsjärvi et al., 2009, 145)

As a basis for model usage, Fivelsdal and Bakka (1998, 33) state that every theory is a simplification of the real world. This is necessary in order to find connections and explanations within scientific disciplines, with the benefit that the research questions may be refined and the uncertainty may be diminished. A model can be implemented in this simplification and sorting process, to illustrate the core idea.

Fivelsdal and Bakka (1998, 33) continue to explain four main motivations for using models: 1) Theory development, 2) Theory profiling, 3) Practical problem solving and 4) Educational purposes. The first one is closest to the cyclic description in Figure 3, while the second concerns a specific part of a

theory, which is then purified and accentuated. The idea with the second motivation might be to get the theory into a shape that can be tested by peers. The third version is more related to mathematical models, while the fourth could be a secondary motive for any of the first three or a stand-alone tool, e.g. an organizational model. Furthermore they conclude that there is a continuous flow between the empiric level and the theory level, and that the model level exists between those two. This generally supports the cycle in Figure 3. (ibid., 33-4.)

1.2.4. Common research methods with the sequential contribution approach

As mentioned before, Morgan chose the word 'motivation' to show what types of research methods would be available in the mixed methods approach, whereas Teddlie and Tashakkori calls the very same choice a research design. The idea is to show how the sequential research method is built. Morgan shows how to extract four designs with a simple two dimensional chart as seen in Figure 4.

Sequence of Methods		Priority of methods	
		Quantitative Priority	Qualitative Priority
Sequence of Methods	Preliminary Contribution	Preliminary Qualitative qual→QUANT	Preliminary Quantitative quant→QUAL
	Follow-up Contribution	Follow-up Qualitative QUANT→qual	Follow-up Quantitative QUAL→quant

FIGURE 4. Sequential Contributions Model for Integrating Qualitative and Quantitative Methods (Morgan, 2014, 13)

The notation indicates which method is the predecessor and also which is the dominant method, as shown by capital letters. The sequence of methods shows what kind of study has been conducted in order to perform the second,

while the capital letters indicate that the method in question could probably stand on its own as a method, but is strengthened by the secondary method. Morgan also describes in great detail the four alternatives while pointing out that these are theoretical narratives of how research *can* be outlined and not *should* be outlined. However, all these four approaches have been used before and have proven useful, but it remains for each researcher to evaluate the suitability in their respective cases. (Morgan, 2014, 85–94.)

Qualitative input designs (qual → QUANT), as seen in the upper left corner of Figure 4, will have a preliminary input based on qualitative methods, which will lead onto the main research performed with quantitative methods. Morgan (2014, 92–3) suggests that such preliminary inputs could be inductive and contextual material, which could form the basis for a broader hypothesis testing.

Quantitative input designs (quant → QUAL), as seen in the upper right corner of Figure 4, will have a preliminary input based on quantitative methods, which will lead onto the main research performed with qualitative methods. In this case Morgan (2014, 93) upholds that qualitative research equals thorough studies of handpicked subjects, but in order to find the most suitable elements it might be advisable to search among a larger population.

Follow-up Qualitative designs (QUANT → qual), as seen in the lower left corner of Figure 4, will have a main research performed with quantitative methods, that is enhanced with a follow-up research utilizing qualitative methods. For these last two designs Morgan informs that the follow-up is based on a need to take the research results one step further. For this design in particular it might be that the main research produces unexpected results and while these might be difficult to handle within the scope of quantitative methods, a very suitable solution will be to investigate the anomalies with qualitative research methods. (Morgan, 2014, 93–4)

Follow-up Quantitative designs (QUAL → quant), as seen in the lower right corner of Figure 4, will have a main research performed with qualitative methods, that is enhanced with a follow-up research utilizing quantitative

methods. Regarding this last design Morgan suggests that if the researcher wants to show that the results from the core, qualitative study can apply on a broader scale, this design could be the correct path, by performing a quantitative appraisal for similar cases.

1.2.5. Research method, hypotheses and research restrictions

This thesis is the result of several methods. Partially it is a study of literature concerning inventory both directly and indirectly, but it is also partially dependent on cognitive observations. The written sources are both academic books and articles authored by scholars and also case-study based theses by bachelor, master and doctoral students. Both new and old sources are included, with the common notation that the essence of the research is relevant to the topics in this thesis, and that the information is not outdated. Based on the sum of these settings and in light of the methods presented in the previous sections, this thesis is designed according to the sequential contribution of qualitative input.

There is a wide spectrum of sources handling each of the aspects, or viewpoints, of the inventory concept, but very limited cross-section theory and analysis. This thesis will try to start filling that gap by claiming the following:

- 1) Inventory can be divided into three aspects – economic, physical and listed.
- 2) Keeping a well-managed inventory can enhance the process quality of the product as well as the production line workers' well-being.
- 3) Success in business can be traced back to the quality and accuracy of inventory data input.

This thesis looks at inventory from several angles: the economical angle through working capital, the physical angle through production line and the listed angle through inventory management, all the while applying quality as a common denominator. However, this thesis does not handle the specifics in each subject other than what is necessary to see how it is connected to the

inventory. The surroundings for this research is set to a production line environment, as mentioned earlier, implying that the focus will be limited to handling inventory relations within those confines.

2. LITERATURE REVIEW

2.1. Inventory

2.1.1. Definition of Inventory

The word 'inventory' comes from the Medieval Latin word 'inventorium' and means 'a list of what is found'. As years go by and times change, the concept of inventory expanded to include much more than just the name of its items. Additionally there are the British-English and the American-English ways of using the word, combined with the extensive mixed usage of the two terms 'inventory' and 'stock'. (*inventory - definition of inventory in English from the Oxford dictionary*, n.d.) This thesis will not use the word 'stock' unless it is part of a commonly accepted term.

Although inventory is basically defined in the same way, nuances and stresses will be added, reflecting the viewpoint of the definer. Weetman (2006, 239), a professor in economics, defines inventory as assets either waiting to be sold, being made into something that can be sold or helping out with the two aforementioned tasks. Muller (2011, 1), who has been involved in inventory management for many years, on the other hand, defines inventory as all material in an organization used in or for operations. It is even possible to consider *everything* to be in someone's inventory (Muckstadt & Sapra, 2009, 1). The difference in stress indicates the point of interest for the specific audience. This thesis will combine these viewpoints and consider inventory defined as:

Goods, from raw material to finished products, that are in the organization's possession and intended for sale or sales related operations.

2.1.2. Types of inventory

There are several ways to divide the inventory into manageable chunks. The most common division is called aggregate inventory, which sorts items by processing state and includes 1) raw material and purchased parts, 2) work-in-process, often in the form of sub-assemblies and 3) finished goods. Inventories regarding spare parts and consumables (copy paper, coffee etc.) will be omitted in this thesis. These three states (1, 2 and 3) represent materials coming into the facility, being handled in the facility and getting shipped from the facility. (Arnold et al., 2012, 196–9; Weetman, 2010, 462–3.)

All three states are important in the scope of this thesis. Purchasing relates mainly to the raw materials and marketing relates to the finished products while assembly handles the transition between those two through work in process.

2.1.3. Costs of inventory

Weetman (2010, 470–5) concentrates on the different costs connected to inventory and divides them into cost of ordering and cost of holding. Ordering costs are naturally linked to a purchasing strategy, but also include the different movements of goods within the facilities and all the personnel activities required for ordering, receiving, controlling, shelving and invoice handling. Holding costs include the costs induced by having either too much or too little inventory. In accounting the three states mentioned in the previous section are all considered within holding costs. (Weetman, 2006, 239–40.)

Arnold et al. (2012, 201–3), however, divide holding costs into carrying costs, shortage costs and capacity-associated costs, as their focus is on materials management. Additionally, they extract item cost from the ordering cost. Arnold et al. (ibid.) continue regarding the potential damage a shortage might ensue, including lost sales, lost customers and back-order costs. Muckstadt and Sapra (2009, 14) also find both the direct and indirect costs of shortage to be significant.

2.1.4. Inventory management and control

According to Muckstadt and Sapra (2009, 5) there are four questions that always need to be answered regarding inventory: 1) what items should be stocked, 2) where should the item be stocked, 3) how much of the item should be ordered and 4) when should the order for items be placed. Arnold et al. (2012, 207) also introduces four questions; 1) how important is the item, 2) how should the item be controlled, 3) how much of the item should be ordered at one time and 4) when should the order for items be placed. The last two questions are identical to those suggested by Muckstadt and Sapra, but the first two represent different angles. The common denominator for all of them is that they show a clear stress on inventory management, but also some indication towards an economic aspect.

Muckstadt and Sapra (2009, 5) explain that their first question ('what items should be stocked?') is connected to both a purchasing strategy and a business strategy. If the stress of the question is phrased in a different way it becomes a question connected to production, namely 'what items do we need'? This phrasing is still related to the purchasing strategy. The second question ('where should the item be stocked?') is connected both to the physical placement of the item, but also to what costs might come as a result of whose inventory includes it. By placing it at the vendor's location, there will be a possibility to save on carrying costs. (ibid.) Arnold et al. (2012, 208) state that their two first questions are answered through an ABC-analysis.

The third and fourth questions ('how much of the item should be ordered?' and 'when should the order for items be placed?') aim towards inventory management, although their answers are strongly connected to what strategies are chosen regarding purchasing and production (Muckstadt & Sapra, 2009, 5). Arnold et al. (2012, 11–2) continues by stating that inventory management is closely connected to both the planning and the implementation of production, as well as purchasing. This shows that inventory management is placed in the middle of the action and needs to interact with all parts of the organization and every aspect of the inventory.

There are certain key concepts in materials management, which could be seen as a branch of inventory management, that are established to ease the handling of the flow of information. First of all there has to be a recipe, called a Bill of Materials (BOM), to make the finished products. This BOM consists of all the items, called Stock Keeping Units (SKU), which are needed in the production of said finished products. SKUs are purchased according to a need, which derives from a demand created by marketing in combination with forecasting based on historic trends. If the order of these words is switched the implication would be that the demand for each SKU follows the forecasting for the different products, which BOMs the SKUs are included in. This also means that it is of utmost importance that the BOM is correct, down to the very last detail. (Arnold et al., 2012, 64–9.)

At this point the person in charge of inventory management has a lot of information available, but no precise way of communicating the exact needs to the purchasing department. The most common way to handle this data is to perform an ABC-analysis.

