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REDUCING SLOW MOVING INVENTORY IN A LARGE MANUFACTURING COMPANY

Master of Science Thesis

Examiner: Professor Miia Martinsuo
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ABSTRACT

TAMPERE UNIVERSITY OF TECHNOLOGY
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This reseach discusses the problem of slow moving inventory. Useless inventories are a dead weight for manufacturing companies. The precedings are idle resources that tie up capital without any output. The motivation for the research comes from CaseCompany's requirements for more efficient use of capital. Consequently, the thesis is strongly influeced by CaseCompany's Capital Efficiency Program. The main objective of this thesis is to gain knowledge and an understanding of the activation and accumulation as well as prevention of excess and obsolete inventory, and utilize gained knowledge to develop a framework for slow moving inventory reduction.

There are two main research questions the thesis. The first question is formulated as:"*What is the current state of the slow moving inventory?"*. The second question is formulated as: "*How can CaseCompany decrease the level of slow moving inventory permanently*". The research method for the thesis is mixed-model research. The research is implemented as a mix of case study and action oriented research. The problem of slow moving inventory is aproached through current state analysis of the inventory in order to build a general knowlegde of the inventory content. Additionally literature review related to subject was made as well as observation from unstructured discussion were done during the research process in CaseCompany.

As a result of this thesis a framework to facilitate the problem related to slow moving inventory was established. The framework is based on fundamental tools and applications that work as enablers for slow moving inventory reduction. Additionally, the framework includes required actions and processes to be ran and executed in order to reduce the slow moving inventory. Actions and processes are divided between slow moving inventory activation -actions and slow moving inventory build-up prevention -actions. Activation actions are aimed to capitalize currently existing slow moving inventory as preventative actions are aimed to stop slow moving inventory accumulation.

ABSTRACT / TIIVISTELMÄ

TAMPEREEN TEKNILLINEN YLIOPISTO
Konetekniikan koulutusohjelma
SUURONEN, JONNE: Hitaastikiertävän varaston vähentäminen suuressa valmistavassa yrityksessä
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Tämä tutkimus käsittelee hitaastikiertävän varaston ongelmaa. Tarpeettomat ja hyödyttömät varastot ovat taakka valmistaville yrityksille. Edellä mainitut ovat turhia resursseja, jotka sitovat pääomaa ilman että tuottavat mitään. Motivaatio tälle tutkimukselle juontaa juurensa kohdeyrityksen (CaseCompany) tarpeista tehostaa pääoman käyttöä. Tämän seurauksena, tutkimus on vahvasti sidoksissa CaseCompany:n projektiin, joka tähtää pääomankierron tehostamiseen. Tutkimuksen päätavoite on kerryttää tietoutta ja ymmärrystä hitaastikiertävän varaston aktivointiin, kertymiseen sekä estämiseen liittyen sekä edellä mainitun tiedon pohjalta muodostaa viitekehys hitaaskiertävän varaston pitkäjänteiseen pienentämiseen.

Tutkimus sisältää kaksi päätutkimuskysymystä. Ensimmäinen kysymys on muotoiltu seuraavasti: ”*Mikä on hitaastikiertävän varaston nykytila?*”. Toinen tutkimuskysymys kuuluu seuraavasti:”*Kuinka CaseCompany voi pienentää hitaastikiertävän varaston tasoa pysyvästi?*”. Tutkimusastelmana työssä on hyödynnetty yhdistelmämenetelmää. Tutkimus on toteutettu toiminta-analyyttisen ja tapaustutkimuksen yhdistelmänä. Hitaastikiervään varastoon liittyvää ongelmaa on lähestytty varaston nykytila-analyysin kautta, jotta on saatu yleistietous varaston sisällöstä. Lisäksi aiheeseen liittyvää tietoutta on kerrytetty kirjallisuuskatsauksen avulla sekä havainnoista, jotka on tehty keskusteluista joita CaseCompany:ssä on työn aika käyty.

Tämän työn tuloksena on kehitetty viitekehys helpottamaan hitaastikiertävään varastoon liittyvää ongelmaa. Viitekehys pohjautuu perustavanlaatuisiin työkaluihin ja sovelluksiin, jotka mahdollistavat hitaastikiertävän varaston vähentämisen. Lisäksi viitekehys sisältää tarvittavat toimenpiteet ja prosessit joita suorittamalla hitaastikiertävää varastoa voidaan pienentää. Toimenpiteet ja prosessit on jaettu hitaastikiertävää varastoa aktivoiviin toimenpiteisiin sekä hitaastikiertävän varaston kertymistä ennaltaehkäiseviin toimenpiteisiin. Aktivointitoimenpiteet tähtäävät pääoman vapauttamiseen varastosta kun taas ennaltaehkäisevät toimenpiteet tähtäävät hitaastikiertävän varaston kertymisen pysäyttämiseen.

PREFACE

A great journey has come to its end. In the beginning of this reseach process on June 2014, I was exited and and full of eager about the interesting research subject provided me by a company for which I had worked during two previous previous summers. At this very moment, I'm thankful for this great opportunity. This has certainly been the most educative process during my studies. Additionally, this has been, with no doubt, one of the most facinating one as well. However, it is a relief to say, that finally the work is done.

There are plenty of people who have supported me during the research process. At first I would like to thank the purchasing director of the CaseCompany for all the guiding during the research process. The preceding person has provided an insight into research subject and also supported the reseach process by offering required connections inside the company. I would like to thank also Miia Martinsuo, the examiner of this thesis, for all the steering during the writing process as well as for the great support for finalizing the thesis. Additionally, I would like to thank all the members of CEP Slow Moving inventory -group.

Ultimately, I would like to wish my greatest thanks for my belowed Sanna-Mari for your adamant suppport from the very beginning of this research process.

Vantaa, 23.3.2015

Jonne Suuronen

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ABBREVIATIONS

BOM	Bill of Materials
CE	Concurrent Engineering
CEP	Capital Efficiency Program
ECM	Engineering Change Management
ECR	Engineering Change Request
ECN	Engineering Change Notice
ERP	Enterprise Resource Planning
GDC	Global Data Center
MRD	Material Review and Disposition
MRP	Material Requirements Planning
OPP	Order Penetration Point
PDM	Product Data Management
PLM	Product Lifecycle Management
PO	Purchase Order
POP	Purchase Order Planned
PTO	Purchase-To-Order
RM	Customer Requirements Management

1 INTRODUCTION

1.1 Research background

For being successful, no matter at what industry or business, it is crucial to be able to recognize key customer's needs and make sure that company's actions are aimed to fulfil the needs in the best possible manner. For the CaseCompany, being successful on highly competitive business, where delivering final products on time is extremely important, well-functioning and reliable supply chain is required. One of the main characteristics of the preceding kind of supply chain is that material flows are exactly aligned with demand. In well-functioning supply chain, no excess raw material or sub-products should remain after the customer orders are delivered. In order out-perform competitors a balance between warehousing and material flow control needs to be discovered.