ABC categorization analysis

The ABC-analysis is based on Pareto's Law² and is used to rank the SKUs according to financial impact, which is calculated by multiplying the demanded amount with the items cost. By defining upper and lower limits for the financial impact, the SKUs may be divided into categories, which will dictate how to follow up on their impact and turnover rate in the inventory. (Arnold et al., 2012, 208–10; Waters, 2003, 207–10.) However, this ranking value will not suffice on its own, as it does not take into consideration the cost of the item NOT being present (Waters, 2003, 210). As mentioned above, the shortage cost far exceeds that of the item itself, as the result might be a total stop in production. For this purpose the SKU's usage frequency should also be considered.

² Vilfredo Pareto (1848-1923), Italian economist, observed that 20 percent of the population in his town controlled 80 percent of the wealth. This 80/20 principle has later become known as the Pareto principle or Pareto's Law. (Waters, 2003, 208.)

The analysis can then be extended with a XYZ-analysis, which is based on the same principles as the ABC-analysis, but instead of financial impact it ranks the SKUs according to frequency (Muller, 2011, 70; Kampen, Akkerman & van Donk 2012, 13). When combining the two analysis methods, one ends up with a two-dimensional chart categorizing the SKUs according to importance. This will assist the inventory manager in calculations to make decisions regarding ordering quantities, which was the third question regarding inventory suggested by both Arnold et al. and Muckstadt and Sapra. A further explanation with figures regarding these analyses is found in Appendix 1.

The aim of these techniques is to find the most suitable order amount that will serve the company and the production line while at the same time keeping the costs as low as possible. This shows how the combination of the ABC analysis (categorized according to cost) and the XYZ analysis (categorized according to frequency) will aid in deciding the order quantity, thus answering the third question ('how much of the item should be ordered?'), and also in finding suitable shelf placements so that the SKUs are intuitively accessible for picking and assembly. (Muller, 2011, 76–8; Arnold et al., 2012, 218–9.) The fourth and final question regarding inventory introduced in the beginning of this section is answered through calculation techniques outside the scope of this thesis and will for this reason be omitted.

2.1.5. Viewpoints regarding inventory

As stated in Section 2.1.1 above, one's viewpoint plays a major role when relating to inventory and what it consists of. Weetman stressed the economical part, while Muller put emphasis on the goods. Muller (2011, 9–13) further explains the importance of considering both the tangible and the intangible aspect to the materials in the inventory. Although Muller refers to the *value* of the item as both tangible and intangible, the aspects can also be interpreted as the tangible or physical aspect being the item itself, while the

intangible or listed entry of the very same item is a record in a database. Emmett (2005, 90–1) argues that a consistent labeling system for the placement of physical items in the warehouse radically diminishes the possibility for human error, but holds even more importance to being consistent and thorough when entering data into the registry.

Based on these observations of viewpoints, there are three distinct aspects to inventory that emerge: an economic aspect, a physical aspect and a listed aspect. The combination is naturally the inventory itself, which is represented by the viewpoint of inventory management. For later reference these aspects will be identified by their first letter capitalized, having 'E' for the economic aspect, 'P' for the physical aspect and 'L' for the listed aspect.

Role	Inventory			Task	Predecessor
	E	P	L		
CEO	x	x		Overseer	
Purchaser	x		x	Purchasing	ABXY analysis
Designer		x	x	Designing	Updated register
Assembly worker		x		Assembly	BOM
Picker		x	x	Picking	Shelved items
Shelver		x	x	Shelving	Received items
Receiver			x	Receiving	Ordered/Purchased items
Shipper			x	Shipping	Sales order
Accountant	x			Accounting	Updated register
Seller	x		x	Sales	Updated register
Inventory manager	x	x	x	ABXY	Updated register

FIGURE 5. Deducted matrix of roles, tasks, predecessors and relation to the inventory.

2.1.6. Tasks related to inventory

Waters (2003, 32–3), Arnold et al. (2012, 263) and Emmett (2005, 90) list several tasks related to inventory functions, including purchasing, receiving, shelving, picking, assembly, shipping and inventory management. These tasks follow each other in sequence, thus the action of one is dependent on another. The natural consequence of this list in combination with the text in this chapter can be seen in Figure 5, which is a matrix of the different tasks accompanied with an indication of which aspect(s) of the inventory they primarily relate to and which task needs to be performed prior to the action in question.

2.2. Working Capital

2.2.1. Definition of Working Capital

Weetman defines working capital as *the amount which a business must provide to finance the current assets of a business, to the extent that these are not covered by current liabilities* (Weetman, 2006, 238). She further goes on to state that inventories play a significant role in the management of working capital (Weetman, 2010, 462). Wöltje (2005, 72–3) upholds that working capital is the result of short term liabilities subtracted from the sum of short term assets and inventories, and points out that this has to be a positive number as it is the basis of the company's ability to pay their dues. This is naturally supported by Weetman as she states the calculation formula for working capital: *current assets minus current liabilities* (Weetman, 2006, 238).

2.2.2. Relation between Working Capital and inventory

There is no great mystery neither as to how the working capital is calculated, nor as what components it consist of, according to the previous section. More

common terms perhaps may be 'payables' and 'receivables' instead of 'liabilities' and 'assets'. Inventory is, as stated above, part of the current assets, but it is not a receivable, thus it has to be mentioned on its own. The mechanics in how these factors relate to each other can be seen in Figure 6. (Weetman, 2010, 467).

Weetman also comments on what particular action is performed between the different boxes seen in Figure 6. Goods or services are sold from the inventory to customers on credit, which adds to the receivables. This is followed by reception of payments, which will add to the cash at hand³. These funds will be used to pay off short term debts, before new material is acquired into the inventory for use in production. (Weetman, 2010, 467).

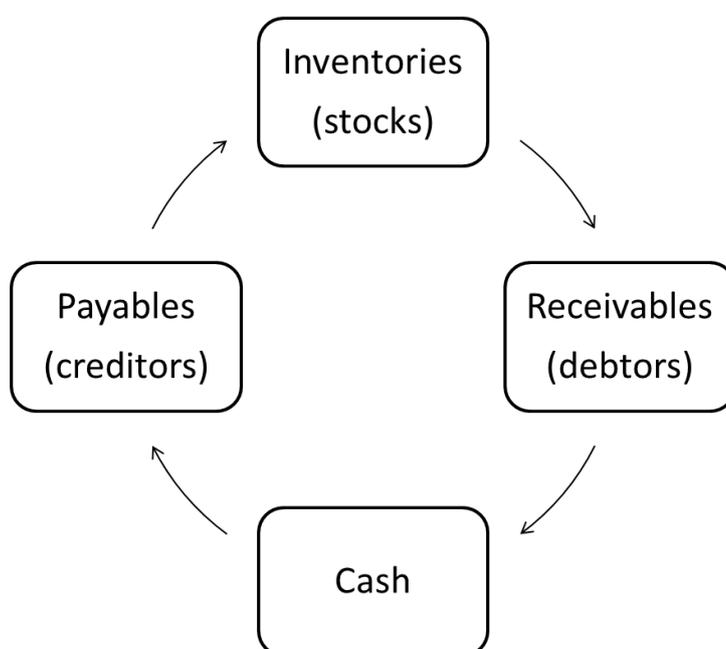


FIGURE 6. Working capital cycle for a manufacturing or service business (Weetman, 2010, 467).

Figure 6 shows quite clearly, that if too much cash is tied up in inventories, there will be a shortage when payments are due in the later sequence of the cycle. In the same way, it is obvious that if the inventory is too little, there will be shortage in the supply to customers and thus shortage in cash to serve

³ An additional figure that describes the cash flow in a company is found on page 38 FIGURE 9. Venn illustration of cash flow.

short term loans. For these reasons alone it is crucial that the inventory is managed on a high level. This is also confirmed by Grant et al. (2006, 135) in their statement that *inventory is a major use of working capital*.

This thesis will not go into fine detail about how this cycle works, as the scope only allows an analysis of the 'inventory' part and interaction to working capital as a whole. A further discussion concerning working capital performance is, however, found in Section 2.4.6.

For the management of inventory in light of working capital there are two factors that will be especially significant. According to Weetman (2010, 462–7), working capital is managed through controlling and planning the levels of inventory, creditors and debtors. The planning is derived from the demand discussed in Section 2.1.4 and the controlling is done through terms of payment. The conditions of these terms may vary depending on the company strategies, but a fairly common term is that the goods must be paid within a certain amount of days from delivery. Weetman (ibid.) suggests that discounts for early payments may be offered, but in such cases the benefit needs to be weighted towards the gain of early payment. Terms of payment naturally works both for creditors and debtors, although it is usually the creditor that sets the terms. (ibid.)

The effect of said terms will naturally have a solid impact on the working capital. As long as the company must wait to receive payment for delivered products, it will have to rely on its own savings and cash on hand. On the other side of the cycle (see Figure 6) the company will build up savings, and possibly interest, during the time it is not obliged to pay its creditors. (ibid.) García-Terual and Martínez-Solano (2007, 12) suggest that the term of payment regarding payables is less significant in relation to the company's return on assets compared to term of payment in receivables, while Tauringana and Afrifa (2013, 13) found that the management of accounts receivables could be seen as slightly more important regarding the company's profitability than management of accounts payables.

2.3. Production line

A production line is exactly what one would think of upon hearing the term – an area where people and/or machinery interact with material to present a product (Aswathappa & Bhat, 2010, 1). In this thesis the term ‘production line’ will also include ‘assembly line’ and ‘installation line’. In this thesis the word ‘line’ does not necessarily point to a line setup.

Commonly the production and assembly area will be categorized according to the nature of business in the organization. The inventory layout is then built up to fit the selected setup strategy. This thesis, however, makes no distinction between a line setup and a cell setup for example, as the chosen setup is not important in this context⁴. The main point is that regardless of the physical layout of the production line, the workers will all need to relate to the inventory and the interaction should not be hindered by poor inventory management. The issues concerning product placements in the inventory will be discussed in Chapter 4.

2.4. Quality

2.4.1. Definition of Quality

Measure what is measurable, and make measurable what is not so.
- Galileo Galilei

Quality is a very common word, but the colloquial meaning of quality is completely dependent on the context of its use. Dictionaries define quality with a slightly different stress, but with a red thread focusing on quality as a comparative measurement between similar entities. This means that a product’s quality measure is meaningless if it is not seen in comparison to a

⁴ Setup will however play an important role in work efficiency, productivity and cost savings, as well as have a notable effect on work related well-being and stress (Pihala, 2009).

similar product. (*Definition of Quality*, n.d., *quality definition, meaning - what is quality in the British English Dictionary & Thesaurus - Cambridge Dictionaries Online*, n.d., *quality - definition of quality in English from the Oxford dictionary*, n.d., *What is Quality? definition and meaning*, n.d.). Kekäle (1998, 15) points out that the general population will use 'quality' to describe something sublime and exceptional, while in business terms (and in the scope of this thesis) 'quality' deals with the area of satisfying a need and an expectation.

Since the rise of quality management in the 1950s, there have been many suggestions as to how quality should be defined. Juran started off with an emphasis and focus on quality in leadership and Kano stressed that quality is connected to expectations. The Kano-model has later on earned great reputation regarding the understanding of customer 'needs' and 'wants'. One of the best known models deriving from this era is the Deming cycle, which was introduced by W. Edward Deming in the 1950 JUSE seminar in Japan (Moen & Norman, 2011, 7)⁵. His Plan-Do-Check-Act cycle (often referred to as the PDCA-cycle) is shown in Figure 7. (Sakala, 1997, 15)

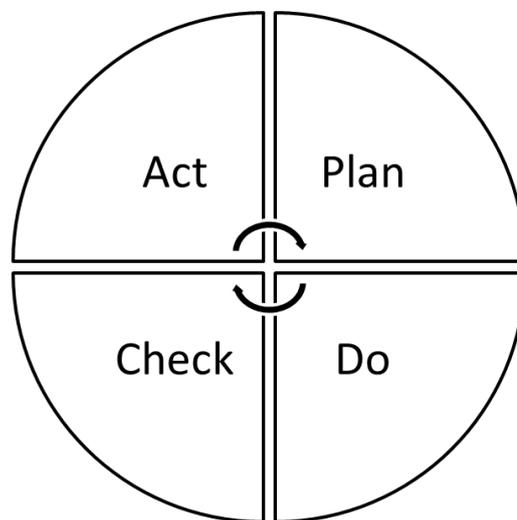
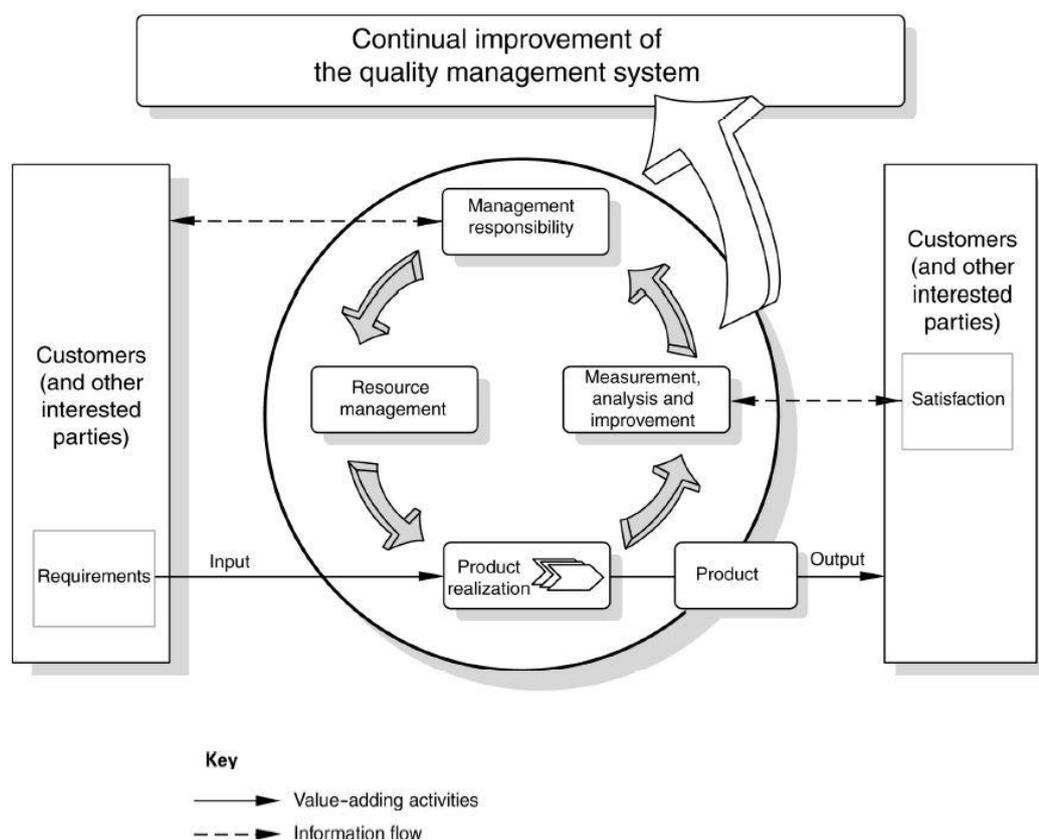


FIGURE 7. Deming's PDCA-cycle

⁵ Deming specified his theory to fit a specific forum and talked about a Plan-Do-**Sales**-Act cycle in the JUSE seminar. The Japanese implemented the cycle in a broader view and changed 'Sales' to 'Check'. No one has claimed the evolvement, thus it is still called the Deming cycle. (Moen & Norman, 2011, 4)

The introduction of the concept of total quality management (TQM) is slightly ambiguous according to Kekäle (1998, 16). The term was first used in context by the US Naval Air Systems Command in 1985, and was made popular during the following years (Martínez-Lorente et al., 1998, 3). The roots and inspiration seems quite clearly to have come from the Japanese quality crusade mentioned above (ibid., 3). TQM originally aimed to fulfill the customer's expectations, while later versions emphasized that quality is never finished evolving (Kekäle, 1998, 16–17). In later years Lean Manufacturing, Six Sigma and, above all, ISO 9000 defined quality and quality management especially for business as a part of TQM. A common point for these three quality management systems is the stress on continuous quality improvement in a process oriented environment. (Martínez-Lorente et al., 1998; Olli, 2003, 8–12; Dahlgard & Dahlgard-Park, 2006.)



NOTE Statements in parentheses do not apply to ISO 9001.

FIGURE 8. Model of a process-based quality management system (SFS-EN ISO 9000:2005, 2005, 3)

From the multitude of definitions, of which only a handful is mentioned above, this thesis will use the ISO 9000:2005⁶ definition of quality as its main basis for implementation in the different aspects. The main reasons are that ISO 9000 is an internationally renowned standard and it forms the basis for ISO 9001:2008, which is a certification standard implemented all over the world. Due to the diversity of the subjects there will necessarily be some stress differences, but the common denominator is formulated as:

Quality is the degree to which a set of inherent distinguishing features fulfils a need or expectation that is stated, generally implied or obligatory (SFS-EN ISO 9000:2005, 2005, 7)

Quality is a huge area that covers in great detail even the smallest items and issues. Due to the complexity of the theme for this thesis, there will not be an exhausting elaboration for each aspect, as there are many excellent predecessors whom have thoroughly expanded on each subject. Instead there will be focus on a few key points regarding quality, including the well-being of workers in a company, inventory management, data input and assembly.

2.4.2. Quality of work environment and the workers' well-being

Dessler (2008, 3) quotes Faulkes (1975) stating that the biggest bottleneck for production is a workforce lacking efficiency and enthusiasm. Kiviniemi and Leppänen (2012, 57) performed research on employee well-being as a competitive advantage and concluded that, in their case study, there was a correlation between the level of well-being and the company's long term profitability. Rosala (1997, 47–9) found that employee commitment would have a distinctive influence on continuous quality improvement in the case organization, as long as management would lead by example. This is supported by the findings of Kokkonen (2005, 58), who also found that management's ability to communicate with the workers strongly influenced the

⁶ According to the ISO 9000 webpage an updated version of this standard is due late 2015. The definitions are to remain the same. (*ISO 9000 quality management - ISO, n.d.*). For a fuller report on the ISO 9000 standard and its application see Olli (2003) and Seppä (2006).

work-related well-being. The obvious conclusion here is that the workers' well-being matters and that it can be enhanced. The challenge is how to accomplish this.

Well-being at work is naturally a subjective matter by nature, although there are some general key issues that will always have an effect on the perceived quality of a work environment. It would be futile to try to cover every aspect of work-related well-being, thus this thesis will concentrate on motivation and stress.

Herzberg, Mausner and Snyderman (1959, 113–9) explain in their dual factor theory the difference between hygiene and motivation factors and how these factors play different roles regarding the will to work. The factor sets are listed in Table 2 below.

TABLE 2. Herzberg's two-factor theory (Fivelsdal & Bakka, 1998, 168)

Hygiene factors	Motivation factors
Company politics and administration	Performance
Management	Recognition
Salary	Work itself
Relationships at work	Responsibility
Working conditions	Promotion

Shortly put, the hygiene factors build a casing in which the motivation factors can grow and thrive. According to Herzberg et al. (1959, 113–9), the hygiene factors by themselves can merely hinder poor work performance and dissatisfaction and not achieve more than this. The motivation factors will not do very well on their own either, since the security of steady surroundings is not present. (Salanova & Kirmanen, 2010, 13–4.) Fivelsdal and Bakka (1998,

167–8) remind that this theory is a product of its time and has later experienced some critique, especially regarding the rigid division between the two sets of factors.

Johnson, Cooper, Cartwright, Donald, Taylor and Millet (2005, 2) cite Cooper and Marshall (1976) on five sources of stress, which are 1) working conditions, 2) role ambiguity/conflict, 3) career development, 4) relationships at work and 5) organizational structure and climate. Sources 1, 4 and 5 are found among Herzberg's hygiene factors. The second source of stress, role ambiguity/conflict, is the opposite effect to that of responsibility, which is one of the motivating factors in Table 2. This also holds for the pairing of career development as a stress source and promotion as a motivator. Johnson et al. (ibid.) continue by referring to the ASSET⁷ model as an important tool to map brewing stress trends in organizations. The ASSET model also introduces four more sources of stress: 6) balance between private and work life, 7) gained satisfaction from work performance, 8) how much control and autonomy the employee has at work and 9) commitment level, both employee to organization and organization to employee.