Fulfilling highly diversified customer requirements including high technical standards and regulations set its own challenge for CaseCompany's supply chain related functions. Above mentioned alignment between material flows and demand is challenging in cases where orders engineered according to customer's needs are occasionally modified after the order has already been placed. Changes and modifications in diversified customer order backlog are likely to disturb material flow in the supply chain resulting delays and excess material at some points of the chain. Small changes in down-stream are likely to build up larger changes in up-stream. The preceding scenario known as a bull-whip-effect is one of supply chain and material flow related issues likely to lead into inventory problems. Difficulties in material flow control could be seen for example through financial examination of inventory performance. All the material that cannot be converted to something profitable is a loss that needs to be covered in a one way or another. In addition excess and obsolete material needs to be stored somewhere and warehousing ties up capital as well.

Common basics of inventory management and control are suitable in situations where it is possible to forecast forthcoming demand with decent accuracy. However, in CaseCompany's businesses, final products are more and more often highly customized according to various different customer requirements. That is due project businesses notable share out of CaseCompany's total sales. Various different customer requirements set challenges for forecasting which in any case is required because of long delivery times of raw-materials and part. Moreover, it could be said that configuration of the product during order-delivery process is one of the characteristics of the CaseCompany's business. Currently customer order revisions occur daily. In some cases the requirements of the final products are changed for example in a midstream of the order-delivery process. And the more late the configuration need occurs, the more challenging it makes management of material flow and the supply chain.

Manufacturing products according to customer requirements in a preceding kind of situation where changes occur relatively often is likely cause accumulation of excess tailored parts and materials. Sub-products built of the afore-mentioned parts and materials are challenging to use in any other final product. Once, customer modifies requirements of the final product after the order has already been placed, it is likely to generate excess inventory, which commonly requires unordinary methods to deal with. For this thesis, a need to control and to prevent a preceding kind inventory, consisting non-active slow moving items, works as catalyst.

Inventory control problem related to slow moving items and discussed in this thesis is part of the wider project at CaseCompany called Capital Efficiency Program (CEP). CEP is a corporate level program which primary objective is to increase return on capital employed. This objective is supposed to achieve by implementing corrective actions in three main categories; in systemic efficiency, production inventories and in sales inventories. Under the abovementioned categories CEP –project is divided into five sub-projects. One of those sub-projects, where the researcher of this thesis acts as a project owner, has its focus on capitalizing slow moving inventory. Another focus is to stop accumulation of new slow moving inventory. Nowadays new slow moving inventory emerge on average worth of X euros per month (O1). The project was executed by team of 9 members and it consisted of 13 milestones that are presented in table 1 shown in appendix 2.

One of the key actions to increase overall inventory turn is to decrease the level of slow moving inventory. That is the objective which this thesis is focusing into. The thesis is supposed to create and implement new solutions to prevent emergence of new inactive items and to improve inventory management practices related to slow-moving inventory in CaseCompany's business. Thus, thesis is supposed serve a bigger entirety by supporting the Capital Efficiency Program.

1.2 CaseCompany

In order to maintain anonymity of the company where this research is implemented the company is called as CaseCompany. CaseCompany is a leading provider of high performance solutions. Company's focus is on the continuous development of intelligent solutions that improve its customer's profitability and sustainability in varios areas.. At the present moment Company employs around X persons in X countries. Company's strong global presence works as a base for Company's global growth strategy.

Business activities of the CaseCompany started in X. At that time, Company was established through the merger of corporations of A and B. At that time, company B's operations were mainly focused on high performance solutions using multiple technologies, whereas company A was concentrating mostly on different machine solutions. As the result of the merger of corporation's A and B, a new solution supplier was established to supply products and services for global industries.

Soon after the merger CaseCompany became one of the world's leading enterprises on its industry. Top class position was achieved by following actively acquisition as well as organic growth strategies. Latest remarkable turning point in CaseCompany's history dates back to year X. In the end of X, CaseCompany announced the decision to split the company into two corporations. Those corporations are nowadays stock listed and independent entities running their own businesses.

CaseCompany is divided into two business segments; Segment A and Segment B. This study is implemented to the segment A. Segment A highlights customer orientation as one of its core values. Offering of highly customized products as well as lifecycle extensive customer support are guaranteed by worldwide network of highly trained professionals. Product portfolio of segment A is built of various types of products.

Currently segment A's most important markets are in industry C and in industry D. At the moment industry C forms X percentages of segment's net sales. Contribution to the industry D and F as well as to industry S is also increasing and significance of those industries for segment A's business is growing. Most remarkable market areas are location H and in location J. In total X percent of segment's orders are received from the preceding areas.

1.3 Research problem

Olkkonen (1994, pp. 89) mentions that in many cases, chosen and already specified problem turns out to be intricate tangle of multiple problems. Thus, examination of the research problem is better to start by structuring it. This often leads to situation in which initial problem is divided into multiple sub-problems, that all requires their own examination. Olkkonen (1994, pp. 89) also writes that overall solution or result of the research is actually a synthesis of the answers of the sub-problems. Thus by carefully specifying and examining well-defined sub-problems, the main research problem can be solved and comprehensive solution could be discovered.

Research problem in this thesis is related to capital tied up into CaseCompany's inventory. The problem is due to stock built of items that has inventory turn of zero. These items remain in shelf long periods of time tying up significant amount of CaseCompany's capital. In order to solve the problem, and like mentioned above by Olkkonen

(1994, pp. 89), well-defined definition for the problem is essential. The research problem of this thesis formulated as:

> *There is continuously accumulating new slow moving items into the inventory; no common policies or practices exist in order to handle currently existing slow moving items or to prevent the accumulation of the new ones.*

Like described above, the research problem is multidimensional. At first, the problem is that CaseCompany does not have any kind of process in order to capitalize its slow moving inventory. Currently the only regularly utilized manner to decrease the level of slow moving inventory is scrapping of items. In the other words, every item that ends-up to slow moving inventory is a loss. First, an item will remain useless, but as an active item, in shelf from 12 up to 24 months depending on item type. After that the item will remain in shelf as a slowing item for a random period, until it is finally scrapped. Thus, in the worst cases slow moving items tie up capital for years, for nothing.

Secondly, the problem is that the level of slow moving inventory is continuously increasing. Due to the preceding the problem with the slow moving inventory cannot be solved only by developing a process to active slow moving items. In this case, activation of the inventory would help the problem only in short term. It is necessary, and in fact even more important than developing an activation process, to build-up a system or establish a process that is actually preventing and stopping the accumulation of new slow moving inventory.

1.4 Objectives and research questions

According to Saunders et al. (2007, pp. 153), objectives and questions are used as a foundation for research project. Thus, to ensure success of this thesis, certain questions and objectives must be comprehensively defined. Research questions and objectives are defined so that they are congruent with each other and achievable. During the research process research questions and objectives can be reviewed in order to ensure that research is progressing as supposed and that it will answer to predefined research questions.

The objective of this thesis is to gain knowledge and an understanding of the activation, accumulation as well as prevention of excess and obsolete inventory, and in the end utilize gained knowledge and information to develop a framework that could be used to get rid of the slow moving inventory. The preceding is done by examining CaseCompany's processes that are indentified as possible sources for slow moving inventory as well as studying literature related to the subject. In order to meet objective of activating the inventory it is necessary to know what kind of items there actually is in the inventory, is it possible to classify items somehow or could similarities or connections between the items be found. In addition it is also important to figure out what are the current slow moving inventory management policies and how those are followed. Hence, the first research question is formulated as:

1. *What is the current state of the slow moving inventory?*

As the research question is focused to gain understanding of the current state of the slow moving inventory, it is necessary to formulate another question which enables this research to meet the rest of its objectives. For the purpose, this thesis would not only be a short time solution through inventory activation actions, it is mentioned earlier that accumulation of slow moving inventory needs to be stopped. To be able to establish a framework for slow moving inventory build-up prevention is necessary to find out a long-term solution. Hence the second research question is formulated as:

2. *How can CaseCompany decrease the level of slow moving inventory permanently?*

In consequence of the above-mentioned research questions the most important objectives for this thesis are at first, to be able to recognize processes or functions that are likely to generate non-active inventory items, and secondly, to be able to invent methods to prevent the emergence of new non-active items. In order to do that, one sub-objective is to indentify manners to utilize items that are currently slow movers. In the other words, the objective is to turn slow moving inventory to active. Sub-objective is also identifying all the possible sources for new excess and obsolete material and figure out how the sources could be blocked. To make sure that long term solution is effective, one sub-objective is to build rules for slow moving inventory management. Generally, in case the preceding sub-objectives could be met, it will make use of non-active items more effective, facilitate preventative work related to new slow moving inventory and capitalize new slow inventory control policy. Hence the following sub-questions are formulated to support the second research question.

2.1. How can slow moving inventory be activated?
2.2. Which functions or processes are most likely to generate excess and obsolete items?
2.3. How can the accumulation of new slow moving inventory be stopped?

Purpose for setting the preceding sub-objectives is a need to decrease the level of slow moving inventory permanently and through that decrease the amount of capital tied up to inactive items. Sub-questions above found a basis to solve the second research question and due that offer a partly solution for the research problem. Sub-questions can be solved in same the order they are presented, however, that is not a requirement. Solving question simultaneously might help finding relations between different questions and through that offer more understanding about the root causes and about available solution options.

In addition to abovementioned objectives, targets for the research were pulled out from CaseCompany's Capital Efficiency Program. Derived from CEP targets for CaseCompany's plant X, it was decided that target of this research for slow moving inventory capitalization over a six months period from July to December 2014 is X euros.

1.5 Scope of research

This thesis concentrates on slow moving inventory control as well as examination of those processes that are likely to generate new slow excess and obsolete items at CaseCompany's factory in location F. Hence, practices related to inventory management and control in other locations in continent S, as well as in continent A, continent D, continent F and other locations are excluded from the research scope. Limitations are also set by business segments and lines, so that, only segment A's business line is included. In consequence, other segments as well as services business are excluded from the research scope.

The main focus is on the control of slow moving inventory and also in invention of methods to prevent emergence of new non-active items. These items are the ones that do not have any consumption during last 12 or 24 months depending on item type. Other items in the inventory are excluded from the scope of research. Also spare part inventory is excluded.

To be able to understand from where, how and why the non-active items emerge certain processes needs to be supervised and studied. Research is concentrated into purchase, product data management, engineering change, revision and new-product design processes as well as the interaction of those processes. Preceding processes are under the research because those are likely to be the maror reasons behind the slow moving inventory accumulation (O1; O7; O9; O13).

Information and data exchange processes related to non-active inventory items between CaseCompany's location W, location E and location F factories are all under the examination. Information exchange with aforementioned locations is included in the study because, such as factory in location F has, factories in location W and in location E have notable improving potential related to use of non-active items (O1; O5). Other operations and supportive functions pertaining to inventory management, like for example human resources are not in main focus, and therefore, those aspects are excluded from the study.

Evaluations, related to slow moving inventory, are calculated by using monetary and quantitative values. Other inventory related values, like for example storage space requirements or personnel requirements are not included into the inventory evaluations.

1.6 Research approach

In this thesis, research objectives are approached by combining theoretical contexts, historical data and examining existing processes and practices related to research problem. Approach used is a combination of an action oriented research approach and a case study. Action oriented approach aims to understand problem under discussion through hermeneutic concept of science. Typical for the subjects approached using action oriented research approach is that issues are related to internal operations of the company and that in addition with so called “hard” factors there is also people, “soft” factors, and their individual targets involved. (Olkkonen 1994, pp. 72-75)

Often questions approached by using action oriented approach are about problems that are difficult to structure, like for example organization related problems, or questions about new and constantly changing situations. It is salient for action oriented research approach that in every phase of the research there exist continuous interaction between researcher and research problem and that result are based on researcher’s interpretations. During the research, data is collected and used to form new hypotheses and theories. In addition, it is possible in some cases to represent improvements achieved during the research, as results. (Olkkonen 1994, pp. 72-75) Figure 1 shown below illustrates action oriented approaches relation to problem discussed.