Organizational culture is listed both as a hygiene factor (company politics and administration) and as a source of stress (organizational structure and climate). This is perhaps the area where management most clearly sees the fruit of their actions. Culture is a dynamic state, which needs to be grown and maintained by leaders. (Johnson et al., 2005, 2; Fivelsdal & Bakka, 1998, 126.) Fivelsdal and Bakka (1998, 126) state that management's most important challenge regarding company culture is to find the correct balance between requirements from the surroundings, expectations of the workers and the strategic evolvement of the organization. This means that the development is continuous and is dependent on the interaction and communication within the organization. The natural conclusion is that the ones who partake in it form the culture.

⁷ ASSET (A Shortened Stress Evaluation Test) is a questionnaire that is used in the first of a two phased stress assessment and is constructed to give a quick overview among all employees regarding problematic stress areas in the company (Johnson et al., 2005, 4).

According to Dahlgard and Dahlgard-Park (2006, 12), a company with ambitions to elevate its quality will need a culture where the workers understand the importance of their contribution and are willing to participate, both by helping each other out, but also in reduction of waste. They go on to claim that waste is everything that increases cost without adding value for the customer and that it is important that everyone within an organization adds their contribution in order to achieve the common goals and continuous improvement towards the customers. (ibid., 4, 11.) This statement points to stress source number 9 regarding level of commitment. This aspect of cooperation versus conflicting motives within the organization is further discussed in Chapter 3.2.

Johnson et al. (2005, 2–3) explain that prolonged stress could have a negative effect on the workers' mental and physical health. They also uphold that stress factors, or stressors, depend on the type of work a person performs. On top of this come aspects of personality and how well the person handles stress. This means that workers within the same profession are likely to be subjected to the same stressors, but would experience the stress differently. They further go on to state that stress is a significant factor regarding psychological well-being. (ibid., 5.) Dessler (2008, 665–6) also adds that job stress leads to diminished quantity and quality of performance.

As described in Figure 8, there are customers for every quality improvement process. Sower (1999) states that these customers are both external and internal. For the scope of this thesis this means that each of the tasks performed in a company have a customer inside the company, as also mentioned in Section 2.1.6.

2.4.3. Quality of assembly

The quality of the finished product derives firstly from the quality of the raw materials that are used and, secondly, from the handling that happens between raw material state and finished product state. While the first factor is

dependent on purchasing performance, the second is a series of tasks, namely receiving, shelving, picking and assembly. All of these are closely connected to the people performing the tasks, thus connecting it to their well-being and motivation, as well as the company culture.

Quality of assembly is dependent on 1) the quality of previous handling, 2) the quality of the tools in use and the working area, and 3) the person performing the assembly. Previous handling will be redundant to discuss, as it would ultimately mean the quality of assembly itself. The two remaining factors are mentioned in the previous section, where tools and working area is a hygiene factor and a source of stress, while the performance of the assembly worker is influenced by the motivating factors and the personal level of stress. The possible stress inducing factors include poor or missing performance from predecessors, missing or faulty equipment and lack of skill. Of these only the first one relates to the inventory. (Emmett, 2005, 98; Ruohomäki et al., 2011, 70–81.)

2.4.4. Quality of inventory management

Grant et al. (2006, 135) state that one of the core objectives of inventory management is to increase profitability along with minimizing cost, while all the time maintaining a customer service level according to the company policy. Although this sounds like a utopic goal, it is in fact an accurate description of an ongoing process, thus it works very well in relation to both the Deming cycle and the ISO 9000 cycle in Figure 8. Inventory management performance is, however, highly dependent on the input produced by the other tasks in the production line.

2.4.5. Quality of data input

Quality of data input refers to how complete and accurate the data is when entered into the data systems. For companies holding inventory, the

improvement of data entries is crucial for effective management and control of SKUs (Wiersema, 2013). Laberge (2011, 40–3) argues that data within the organization is an asset and needs to be handled accordingly and further contemplates that data quality is a subject of many facets, among which he mentions context determination, input types classification and constant governance. Regarding websites' quality assessment there is even an applied quality factor of easy-to-use (Nguyen, 2014, 15–16). Even though computer programmers will do their utmost to prevent faulty data entries, a degree of unpredictability will always be present (Williams, 2006, 8). The probability of faulty entries will naturally increase with the complexity of the data system in use (Hänninen, 2012, 5). This issue can be diminished with sufficient training, which will also have a positive effect on workers' well-being, as it will support the worker's feeling of mastering the given tasks.

2.4.6. Quality enhancement beneficiaries

The enhancement of quality in the above mentioned areas will naturally benefit the whole production chain. Some of those areas play a significant role in the progression of this thesis and are briefly handled below.

Quality and purchasing

Arjan van Weele (2014, 224–5), a renowned scholar in the field of purchasing management, applies the Deming cycle and extends it with purchasing terminology to show how it is a crucial part of the purchasing operation. He goes on to conclude that the measured performance of purchasing in an organization is highly dependent on purchasing's function and importance from management's point of view (ibid., 286-7). This is also supported by Benton (2010, 256), who states that purchasing plays an increasingly important role regarding an organizations level of TQM. van Weele (2014, 70) also suggests four dimensions to measure purchasing performance: price/cost, product/quality, logistics and organizational. Even though these, for

the most part, point towards the economic aspect of inventory, the logistics dimension is clearly also part of the listed aspect.

Quality and Working Capital

When it comes to the quality of working capital there will be an issue with the nature of the subject. As seen in Figure 6, the working capital cycle consists of several steps and the relative value of working capital will naturally depend on what part of the cycle is more prevalent in the organization at the given time. For this reason it makes more sense to discuss the performance of working capital.

García-Teruel and Martínez-Solano (2007, 12) state that the management of working capital is crucial for the profitability in small and medium sized companies. Tauringana and Afrifa (2013, 13) add that the company's focus should be on careful management of payables and receivables. According to Weetman (2010, 468), there are mainly two tools that are used to measure working capital: current ratio and liquid ratio.

Current ratio is calculated by dividing current assets by current liabilities. The idea is to find out how well a company will be able to handle its debts (ibid.). The Committee for Corporate Analysis (2005, 67) suggests that this ratio is good if it is more than 2, satisfactory if it is between 1 and 2 and weak if it is less than 1. Weetman (2010, 468) claims that a common ratio for companies is between 1 and 1,5. However, if it greatly exceeds 2 this could be a sign that the company has excess inventory and debtors (ibid.)

Liquid ratio is calculated in almost the same way, but the inventory is extracted from the current assets so that only cash on hand and incoming funds are taken into account. This is, according to Weetman (ibid.), to show how well prepared a company is to handle an immediate crisis, where all trade creditors have to be served at the same time, however unlikely such a scenario might be. Weetman (ibid.) estimates that most companies keep this

ratio between 0,75 and 0,9. A ratio of 1 or higher implies a safe coverage of payables, but could also mean that the company has too much cash or debtors. If the ratio is below 0,75 the creditors might be nervous regarding the company's liquidity and so demand payment, which in turn would lead to a crisis. (ibid.)

Quality and management

As mentioned in Section 2.4.2 management is in a crucial spot regarding the well-being of the workers in the company. Ojala and Ahonen (2005, 92–6) state clearly that shortcomings and indifference towards well-being is an entrepreneurial risk and will lead to increased stress and risk of burnout, a bad climate and weak management. They continue to conclude that the result of weakened management is ultimately loss of wealth.

Hirvonen (2005, 82–3) states that a successful implementation of management is dependent on how well the manager picks up on the culture in the organization and, subsequently, how well the different quality management aspects, like focus on continuous improvement, are applied. She follows up by adding that the manager also needs to have a broad understanding of quality for all areas of the organization (ibid., 88).

Quality and finished products

As stated in Section 2.4.3 the quality of finished products is the result of the quality of the utilized raw materials and the quality of the handling, which implies assembly. The quality of raw materials is naturally the result of purchasing, which is discussed above. The combination is then ultimately the quality of the product that goes out to the external customer.

2.5. Summary of the literature review

Due to the complexity and depth of the subject in this thesis the literature review consist of several approaches towards inventory and its different facets. Section 2.1 introduced the concept of inventory and extracted three main viewpoints – an economic, a physical and a listed aspect. By applying these aspects in the context of the section it was shown in Figure 5 how people within a production company relate to the inventory according to their task and agenda. Section 2.2 looked into how Working Capital is linked to the inventory and also why inventory management is so crucial regarding the Working Capital. This was a much more theoretical approach, though necessary to illustrate the fact that it is the same inventory throughout the chapter. Section 2.3 concluded that production workers interact with the inventory in a hands-on approach, while Section 2.4 handled quality as a common denominator for every interaction with the inventory. The quality approach also showed how one person's action could affect another's premises for performing their own tasks, according to the Deming cycle and the definition of quality itself.

3. IN SEARCH OF A MORE COMPLETE INVENTORY MODEL

3.1. Introducing the model

The development of this model has been a fairly long process and it is complicated to pin-point exactly how I got this idea and what inspired its development stages. The Venn in Figure 1 on page 6 is one of the inspiration sources, but an equally heavy contributor is the illustration seen in Figure 9. This is a presentation of cash flow forecasting in a company and is an illustration I had the pleasure of developing with my fellow student Minna Kauppi when we were trying to understand the impact of working capital. This model is also referenced in the section about working capital earlier in this thesis.

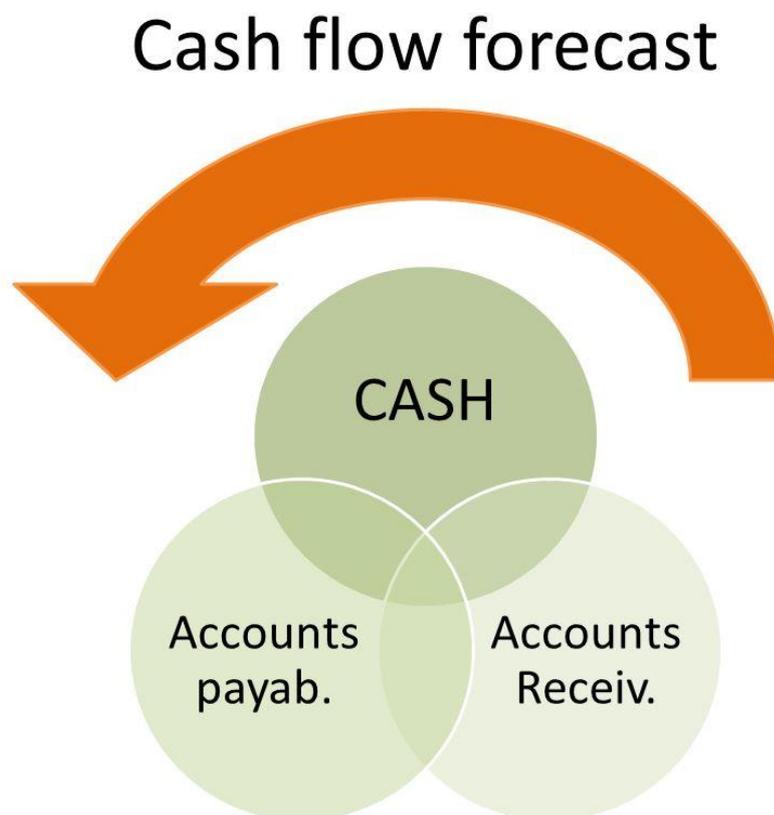


FIGURE 9. Venn illustration of cash flow.