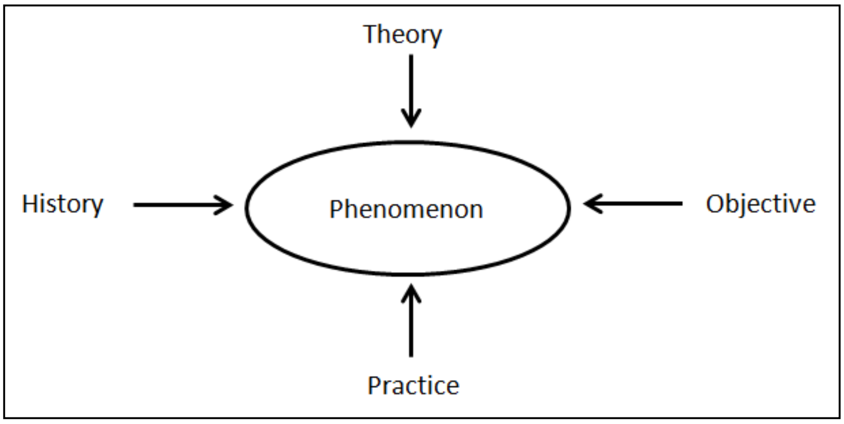

Figure 1. Action oriented approaches relation to phenomenon under research. Adapted from Olkkonen (1994, pp. 75)

During this research researcher is working for the CaseCompany as a project owner, not as an external observer. This means that there is going to be daily efforts in order to achieve improvement targets set by CaseCompany. According to Olkkonen (1994, pp. 74) researcher working with subject under discussion and simultaneously doing the research has impact for the results. That is because researchers might be either unconsciously or consciously steering the result towards predefined target.

Theoretical context of this thesis is built by literature review and it is used to support analysis of current processes in CaseCompany. Information for theoretical part of the study is acquired from multiple scientific databases in Internet as well as from libraries of Tampere University of Technology and Aalto University. Simultaneously with literature review data collection for empirical research is conducted. Empirical data is used to analyze current slow moving inventory related processes. Focus is on the backgrounds and root causes of slow moving inventory and disposition of useless material.

Examination of existing processes is focused on management of slow moving inventory. Under the research are all the already existing practices that are used in CaseCompany in order to cope with inactive inventory items. That includes current identification of slow movers as well as excess and obsolete material disposition process. Also current practices at customer order change management are revised simultaneously with review of current purchase order cancellation process. The above mentioned and currently existing processes and practices will be examined in order to further develop existing processes, and in addition to create new ones if necessary.

1.7 Structure of the thesis

Structurally this thesis is divided in seven chapters. Introduction to thesis is presented in first chapter. Literature review of the study is in chapter 2. It introduces necessary theory required to examine the research problem and to find out solutions options

After literature review research methodologies utilized in this thesis are introduced in chapter 3. These's empirical part, in chapter 4, discusses about current state of slow moving inventory. Chapter 5 presents the backgrounds of slow moving inventory, activation actions and result gained during the thesis. Chapter 6 includes discussion of thesis. There suggestions of corrective actions in order to solve problems related to slow moving inventory are made. Chapter 7 is a conclusion of the thesis. It discusses about managerial implication, academic contribution and limitations of the thesis. In addition, suggestions for further research are made.

2 LITERATURE REVIEW

2.1 Key concepts

Theoretical part of this research is based on literature review. Under the examination are change management, product data management and material management. Positioning of this research is illustrated in figure 2.

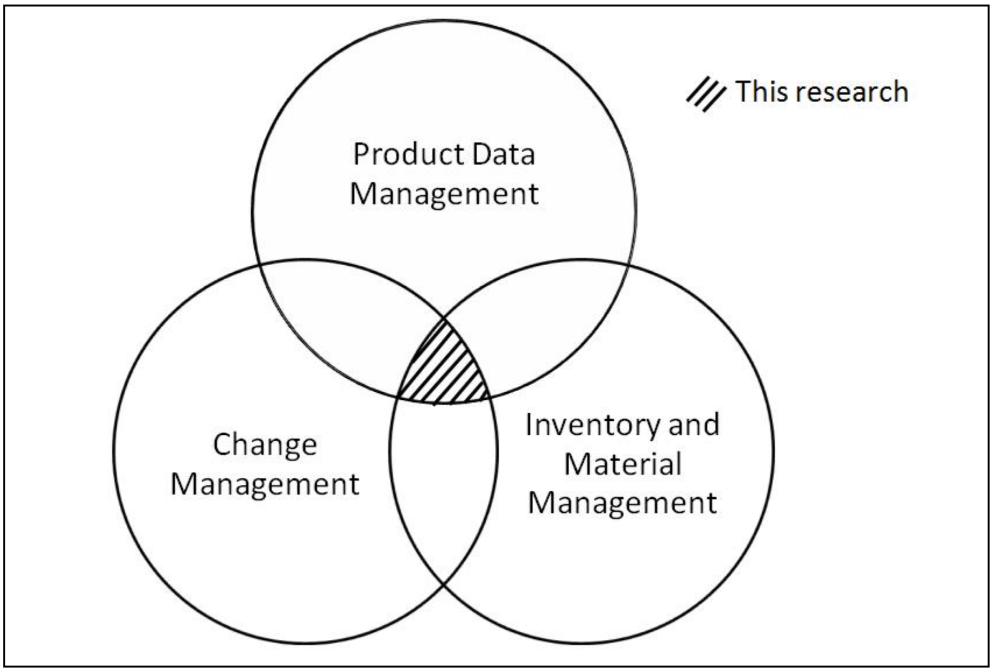

Figure 2. Positioning of the reseach.

The subjects of this thesis are examined and discussed by pointing out their connection to accumulation of excess and obsolete inventory. Also the inventory capitalisation and preventative actions in order to stop emergence of new slow moving inventory are studied. Currently there is no such a scientific research that would focus exactly to the field discussed in this thesis. Consequently, it necessary to combine findings related to inventory problems of researches that focus on subjects represented in figure 2.

In the area of change management, subject is mainly discussed at the company level, though some examination is done also at supply chain level. Focus is on customer order changes and engineering changes. All the possible change types that might have negative impact on inventory and material flows are taken under the research. The preceding situations could be for example revised order quantity, modified end-product type or order cancellation, in order to mention few types of customer order revisions.