The fact that inventory is a part of working capital, as discussed in Section 2.2.2, got me thinking that perhaps inventory could be extracted from some other similar contexts as well, assuming it would be the same inventory reference, just with different vantage points. The most obvious aspect was the physical, as the inventory is, first and foremost, tangible. While keeping these two aspects in mind – the economic and the physical – my reasoning concluded that there has to be an intangible aspect as well, due to the very nature of the word ‘inventory’ (‘list of what is found’, see Section 2.1.1). I tried to set up the three aspects as a Venn diagram, as shown in Figure 10, but I soon discovered that such an illustration does not work. There are no possibilities to perform sound and logical deductions from this model, as the cross sections do not represent anything related to the inventory. Also, the center, which should represent the complete inventory, would be far smaller than the parts it is made from. Based on this I concluded that this model is not suitable.

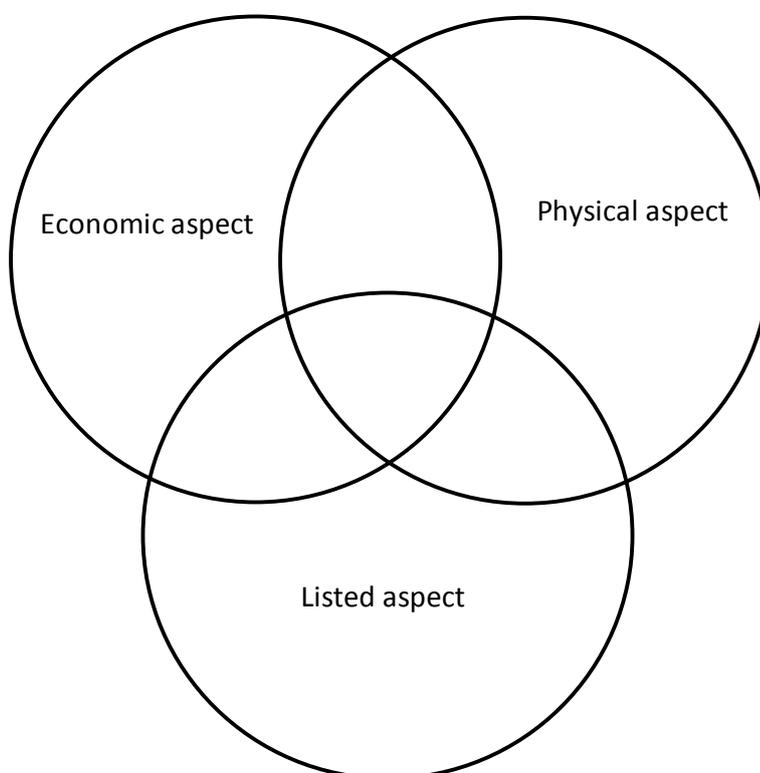


FIGURE 10. Initial division of the inventory aspects.

The contemplation process continued and after some more drawing I ended up with the design seen in Figure 11. Here the complete inventory is represented as a ring divided into three sectors. Each sector illustrates one of the aspects ('economic', 'physical' and 'listed'), thus making each aspect a part of the total inventory without any of them individually growing too large. I also drew in some strategically placed small circles to represent different roles and tasks within a production company and show how they could relate to the inventory. When each of these smaller circles are understood as a point of view, the model itself could be interpreted into a three dimensional figure, which led to the name 'Doughnut model for inventory'. The model is drawn in two dimensions to make it easier to reproduce on a whiteboard or similar medium.

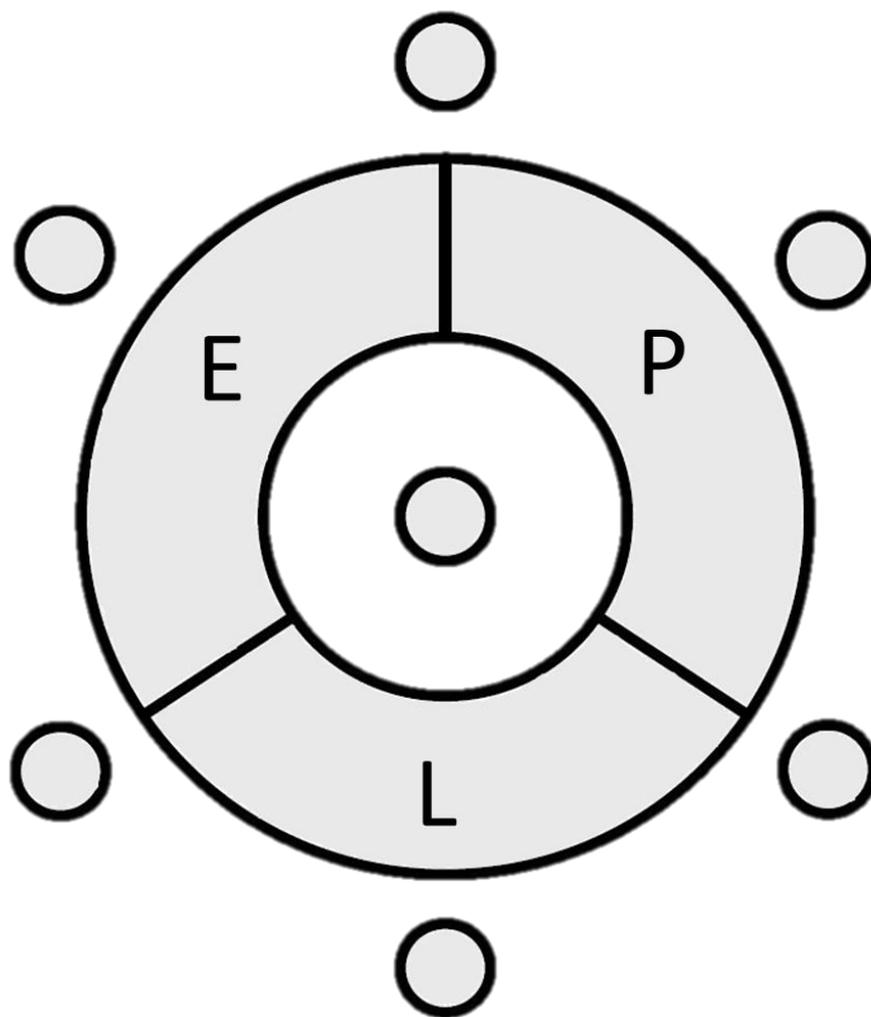


FIGURE 11. The Doughnut model for inventory.

Role	Inventory			Task	Predecessor	Expectation	Requirements	Customer(s)	Result
	E	P	L						
CEO	x	x		Overseer					
Purchaser	x		x	Purchasing	ABXY analysis	Complete data	ABXY analysis	Receiving	Incoming goods
Designer		x	x	Designing	Updated register	Complete data	Updated register	Inv. Manag., Purchasing	BOM
Assembly worker		x		Assembly	BOM	Materials ready for assembly	Shelved items	Shipping	Finished goods
Picker		x	x	Picking	Shelved items	Items in place	BOM	Assembly	Materials ready for assembly
Shelver		x	x	Shelving	Received items	Updated register	Received items	Picking, Assembly	Items shelved correctly
Receiver			x	Receiving	Ordered/Purchased items	Complete data	Ordered/Purchased items	Shelving, Accounting	Register updated
Shipper			x	Shipping	Sales order	Finished goods	Sales order	Accounting	Register updated
Accountant	x			Accounting	Updated register	Complete data	Updated register	Inv. Manag., Purchasing	Register updated
Seller	x		x	Sales	Updated register	Complete data	Updated register	Inv. Manag., Purchasing	Sales order
Inventory manager	x	x	x	ABXY	Updated register	Complete data	Updated register	Purchasing, Shelving, Accounting	ABXY analysis

FIGURE 12. Matrix extended from Figure 5 with expectations, requirements, customers and results.

3.1. Model implications

A matrix of tasks and roles interacting with the inventory was deduced in Chapter 2 and was presented in Figure 5 on page 22. Viewed in light of the discussion regarding quality in Section 2.4 the matrix can be extended with some more columns. This new matrix is presented in Figure 12 on the previous page. The model in Figure 11 is an illustration of the very same tasks seen in connection to the inventory. While the tasks and roles are the main focus in the extended matrix, the Doughnut model focuses mainly on the inventory, having the tasks to support the division. The role of the inventory manager would be the small circle in the middle of Figure 11, due to the need of being in contact with all parts of the inventory, as stated in Section 2.1.4. This is then found in Figure 12, as the role of inventory manager has markings in all three inventory columns. Appendix 2 shows how Figures 11 and 12 can be more thoroughly combined.

Everyone relating to the inventory will do so based on their own agenda, as mentioned in the introduction. Based on the findings in Section 2.4.2 on well-being and work environment, it is evident that – in the case of the doughnut model – seven different approaches and agendas will lead to a conflict of interests (see also Figure 2).

Conflicts within a company are in fact more or less always present, as the term handles just the kind of situation presented above. According to Fivelsdal and Bakka (1998, 188), these conflicts usually regard differences in opinion on how a problem should be solved, while retaining a common goal. They also claim that having conflicts is a healthy sign, as it means that the workers are not afraid of speaking their mind. This does not mean that a state of conflict is preferable, but rather that the management and leadership should learn to expect it. It takes considerable communication skills to solve these issues, but it is made easier through a clear company strategy and a positive culture. (ibid., 188-90.)

Any solution will have to come through communication. Everyone within the company who interacts with the inventory to whatever degree has to understand their own relative position regarding the inventory and also the complexity of the inventory concept. The model in Figure 11 will serve as a tool for this communication.