In a field of product data management focus is on data accuracy and handling. The subject is covered through the whole product lifecycle, though special attention is given on product data management in the beginning and in the end of lifecycle. Focus is in the beginning of lifecycle because for example decisions of products relations with other products are made during the first phases of products lifecycle. Those decisions have impact to final products modularity and relations with other products on module and component level. Focusing to the end of products lifecycle is as for reasonable from inventory point of view because that is the critical phase where items in stock are either depleted or left in the shelf. Thus, situations where new items are replacing older ones, phase-in - phase-out process, is considered as one on the main topics of product data management related section in this study.

Material management in this research covers inventory and material flow related problems. Inventory management is examined in order to gain knowledge about common problems related to management of excess and obsolete inventory. Examination aims also to gain knowledge to support development of a framework for excess and obsolete material identification and capitalization of slow moving inventory. Material flow related research concentrates on in coming material flow.

2.2 Problem of slow moving inventory

At first, it necessary to explain the meaning of term slow moving inventory in this study. This research uses slow moving inventory -term to refer to inventory that has no use. This definition is used because that is CaseCompany's definition for useless inventory which inventory turn is zero. In literature related to subject, slow moving inventory often refers to poorly turning inventory, and for example terms non-active inventory or dead inventory are used to refer to inventory with zero turn. Now, when the definition used in this research is clarified, a short description of the problem could be looked through.

Slow moving inventory is often described an idle resource with real costs associated (Vrat 2014, p. 10; Chaneski 2003, p. 52). It is a concern especially of those companys that are manufacturing complex end-products requiring large amount of customized parts (Balaji & Kumar 2013, p. 243). In case of slow moving inventory problem, a part the inventory value is tied up to items that has no consumption. While items are not beeing used, those remain in shelf tieing up capital and increasing warehouse costs without contributing to companys performance (Murphy & Wood 2008, p. 231). It also stated that the level of slow moving inventory can be used to measure the level of overall inventory management (Shiau 2011, p. 1).

Companies having various different operating models might have different reasons for accumulation of excess and obsolete inventory. However, what all the companies have in common is that they should get rid of the slow moving inventory. Nenes et al. (2010, p. 313) mentions that inventory management has been recognized as one of the most important functions of industrial enterprises which has great impact to companies overall performance. It might be that getting rid of all the inventories keeps industries still waiting. However, for excess and obsolete inventories there should not be room.

Previously general overview to slow moving inventory problem was described. As evaluated in the beginning of this research, product data management, change management and material management have strong relation to slow moving inventory accumulation. Albeit root causes are company-sensitive it is possible to recognize couple main factors behind the problem of slow moving inventory. Consequently those are described in more detail next.

2.3 Product data and lifecycle management

Importance of product data management / product lifecycle management (PDM/PLM) is increasing for organizations acting in competitive and dynamic environment as PDM/PLM improves decision-making and reduce costs by taking advantage of the efficiencies and effectiveness coming from improved market intelligence and collaboration of partners (Vezzetti et al. 2013, p. 899) Continuously evolving industrial context requires flexibility and capability to adjust functions in order to achieve required level of operational efficiency. According to Demoly et al. (2013, p. 833) especially in the area of product development, whereas design and development process needs to result lifecycle oriented products, several product data and lifecycle related issues have to be considered. Demoly et al. (2012, p. 544) mentions that current industrial practices in PDM require better efficiency, flexibility, and sensitivity in managing product information at various levels of abstraction throughout products lifecycle.

Design of product structure, manufacturing and assembling is required to be realized all at once and so that they supporting each other. The preceding functions, PDM, PLM, and concurrent engineering (CE) are also one of the key factors when examining industrial company in inventory and material flow point of view. By establishing a framework that combines those functions diminish the uncertainty related to products that as for result less excess material and left over parts as well as obsolete items.

Product data and lifecycle management are one of the core functions utilized to design flexible and compact products with intelligent lifecycles. PDM/PLM could be defined as a tool that helps for example engineers to collect, manage and save variety of product data during different steps of product lifecycle (Karniel & Reich 2011, p. 3; Yang et al. 2008, p. 1033; Weber et al. 2003, p. 60; Leong et al. 2002, p. 289; Philpotts 1996, p. 5).

PDM system is used to keep track of masses of data and information required to design, manufacture and build products and after that update and maintain data.

PDM working as an integrative tool between different systems and databases makes it valuable in all departments of the company where product related information is needed. PDM/PLM system enables to manage engineering technical data usch as eBOM's (engineering bill of materials), subassemblies, parts and also manufacturing data such as mBOM's (manufacturing bill of materials), and operations (Demoly et al. 2013, p. 839; Philpotts 1996, p. 5). Weber et al. (2003, p. 460), Eigner & Nem (2010, p 205) and Young et al. (2007, p. 1510) points out the importance of the system as an enabler for cooperative working and simultaneous engineering through flexible workflow management. Demoly et al. (2012, p. 547) clarifyis the usefulness of PDM system by mentioning that the system is intented to ensure that the right information is availalble for the right person in the right format and at the right time by introducing versatile functionalities such as bill of materials (BOM) management, versioning, workflow management, check-in / check-out procedures, change management and configuration management.

The preceding functionalities are using product information in daily practices and PDM could be used to facilitate communication between those. Different departments and locations might be using different information types to store product data, which causes difficulties in order to have one integrative system.

Philpotts (1996, p. 5) mentions that PDM systems provide a structure in which all types of information could be stored and controlled as electronic documents and files. Once stored in same system it makes it more effective to manage and control data throughout product's lifecycle. In addition, files are accessible to all people and systems that have need for product information. Depending on users needs, the PDM system can set up for example to manage product conception, design, prototyping and testing. Yang et al. (2008, p. 1038) adds that data converter feature can be included in PDM system in order to facilitate data exchange between different file types. In order to solve data exchange problem comprehensively, Yang et al. (2008, p. 1043) introduces model for data exchange based OpenPDM, that works as a virtual data warehouse integrating various systems storing data physically in a distributed environment. OpenPDM solves partly problem related to information exchange by integrating and synthesizing product data across PDM systems. Thereby it enables cross-enterprise engineering and provides data access to all partners in a various data processing environments.

Another feature in PDM system, which should be examined from excess inventory and obsolete material point of view, is item atribute managing. By utilizing item atributes it is possible compare items about to be designed with already existing ones. Comparison is possible when new item is defined at certain level and critical some of the attributes, including for example dimensions and material, are defined. Philpotts (1996, p. 10) confirms the preceding by noting that classification functionality in PDM application provides an efficient mechanism for finding standard and similar parts. Philpotts adds that in case engineers and designers are able to find similarities between parts with relatively small amount of work, they are more likely to utilize existing items instead of starting to design a new one from scratch. According to Philpotts (1996, p. 10) attribute comparison is beneficial because that allows standardization of parts. By reducing variety also the level inventory is likely to decrease. (Vrat 2014, p. 14; Philpotts 1996, p. 10)

2.3.1 New product development

New-product development processes, involving multiple disciplines contributing to the development of a new product, are always highly complex, dynamic, iterative and unique (Karniel & Reich 2011, p. 19; Weber et al. 2003, p. 460). In order to facilitate new-product development process, Weber et al. (2003, p. 460) mentions that it is essential that the product model is accessible from the very beginning for all the teams responsible for different lifecycle phases. Accessibility is important because through that teams can identify conflicts earlier than in conventional procedure where the model is passed on to next team only when a certain state of maturity is achieved (Weber et al. 2003, p. 460).

According to Hoover et al. (2001, p. 102) a launch of a new product is always affiliated with a significant risk for ending up with excess inventory. The risk emerges for example when old product is replaced, not with an updated version, but with totally a new one. Hoover adds that excess inventory is often the result whether the launch was successful or not. That is where both product data management and change management should co-operate. While introducing a new product for the market, company should have an action plan for either to use or dispose material used to manufacture old and obsolete products. Also plan for possible product upgrades needs to be envisaged already during the products conceptual design phase (Tacvar & Duhovnik 2005, p. 208).

In addition to abovementioned, it is essential from inventory standpoint that purchasing and sourcing are strongly involved to the new-product development process from the very beginning. That is because when sourcing decision are made at the early stage of the lifecycle, the full effect of sourcing decisions over the product's life can be considered (Monczka et al. 2005, p. 343). Tuli & Shankar (2015, p. 2458) brought out that through involvement of sourcing also the suppliers could be involved in to development process which is likely to lessen the amount of changes at the later stages. Ou-Yang & Cheng (2003, p. 161) also support collaborative approach to the new-product development by mentioning that design engineers pay very little attention to required materials or components during the design stage and thus the process might result materials and components that cannot be purchased or produced. The aforementioned causes atleast the necessity of engineering change but also inventory scrap in case some other parts have already been purchased or produced but those cannot be used due to the engineering change.

Therefore, early involvement of stakeholders and sustained collaboration with focus on people and processes is essential for the performance of new-product development (Tuli & Shankar 2015, p. 2458). At the earlier stages of product development process it is possible to compare for example different minimum order quantities of different material and thus optimize acquisition and manufacturing for example from inventory standpoint. In case the decisions are made later, those have minimal impact to costs because the major decisions for example regarding types of materials have already been made (Monczka et al. 2005, p. 343).

2.3.2 Product relationship management

In order to design lifecycle oriented products, several lifecycle issues have to be considered in the beginning of product lifecycle. Development phase is especially essential because at that phase where possible relationships among products and operations as well are recognized and usage of the relationships is maximized (Demoly et al. 2013, p. 834). In order to gain understanding of product life, it is good to get familiar with produt lifecycle model.

Product lifecycle model is used describe and structure different phases of products life. According to Crnkovic et al. (2002, p. 5) the model helps to understand processes involved in the product’s development and operation as well as activities of the people involved in the processes. Crnkovic et al. divide lifecycle in six generic phases, that are each characterized by its inputs and outputs, by its activities, support provided, by the roles of required people and by the different techologies and techniques utilized in that particular phase. Figure 3 shown below, illustrates the phases of product lifecycle according to Crnkovic et al. (2002, p. 5)

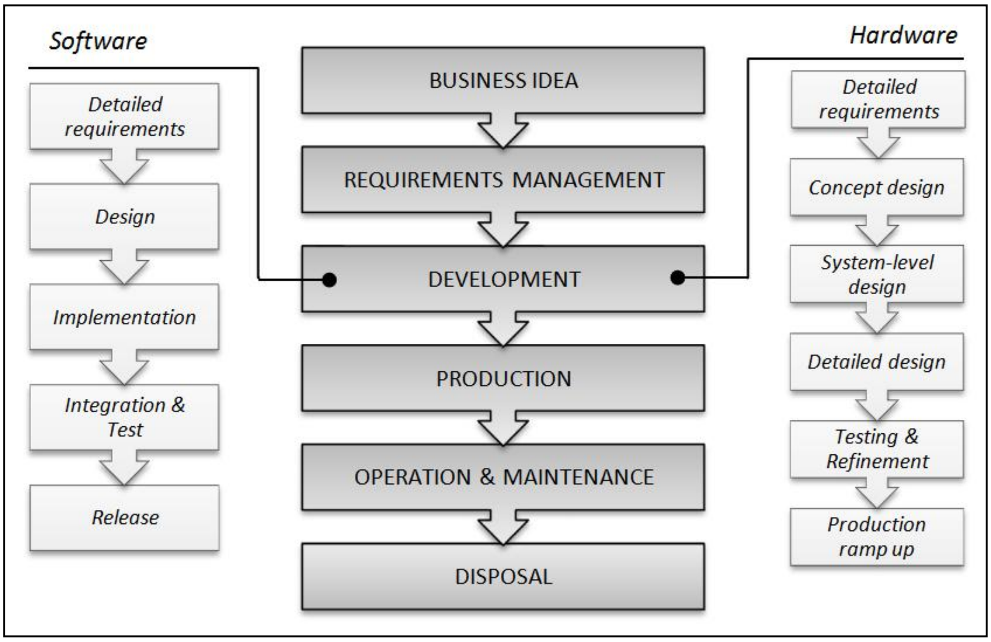

Figure 3. Product lifecycle -model and lifecycycle phases (Crnkovic et al. 2002, p. 7).

Each phase of the lifecycle has its own kind of requirements for product data management from inventory and material management point of view. Especially the development and disposal phases are essential. In the figure 3, development -phase is divided into software and hardware development. Both of these have their own unique details. The most remarkable difference between software and hardware development is that on hardware's testing phase physical prototype is built. Comparing to software's test -phase, building prototype is an additional phase.