3.2. Relation to ABXY

The placement of the inventory manager in the middle of the Doughnut model might come across as arrogant, but is in fact a logical and natural conclusion, supported by Arnold et al. (2012, 11–2). The analysis of the inventory is naturally one of the tasks allotted to the inventory manager. As discussed in Section 2.1.4, the most common analysis method is the ABC classification which, in combination with the XYZ-analysis, will serve as an important tool in managing the complexity of the inventory. The other roles and tasks will in turn draw benefit from these analyses, which will pave the way for improved analyses in the future, as seen in Figure 12. The stress here is yet again that each role needs to comprehend their own position in relation to the inventory and that the inventory is more than the aspect to which they most naturally relate. This is the undisputable key to advancement.

3.3. Relation to quality

As mentioned in Section 1.2.5, quality serves as a common denominator, which implies that there should be a connection between the model in Figure 11 and quality. There are a few key points that will work together towards the goal of enhanced quality: 1) the management has to lead by example, 2) the organization culture has to support openness and conflict resolution through communication and 3) the workers have to know their positions in relation to the inventory, and the complexity of the inventory beyond their own usage.

4. DISCUSSION

4.1. Grounds for discussion

The following claims were introduced in Section 1.2.5:

- 1) Inventory can be divided into three aspects – economic, physical and listed.
- 2) Keeping a well-managed inventory can enhance the process quality of the product as well as the production line workers well-being.
- 3) Success in business can be traced back to the quality and accuracy of inventory data input.

The first and second claims found support through the different opinions and viewpoints expressed in the chosen literature, which was reviewed in Chapter 2 and summarized in Section 2.5. The third claim found support to some extent through the literature review, though it was not indisputably proven to be the only source of success. The importance of accurate data input was considered very significant.

The initial method of literature review handled 46 sources from several different fields of expertise. The aim for this part was dictated by the claims mentioned above, thus limiting the survey scope to a manageable size. The next method of logical deduction and model development was built upon the literature review in combination with personal observations.

The model synthesis culminated in the presentation of the 'Doughnut model for inventory'. The intention and implementation of the model was deducted from the preceding parts of the thesis and explained with referral to the text.

4.2. Research limitations and weaknesses

The limitation set by the claims made the scope narrow enough to handle within the requirements of a bachelor thesis, yet left it sufficiently wide so that all the necessary issues could be taken into consideration. As there are numerous books, articles and theses available on each specific subject that this thesis touches on, the amount of sources handled could come across as small. Additionally, it should be mentioned that the majority of the sources, about 80 percent, are 10 years old or less, while a few key sources are between 16 and 18 years old. This could be seen as a too narrow base for the research and implied findings.

The fact that some of the sources used are somewhat old does not make them insignificant or outdated. As stated in Section 1.2.5 the sources were chosen because they explained their subject in a clear and concise way, and, to keep within the context and essence of the matter at hand. This evaluation, however, was performed in solitude, albeit in light of the other sources.

The sources are mainly from Europe and North America, thus reflecting the results in a light of western thinking and business approach. Even though the definition of Working Capital likely remains the same throughout the world, the concepts of well-being, efficiency and organization culture are prone to interpretations depending on geographical placement and cultural belonging.

4.3. Evaluation of the Doughnut model

Regarding the Doughnut model for inventory, there are several issues to consider: the word 'inventory', validity, reliability, innovation and usability.

As mentioned in the beginning of Section 2.1.1, the word 'inventory' holds different meaning depending on which type of English language is dominant. This thesis has regarded the word 'inventory' very inclusively, which was, without a doubt, a simplification made on the assumption that the majority of

people in the world are not native English speakers, thus being somewhat indifferent regarding the quite subtle difference between 'inventory' and 'stock'. How professionals within the field of inventory management or similar fields would react was never an issue, as the main target group mainly consisted of people not identified as said professionals.

The question concerning whether the model in Figure 11 is valid or not is highly interesting. Based on the literature review in Chapter 2 and the discussion above, it is safe to state that the model is supported and thus not incorrect. Although that in itself is a milestone towards a general model, it does not represent conclusive evidence of the model's universal validity. To some extent it is futile to prove a newly developed model without further research, as shown in Figure 3. Such research would also serve to test the reliability in an applied setting.

The model is reliable to the degree of theoretical basis, at least within the confines discussed earlier. See below for a further evaluation of usage limitations. The cognitive observations also support the reliability claim, but yet again the proof is not conclusive. The model's usability will naturally follow the limitations of its sources, at least until further research can validate its reliability.

For professionals within inventory management or logistics engineering the model hardly present any new information, as all the subjects handled in this thesis are within the scope of both fields. The graphical presentation and contextual setting might prove innovative even to these groups, but as mentioned earlier, the target group does not primarily include professionals within these fields. For managers and other workers in production companies this model will represent a new way of relating to the inventory.

4.4. Support beyond the presented material

The idea of cooperation within an organization across professions is not by any means a new concept, even though it might seem so based on the

previous section. van Weele (2014, 365) talks about cross-functional buying teams as a part of an organization's purchasing strategy, with the purpose of gathering sufficiently broad expertise to perform the best possible acquisitions. The purchasing professional cannot manage the complexity of future sourcing alone, due to the myriad of technical details and specifications (ibid.). If the purchasing strategy also includes supplier involvement within the supply chain, the cooperation is completely necessary. Hadaya and Cassivi (2007, 16–7) found that collaboration with the closest and second closest suppliers in a supply chain had a significant and positive impact on both the relationship strength but also the company's own flexibility.

Within the field of entrepreneurship, Timmons and Spinelli (2009, 109–16) utilize the Timmons model to show how success in entrepreneurial processes derives from entrepreneurial teams. The model was constructed almost four decades ago and fairly recent research has confirmed its validity, thus supporting the claim of teams as a winning factor (ibid.).

4.5. Critique of the ABXY-analysis

The analyzing methods ABC and XYZ were explained in Section 2.1.4. There is no doubt that these methods have proved to be very useful in countless situations, and will continue to be significant in inventory management for years to come. Yet, as so often with theory versus applied practice, these two methods do have shortcomings.

One of the issues with this kind of combination of methods is that the result can be difficult to comprehend and implement. The research performed by Kumar and Chakravarty (2015) gives a good example of how the methods have been applied correctly and the calculations have been performed correctly, but the conclusion based on the results is unclear and to some extent even misleading. They managed to get even more A-items from the combined analysis, which is not the aim of the ABXY-technique, thus being counterproductive in the eyes of inventory management.

The ABXY-analysis has naturally been implemented with success on several occasions. Turunen (2011, 56–58, 66–67) performed this analysis as a part of his work with implementation of product data management, and the results were useful and informative. Lapp (2013, 30–33) utilized five categories instead of the usual three, for more applicable results, and was able to reorganize the shelving placements for the case company in a more efficient way. Karjalainen (2012, 53) utilized the same analysis method in his research to improve the picking process and the results led to a substantial cost reduction for the case company. All of these analyses were performed by logistics engineering students and all of them had consistent data to analyze.

Several scholars have laid down hours of effort to develop new ways to perform these analyses. The research papers by Ding and Sun (2011) as well as Kaabi, Jabeur and Ladhari (2014) develop the traditional calculation techniques with integral calculus. The results are very interesting and will without a doubt serve several organizations well, but the implementation is complicated and will probably be too scientific for most small and medium sized companies. Scholz-Reiter, Heger, Meinecke and Bergmann (2012) suggest integrating forecasted demand into the analysis instead of only using historic data. This is a much more intuitive approach, as long as the company is able to perform actual forecasting. One of the more promising techniques includes the use of fuzzy sets, which is a way of weighting each item before the analysis is performed. Mahendrawathi, Nurul Laili and Kusumawardani (2011) give an example of how this technique can be utilized, also when criteria are more than two. They continue to state that the traditional ABC-XYZ analysis method becomes unnecessarily complicated for three or more criteria (*ibid.*, 2).

It is obvious that as the world is evolving and information flow increases in both speed and amount, that this area of inventory analysis also needs to evolve, by continuously searching for improved ways of classifying SKUs. There are many more researches performed in this area than what is mentioned here. The bottom line, however, is that analysis needs to be performed and the inventory manager needs consistent data to perform it.

4.6. Possible impact of item registry setup

Even though the third claim did not give conclusive proof that data input is the source of success, the deductions based on the literature did show its significance to be substantial. It is a well-known fact within computer science that the layout or interface of a program or a website is crucial regarding its usability (Ribeiro & Mont'Alvão, 2015, 5). This will necessarily also be true for the computer application in use for inventory management.

One of the most central principles regarding program design, as shown by Maliranta (2012, 12–4), is the concept of the golden mean, which is an ancient way of constructing something that will be soothing for the human eye (Nikolic et al., 2011, 13). The result of following this philosophy will produce a web page or an application which is more intuitive to use, thus making the interaction more efficient.

According to van Kampen et al. (2012), there ought to be a conceptual consensus of how SKU classifications are constructed. Their survey discovered that SKUs quite often were constructed with a narrow aim that would not be suitable in other settings. They suggest that the SKUs should be constructed according to certain logic, taking into account aim, characteristics, technique, class and context. They end their survey by predicting that soon there will be a framework available to help decide the buildup of the SKUs. (ibid.)

The possibility exists that the first step towards conclusive proof of the third claim mentioned in the beginning of this Chapter lies within the construction of SKUs. The connection between functional inventory and enhanced quality has been shown to exist, thus it is possible that there will be a connection between the quality of data input and a logically constructed SKU in combination with a soothing and intuitive layout.

5. CONCLUSION AND FURTHER RESEARCH SUBJECTS

5.1. General conclusions

This thesis introduced three claims, which were largely shown to be correct. The concept of inventory can be seen as having three aspects connected to it. Maintaining a well-groomed inventory, for all three aspects, will affect the workers' well-being positively, which in turn will induce better working conditions and ultimately an enhanced quality in the finished product. The accuracy of data input has a significant impact on the management of the inventory, thus also affecting the company's performance, but it was not shown to be the only factor towards success in business.

Based on the findings this thesis introduced the Doughnut model for inventory. The model is meant for use as a communication tool to show the different roles in a production company that their vantage point towards the inventory is a part of a bigger picture than what they experience and naturally relate to. This communication would hopefully lead to a stronger sense of being a part of the organization and its strategy. This inclusiveness will lead to lessened stress, thus enhancing quality.

5.2. Suggested research subjects

In this thesis the claim regarding the production line workers' well-being correlation with an effective inventory was made and shown to be correct. However, this claim would be important to be investigated further in a qualitative way so that additional stressors might be uncovered and brought into the light.