What is important and in common both for hardware and software at the development phase, is that product data management is able to recognize similarities with already existing products and one to be designed Demoly et al. (2013, p. 839).That is especially important in case of hardware development. In order to minimize the amount of new items, an effective way the compare items features has to be established. In order to build products that can be assembled from standardized selection of subassemblies and parts, it required to set requirements of the new product so that those can supported by the available item category. In the long term the preceding kind of policy of new item creation is going lead into reduction in amount of item numbers which as for facilitates item management. What comes to disposal phase of a product, it is essential that a comprehensive disposition plan for all the related parts and subassemblies has been made in order ensure that no excess raw material or obsolete parts or subassemblies is left in inventory.

Demoly et al. (2013, p. 842) mentions that by capturing the relationships between parts and sub-assemblies of a product a solid base for successful product development can be established. In order to build more standardized product portfolio, it is necessary be able to recognize similarities between product structures. Standardization of the products has multiple benefits, but the one that that is interesting for this study, is reduced obsolete and excess material that would result from more intelligent design and lifecycle management.

2.3.3 Challenges in product data and lifecycle management

Previously basics of product data management and some possible benefits that could be achieved in case utilization of PDM is at on effective level were described. From inventory and material management point of view, the beginning of product lifecycle is essential. That is the phase where many lifecycle-long decisions that affect for example to product's bill of material are clinched. The better the decisions are founded and better the requirements are understood, the less unexpected change needs should emerge.

Currently main challenges in the field of PDM/PLM are data-related. According to Feng et al. (2009, p. 49) data management in efficient manner is a one of the marjor issues. Lack of appropriate information or access to it is an issue especially in the beginning of lifecycle, because lifecycle-oriented decisions can only be made if there is sufficient information available (Demoly et al. 2012, p. 559). Common problem related to management of data is that information is buried within various documents and file types being processed by different software tools that are not compatible (Weber et al. 2003, p. 448; Leong et al. 2002, p. 296). Consequently, it is difficult to make overall analysis from the data because various methods are required to analyse the different formats. The aforementioned difficulties are concretized in real-world example-case from CERN presented by Pettersson et al. (2000). According to Pettersson et al. (2000, p. 2450) management of various documents with distributed approval process turned out tho be considerably more difficult that was initially envisaged.

Lack of appropriate information is partly because of currently used PDM/PLM applications and practices are not compatible. According to Yang et al. (2008, p. 1043) the fact that each company manages its product data by its own method and applications has become a main obstacle with respect to the sharing of product data. Vision of current academic and industrial PLM – that includes for example setting up a comprehensive set of models, methodologies, processes and information systems covering the entire lifecycle of the product – has not yet fulfilled requirements of the all life phases of product and especially in the beginning of the lifecycle there are deficiencies (Demoly et al. 2013, p. 833). From inventory point of view, especially the beginning of lifecycle and the end of lifecycle are essential. At the beginning of lifecycle the lifelong decisions are made, in case decisions are not inventory friendly, the weight is carried all the way during the products life.

At the first steps of the lifecycle, product designers, process engineers and assembly planners are still working separately without for example any recovery or feedback loop facilities or features in their tasks. Improvements in the field product design and in integration of all constraints of each life phases has been achieved due development of design for X and knowledge-base techniques. However, there still exist gaps in the management of the various technical entities and the control of information flow through the lifecycle of the product. Demoly et al. (2013, p. 833) It is explained by Yang, et al. (2008, p 1033) that albeit the different systems would be compatible problems emerge because each user has not know what information to find in which system, how to collect the necessary information from individual systems and how to assemble partial information so that it becomes complete. Consequently, in the future it is necessary to move from product data exchange to product information exchange and eventually towards product knowledge exchange (Subrahmanian et al. 2005, p. 9). In future, it also necessary according to Jimenez-Narvaez et al. (2012, p. 22) that all the implicit information related to product can be included in to PDM/PLM system, not only the explicit information.

As application's incompatibility relates issues could be mentioned as one the main problems currently related to PDM/PLM, difficulties emerge also in the field of requirements management (RM). Naturally, the latter is partly a consequence of the former. Nowadays, RM is often not included in the PDM/PLM systems, eventhough it is important activity throughout the PLM (Papinniemi et al. 2014, p. 4412). The preceding is due the fact that there is no customer requirements management -tools that would have proper and effective interface with project management tools (Zwikael & Tilchin 2007, p. 50). However, RM could be brought out as an individual problem because its high importancy. Customer requirements and understanding those are key criterion for high quality products (Cudney et al. 2012, p. 49).

According to Jiao & Chen (2006, p. 175) commonly problems emerge when converting customer requirements into specifications of the product. Process is problematic because customer requirements are commonly qualitative and tend to be imprecise and ambiguous (Jiao & Chen 2006, p. 175). It is also not uncommon at all, that requirements are conflicting with each other (Jiao & Chen 2006, p. 175). In addition, customer requirements typically change during the development phase and requirements might be implemented differently in different parts of the organisations (Möttönen 2009, p. 61)

Issues related to RM emerge also due the way how the requiremens information is delivered for the engineers. According to Jiao & Chen (2006, p. 176) there does not exist any definitive structure of requierement data. Commonly variables used to describe product's requirements are poorly understood and expressed in abstract or conceptual terms which as for lead to situation where engineers need found their work on vague assumptions.

Customer orientation is essential in the field on PDM/PLM and customer requirements should be considered in the first place, however customer is not the only source for requirements. Additionally, there are multiple engineering concerns to consider. Like for example Prudhomme et al. (2003, p. 339) mentions that in addition of customer requirements, requierements set by manufacturing, maintenance and recycling has to be considered. Consequnelty, multiple view-points has to be taken into accout which in case of complex products is likely to make things challenging.

Based on the aforementioned issues there is still a lot to improving potential in the field of PDM/PLM. It is important to understand that struggling at the very first steps at the lifecycle is likely to lead into difficulties at the later phases as well. Understanding customer's needs and knowledge of how to convert that in to product specifications are essential for succesfull design and development (Cudney et al. 2012, p. 47). Previously product data and product lifecycle management -related topics were discussed. Literature review shows that the preceding subject has relations to excess and obsolete inventory. Next topic to be looked trough is change management. At fist general overview in to subject is taken and then topic's relation to slow moving inventory accumulation is examined.