The division of the inventory concept is shown in this thesis, but it would be interesting to see if there are even more distinctions to be made regarding the aspects mentioned here.

The Doughnut model for inventory needs to be tested for other circumstances as well, to see if it can be generalized. While the model is meant for communication, there is a secondary aim to it, which is for other students and researchers to form new hypotheses and research. This could be regarding any combination of the aspects for cross-sectional subjects, such as 'quality of inventory', which could be a merger of all three aspects.

As mentioned in the end of the previous chapter, there could be a connection between the accuracy of data input and the construct of the SKUs. This would probably be a ground-breaking discovery, both for companies worldwide and for the support of the Doughnut model for inventory.

REFERENCES

- ARNOLD, J. R. T., CHAPMAN, S. N. & CLIVE, L. M. (2012). *Introduction to materials management*. 7th ed., international ed. Pearson.
- ASWATHAPPA, K. & BHAT, K. S. (2010). *Production and Operations Management*. Mumbai, IND: Himalaya Publishing House
<http://site.ebrary.com/lib/alltitles/docDetail.action?docID=10416187>
 (Accessed 13.April.2015).
- BENTON, W. C. (2010). *Purchasing and supply chain management*. 2nd rev. ed. McGraw Hill.
- CRESWELL, J. W. & PLANO CLARK, V. L. (2011). *Designing and conducting mixed methods research*. 2nd ed. SAGE.
- DAHLGAARD, J. J. & DAHLGAARD-PARK, S. M. (2006). *Lean production, six sigma quality, TQM and company culture*. *The TQM Magazine* **18**, 263–281.
- Definition of Quality* (n.d.). <http://www.merriam-webster.com/dictionary/quality>
 (Accessed 24.February.2015).
- DESSLER, G. (2008). *Human resource management*. 11th ed., International ed. Pearson Prentice-Hall.
- DING, B. & SUN, L. (2011). *An inventory classification model for multiple criteria ABC analysis*. In *2011 8th International Conference on Service Systems and Service Management (ICSSSM)*, pp. 1–6.
- EMMETT, S. (2005). *Excellence in warehouse management : how to minimise costs and maximise value*. West Sussex, England: John Wiley & Sons Ltd.
- Fenomenografia* (2014). *Wikipedia*.
<http://fi.wikipedia.org/w/index.php?title=Fenomenografia&oldid=14360961>
 (Accessed 25.March.2015).
- FIVELSDAL, E. & BAKKA, J. F. (1998). *Organisasjonsteori: struktur, kultur, prosesser*. 3rd ed. Oslo, Norway: Cappelen.
- GARCÍA-TERUEL, P. J. & MARTÍNEZ-SOLANO, P. (2007). *Effects of working capital management on SME profitability*. *International Journal of Managerial Finance* **3**, 164–177.
- GRANT, D. B., LAMBERT, D. M., STOCK, J. R. & ELLRAM, L. M. (2006). *Fundamentals of logistics management*. European ed. Boston; London: Irwin/McGraw-Hill.
- HADAYA, P. & CASSIVI, L. (2007). *The role of joint collaboration planning actions in a demand-driven supply chain*. *Industrial Management & Data Systems* **107**, 954–978.

- HÄNNINEN, A. (2012). '*Logiikan ja tiedonkeruuohjelman välisen kommunikointiohjelman suunnittelu ja toteutus*'. Bachelor thesis, JAMK Jyväskylä University of Applied Sciences <http://urn.fi/URN:NBN:fi:amk-2012060611793> (Accessed 4.March.2015).
- HERZBERG, F., MAUSNER, B. & SNYDERMAN, B. B. (1959). *The Motivation to Work*. 2nd ed. Wiley.
- HIRSJÄRVI, S., REMES, P. & SAJAVAARA, P. (2009). *Tutki ja kirjoita*. 15. uud. p. Helsinki, Finland: Tammi.
- HIRVONEN, K. (2005). '*Laadun tarkkailusta laatujohtamiseen : teoreettinen synteesi laatujohtamisen käsitteestä*'. Master thesis, Kuopion Yliopisto.
- inventory - definition of inventory in English from the Oxford dictionary* (n.d.). <http://www.oxforddictionaries.com/definition/english/inventory> (Accessed 13.April.2015).
- ISO 9000 quality management - ISO* (n.d.). http://www.iso.org/iso/iso_9000 (Accessed 2.March.2015).
- JOHNSON, S., COOPER, C., CARTWRIGHT, S., DONALD, I., TAYLOR, P. & MILLET, C. (2005). *The experience of work-related stress across occupations. Journal of Managerial Psychology* **20**, 178–187.
- KAABI, H., JABEUR, K. & LADHARI, T. (2014). *Genetic Algorithm to infer criteria weights for Multicriteria Inventory Classification*. In *2014 International Conference on Control, Decision and Information Technologies (CoDIT)*, pp. 276–281.
- KAMPEN, T. J. VAN, AKKERMAN, R. & DONK, D. P. VAN (2012). *SKU classification: a literature review and conceptual framework. International Journal of Operations & Production Management* **32**, 850–876.
- KARJALAINEN, V. (2012). '*Varaosavaraston keruutehokkuuden parantaminen*'. Bachelor thesis, JAMK Jyväskylä University of Applied Sciences <http://urn.fi/URN:NBN:fi:amk-2012061112382> (Accessed 16.April.2015).
- KEKÄLE, T. (1998). '*The effects of organizational culture on successes and failures in implementation of some total quality management approaches : towards a theory of selecting a culturally matching quality approach*'. Doctoral thesis (Acta Wasaensia No. 65), University of Vaasa.
- KIVINIEMI, J. & LEPPÄNEN, M. (2012). '*Employee Well-Being as Competitive Advantage*'. Bachelor thesis, Rovaniemi University of Applied Sciences <http://urn.fi/URN:NBN:fi:amk-2012101914525> (Accessed 10.April.2015).
- KOKKONEN, N. (2005). '*Enhancing the quality of work life by assessing management and supervisor training needs at Vähälä Group*'. Bachelor thesis, JAMK Jyväskylä University of Applied Sciences.

- KUMAR, S. & CHAKRAVARTY, A. (2015). *ABC–VED analysis of expendable medical stores at a tertiary care hospital. Medical Journal Armed Forces India* **71**, 24–27.
- LABERGE, R. (2011). *The data warehouse mentor : practical data warehouse and business intelligence insights*. McGraw-Hill.
- LAPP, M. (2013). 'Varastoitavien nimikkeiden uudelleensijoittelu'. Bachelor thesis, JAMK Jyväskylä University of Applied Sciences <http://urn.fi/URN:NBN:fi:amk-2013053112244> (Accessed 16.April.2015).
- MAHENDRAWATHI, E., NURUL LAILI, E. & KUSUMAWARDANI, R. P. (2011). *Classification of hospital pharmaceutical drug inventory items by combining ABC analysis and fuzzy classification*. In *2011 International Conference on Advanced Computer Science and Information System (ICACISIS)*, pp. 215–220.
- MALIRANTA, J. (2012). 'Käyttökokemus ja visuaalisuus verkkosivujen suunnittelussa'. Bachelor thesis, Turun Ammattikorkeakoulu <http://urn.fi/URN:NBN:fi:amk-2012121819844> (Accessed 16.April.2015).
- MARTÍNEZ-LORENTE, A. R., DEWHURST, F. & DALE, B. G. (1998). *Total quality management: origins and evolution of the term. The TQM Magazine* **10**, 378–386.
- MOEN, R. D. & NORMAN, C. L. (2011). *Circling Back. Quality control and applied statistics* **56**, 265–266.
- MORGAN, D. L. (2014). *Integrating qualitative and quantitative methods : a pragmatic approach*. SAGE Publications.
- MUCKSTADT, J. A. & SAPRA, A. (2009). *Principles of inventory management*. Springer.
- MULLER, M. (2011). *Essentials of inventory management*. 2nd ed. AMACOM.
- NGUYEN, T. T. (2014). 'Website development for online retailing. Case Study: Viet Center Tourist Co., Ltd'. Bachelor thesis, JAMK Jyväskylä University of Applied Sciences <http://urn.fi/URN:NBN:fi:amk-2014100914582> (Accessed 4.March.2015).
- NIKOLIC, S. T., COSIC, I., PECUJLIJA, M. & MILETIC, A. (2011). *The effect of the 'golden ratio' on consumer behaviour. African Journal of Business Management* **5**, 8347–8360.
- OLLI, J. (2003). 'Identifying and documenting warehousing-related processes within the context of ISO 9001'. Bachelor thesis, JAMK Jyväskylä University of Applied Sciences.
- OTALA, L. & AHONEN, G. (2005). *Työhyvinvointi tuloksetekijänä*. 2. uud. p. [WSOY] : WSOYpro : [Suomen ekonomiliitto].

- PIHALA, J. (2009). *'Kaivoslastarin linjakokoonpanon kehittäminen'*. Bachelor thesis, Turun Ammattikorkeakoulu <http://urn.fi/URN:NBN:fi:amk-2011061712273> (Accessed 2.March.2015).
- quality definition, meaning - what is quality in the British English Dictionary & Thesaurus - Cambridge Dictionaries Online* (n.d.). <http://dictionary.cambridge.org/dictionary/british/quality> (Accessed 24.February.2015).
- quality - definition of quality in English from the Oxford dictionary* (n.d.). <http://www.oxforddictionaries.com/definition/english/quality> (Accessed 24.February.2015).
- RIBEIRO, C. E. & MONT'ALVÃO, C. (2015). *The Influence of Interface Design on Knowledge Management through Virtual Communities of Practice for Permanent Education in Health. International Journal of Innovation, Management and Technology* **6**, 46–51.
- ROSALA, P. (1997). *'Henkilöstön sitoutuminen - edellytys jatkuvalle laadun parantamiselle'*. Bachelor thesis, JAMK Jyväskylä University of Applied Sciences.
- RUOHOMÄKI, I., ANTTILA, J.-P., HEIKKILÄ, A., KANSOLA, M., LEINO, K., PARO, J. & SALMI, T. (2011). *Parempiin tuotantostrategisiin päätöksiin. Teknologiainfo Teknova Oy* <http://www.ellibs.com/book/978-952-238-089-0/parempiin-tuotantostrategisiin-paatoksiin> (Accessed 15.April.2015).
- SAKALA, M. (1997). *'Laadunkehittäminen : tutkimus erään tuotantolaitoksen työntekijöiden mielipiteistä ja kokemuksista laatuja järjestelmän kehittämisestä'*. Bachelor thesis, JAMK Jyväskylä University of Applied Sciences.
- SALANOVA, A. & KIRMANEN, S. (2010). *'Employee Satisfaction and Work Motivation : Research in Prisma Mikkeli'*. Bachelor thesis, Mikkeli University of Applied Sciences <http://urn.fi/URN:NBN:fi:amk-201003195785> (Accessed 10.April.2015).
- SCHOLZ-REITER, B., HEGER, J., MEINECKE, C. & BERGMANN, J. (2012). *Integration of demand forecasts in ABC-XYZ analysis: practical investigation at an industrial company. International Journal of Productivity and Performance Management* **61**, 445–451.
- SEPPÄ, J. (2006). *'Hitsauksen laadun varmistaminen : laatuvaatimusten ja teknisten dokumenttien päivitys'*. Bachelor thesis, JAMK Jyväskylä University of Applied Sciences.
- SFS-EN ISO 9000:2005 (2005). <http://sales.sfs.fi/sfs/servlets/ProductServlet?action=productInfo&productID=251042> (Accessed 25.February.2015).
- SILVER, E. A., PYKE, D. F. & PETERSON, R. (1998). *Inventory management and production planning and scheduling*. 3rd ed. John Wiley & Sons.

- SOWER, V. E. (1999). *Definition of Quality, Lesson 1 outline*.
http://www.shsu.edu/~mgt_ves/mgt481/lesson1/lesson1.htm (Accessed 8.April.2015).
- TAURINGANA, V. & AFRIFA, G. A. (2013). *The Relative Importance of Working Capital Management and Its Components to SMEs Profitability*. Rochester, NY: Social Science Research Network
<http://papers.ssrn.com/abstract=2341848> (Accessed 14.April.2015).
- TEDDLIE, C. & TASHAKKORI, A. (2009). *Foundations of mixed methods research : integrating quantitative and qualitative approaches in the social and behavioral sciences*. Sage Publications.
- TIMMONS, J. A. & SPINELLI, S. (2009). *New Venture Creation: Entrepreneurship for the 21st Century*. McGraw-Hill/Irwin.
- TÖTTÖ, P. (2004). *Syvällistä ja pinnallista : teoria, empiria ja kausaalisuus sosiaalitutkimuksessa*. Tampere, Finland: Vastapaino.
- TURUNEN, A. (2011). *'Development of product data management and material control'*. Bachelor thesis, JAMK Jyväskylä University of Applied Sciences <http://urn.fi/URN:NBN:fi:amk-201105178212> (Accessed 16.April.2015).
- WATERS, D. (2003). *Inventory control and management*. West Sussex, England: Wiley.
- WEELE, A. J. VAN (2014). *Purchasing & supply chain management : analysis, strategy, planning and practice*. 6th ed. Cengage Learning.
- WEETMAN, P. (2006). *Financial accounting : an introduction*. 4th ed. Financial Times Prentice Hall.
- WEETMAN, P. (2010). *Management accounting*. 2nd ed. Prentice Hall/Financial Times.
- What is Quality? definition and meaning* (n.d.). *BusinessDictionary.com*.
<http://www.businessdictionary.com/definition/quality.html> (Accessed 24.February.2015).
- WIERSEMA, W. H. (2013). *Controlling inventory*. *Electrical Apparatus* **66**, 29–30.
- WILLIAMS, R. (2006). *Real-time systems development*. Elsevier Butterworth-Heinemann
<http://site.ebrary.com/lib/jypoly/detail.action?docID=10138749>.
- WÖLTJE, J. (2005). *Yrityksen laskentakaavat ja tunnusluvut*. Helsinki, Finland: Rastor.
- YRITYSTUTKIMUSNEUVOTTELUKUNTA [THE COMMITTEE FOR CORPORATE ANALYSIS] (2005). *Yritystutkimuksen tilinpäätösanalyysi*. Helsinki, Finland: Gaudeamus.

APPENDICES

Appendix 1. The mechanics of an ABC-analysis

The ABC analysis follows certain steps. Firstly, the input data needs to be complete in order to get a correct result. Secondly, the data should be arranged as seen for the example entries in Figure 13 below.

SKU	Unit cost	Orders	Amount	Sum
12001	2,50	15	345	862,50
12002	3,45	50	128	441,60
12003	23,60	23	94	2 218,40
12004	33,00	58	88	2 904,00
12005	76,36	35	24	1 832,64
12006	443,00	9	27	11 961,00
12007	27,99	15	29	811,71
12008	2,10	46	214	449,40
12009	54,00	20	69	3 726,00
12010	243,60	7	28	6 820,80
12011	25,00	35	68	1 700,00
12012	20,89	75	335	6 998,15
12013	35,00	1	82	2 870,00
12014	72,67	33	40	2 906,80
12015	47,25	59	154	7 276,50
12016	6,67	94	99	660,33
12017	0,80	25	635	508,00
12018	18,50	42	50	925,00
12019	3,80	31	230	874,00
12020	30,70	8	52	1 596,40

FIGURE 13. Initial data set for the ABC analysis.

The next step is to order the data according to the sum, so that the SKU with the highest sum is on top. Once SKUs are sorted this way, four columns need

to be added to the spreadsheet, one before the data and three after. The numbers in the first column indicates which row the SKU is on, simply running from 1 until there are no more SKUs. The next new column is added after the data and will indicate the SKUs value as a percentage of the total value. The following column indicates the cumulative amount of SKUs handled above the current row, itself included. The last column will give the cumulative value of the SKUs until the current row. The result for the example entries is seen in Figure 14.

#	SKU	Unit cost	Orders	Amount	Sum	Value of total sum	# of product [%]	Cumulative value [%]
1	12006	443,00	9	27	11 961,00	20,5 %	5 %	20,5 %
2	12015	47,25	59	154	7 276,50	12,5 %	10 %	33,0 %
3	12012	20,89	75	335	6 998,15	12,0 %	15 %	45,0 %
4	12010	243,60	7	28	6 820,80	11,7 %	20 %	56,7 %
5	12009	54,00	20	69	3 726,00	6,4 %	25 %	63,0 %
6	12014	72,67	33	40	2 906,80	5,0 %	30 %	68,0 %
7	12004	33,00	58	88	2 904,00	5,0 %	35 %	73,0 %
8	12013	35,00	1	82	2 870,00	4,9 %	40 %	77,9 %
9	12003	23,60	23	94	2 218,40	3,8 %	45 %	81,7 %
10	12005	76,36	35	24	1 832,64	3,1 %	50 %	84,9 %
11	12011	25,00	35	68	1 700,00	2,9 %	55 %	87,8 %
12	12020	30,70	8	52	1 596,40	2,7 %	60 %	90,5 %
13	12018	18,50	42	50	925,00	1,6 %	65 %	92,1 %
14	12019	3,80	31	230	874,00	1,5 %	70 %	93,6 %
15	12001	2,50	15	345	862,50	1,5 %	75 %	95,1 %
16	12007	27,99	15	29	811,71	1,4 %	80 %	96,5 %
17	12016	6,67	94	99	660,33	1,1 %	85 %	97,6 %
18	12017	0,80	25	635	508,00	0,9 %	90 %	98,5 %
19	12008	2,10	46	214	449,40	0,8 %	95 %	99,2 %
20	12002	3,45	50	128	441,60	0,8 %	100 %	100,0 %
				Total sum	58 343,23			

FIGURE 14. Data set from Figure 13 after applied ABC analysis.

The information that can be extracted from this data set is how many SKUs account for how much value. As mentioned in the text, the rule of thumb is that 20 percent of the SKUs should account for 80 percent of the value. In Figure 14 this is not the case, because 80 percent in the last column is passed at row 9, thus implying that 45 percent of the SKUs account for 81,7 percent of the value. The results will vary between companies and data sets.

If the original set of data is ordered according to ordering frequency rather than sum, as seen in Figure 15, the sequence of the SKUs will probably look different. The same steps apply also to this method, but the result should be interpreted according to the sorting method. This latter way of sorting SKUs is an example of the XYZ analysis and will indicate how often a certain SKU is ordered and subsequently needed. If it is an item that is used several times per day it should be placed close and easily accessible to the point of usage.

#	SKU	Unit cost	Orders	Amount	Sum	Percentage of total orders	# of products	Cumulative orders
1	12016	6,67	94	99	660,33	13,8 %	5 %	13,8 %
2	12012	20,89	75	335	6 998,15	11,0 %	10 %	24,8 %
3	12015	47,25	59	154	7 276,50	8,7 %	15 %	33,5 %
4	12004	33,00	58	88	2 904,00	8,5 %	20 %	42,0 %
5	12002	3,45	50	128	441,60	7,3 %	25 %	49,3 %
6	12008	2,10	46	214	449,40	6,8 %	30 %	56,1 %
7	12018	18,50	42	50	925,00	6,2 %	35 %	62,3 %
8	12011	25,00	35	68	1 700,00	5,1 %	40 %	67,4 %
9	12005	76,36	35	24	1 832,64	5,1 %	45 %	72,5 %
10	12014	72,67	33	40	2 906,80	4,8 %	50 %	77,4 %
11	12019	3,80	31	230	874,00	4,6 %	55 %	81,9 %
12	12017	0,80	25	635	508,00	3,7 %	60 %	85,6 %
13	12003	23,60	23	94	2 218,40	3,4 %	65 %	89,0 %
14	12009	54,00	20	69	3 726,00	2,9 %	70 %	91,9 %
15	12001	2,50	15	345	862,50	2,2 %	75 %	94,1 %
16	12007	27,99	15	29	811,71	2,2 %	80 %	96,3 %
17	12006	443,00	9	27	11 961,00	1,3 %	85 %	97,7 %
18	12020	30,70	8	52	1 596,40	1,2 %	90 %	98,8 %
19	12010	243,60	7	28	6 820,80	1,0 %	95 %	99,9 %
20	12013	35,00	1	82	2 870,00	0,1 %	100 %	100,0 %
		Total orders	681					

FIGURE 15. Data set from Figure 13 after applied XYZ analysis.

This appendix aimed to show how these analyses are performed. The next step would be the interpretation of the results, but this goes beyond the scope of this thesis.

Appendix 2. The Doughnut model complete with named positions

This is an example of how the Doughnut model for inventory could be filled out according to the matrix in Figure 12.