2.4 Change management

Delivering highly customized products into various different needs requires preparedness to cope with unpredictability. No matter at what phase of the order delivery process a need for a change occurs, it needs to be processed in an effective manner. In a first place, it is required that the change is implemented within a given time, which in many cases means immediately or at least in the very near future. At the same time, implementation should to be executed with the lowest possible cost. In addition, this all should happen with causing no interruptions for example to predetermined delivery dates of the end-product. Though it is a question of complex process, it is crucial because engineering changes has important role in improving products (Elezi et al. 2013, p. 568)

The agility of an enterprise is reflected from its ability to manage engineering changes (Tacvar & Duhovnik 2005, p. 205).Engineering change refers to making of alterations to products or to manufacturing prosesses (Jarrat et al. 2011, p. 105; Ullman, D. 2010, chapter 12.4; Tacvar & Duhovnik 2005, p. 205). The alterations are carried out by using engineering change request (ECR). Engineering change request works as a proposal for a change. Those are initiatives that should take place for example when product's features are not in line with the products requirements and something needs to be redesigned or modified. Once the process for change has started, it commonly induces a series of down-stream changes where multi-disciplines work together dealing with these induced changes (Huang, et al. 2003, p. 481).

That whole process of managing engineering changes is organized and controlled by engineering change management (ECM). Bhuiyan et al. (2006, p. 6) points out the importance of the engineering change management by mentioning that changes should be well controlled and implemented in order to minimize costs and time delays. ECM aims on taking care of the whole change process in order to minimize unwanted effects while implementing the change. It is responsible of analyzing all the possible pros and cons related to and caused by the change. By analyzing the effects of the change, ECM should be capable to end up with a justified decision whether or not the change is profitable and acceptable to implement. Engineering change management is also responsible for ensuring that all the requirements of the change are took into account at every phase of the change process. Hence, it could be said that with the proper utilization of ECM, it is possible to obtain a required level of preparedness for all the possible, both inner and external, change needs related to company's products.

Depending on the nature of a change, the management of it might require efforts of various departments of the company. Bhuiyan et al. (2006, p. 6) mentions that implementing change requests is likely to affect for example functions like engineering, sales, manufacturing, purchasing, inventory control and accounting. Once the change is likely to require cross-functional operations, like it does in many cases, implementation of the change sets its own challenges for the share of information. Effective cooperation and conversation is essential in order to process engineering change requests quickly and accurately.

Share of information between the functions collaborating to change management is one of the prerequisites for successful execution of ECR's (Tacvar & Duhovnik 2005, p. 205). Misunderstandings, wrong kind of or lack of information are likely to gain for example scrap material, delays, new purchases and unnecessary inventory transactions. The preceding faults are likely to have a negative effect for example on quality that as for, has a direct impact for example on customer satisfaction and brand image. It is difficult to put a monetary price for the losses on two last mentioned areas. However, by understanding that poorly handled changes affect negatively, among various other areas, for example on those two, it helps to build a mindset and standpoint of the importance of ECM.

2.4.1 The nature of change

As a general rule, the very first step when dealing with a change situation, no matter if it is a technical or for example organizational change, is to analyze the nature of it. The goal for analyzing the nature of a change is to develop required information to make further decisions. Comprehensive analyze is important because the result works as a guideline for further actions. However, time used to analyse the change, is often of great concern as well. Sometimes it is crucial to get change implemented within a very narrow timeframe. In such cases the analysis needs to be proportioned with available time and only the most crucial information for planning the further actions needs to be generated.

Paton et al. (2000, p. 17) mentions that only by considering the nature of change, it is possible to determine change's presumable magnitude and potential impacts. To support implementation of changes Paton et al. (2000, p. 21) introduces a change spectrum. The purpose of the spectrum is to provide information for decision making process. By analyzing the change's interface between people and system, and complexity and variability of the change environment, proposals related to for example on how the change should be approached and implemented, could be found.

The nature of a change, whether it is a so called hard or mechanistic, or so called soft or complex, can be defined by using TROPICS -questionnaire introduced by Paton et al. (2000, p. 21). The questionnaire helps change analyst to define the change, designing the needed actions and make implantation plan to execute the actions. The more detailed structure and example content of the TROPICS is illustrated on appendix 3 in figure 4. As an example case, one of the CaseCompany's engineering change proposals is used. After completing the TROPICS -questionnaire, it is possible to locate that particular change on the change spectrum. By perceiving change's location on the spectrum a decision of how the change will be managed could be done. The change spectrum is presented below in figure 5.

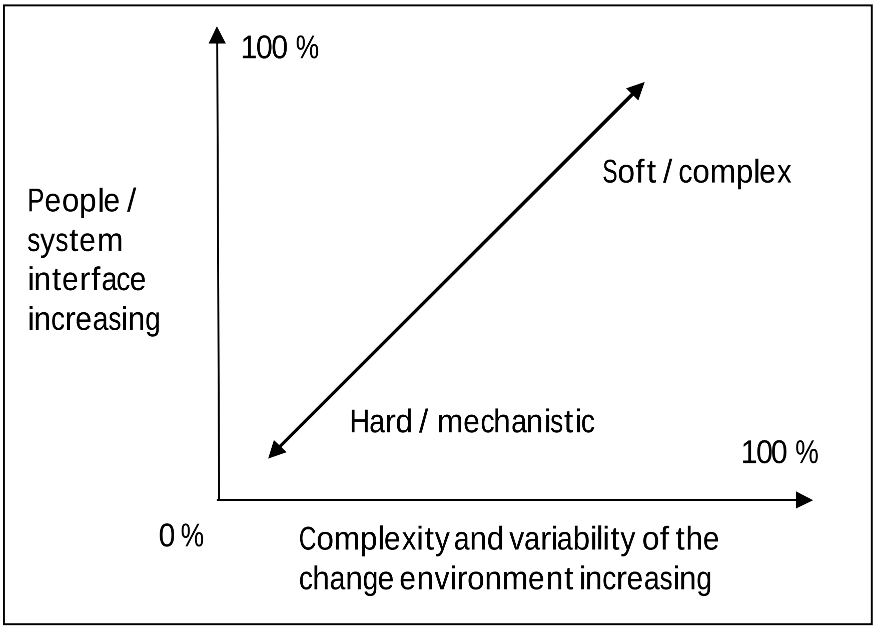

Figure 5. The nature of change spectrum according to Paton et al. (2000, p. 21).

Because the nature of the change influences on methods used to deal with the change, it is necessary to recognize change's interfaces with people and systems as well as with its environment. As shown in figure 5, the less complex and unstable the change's environment is, and the less there exist interaction between people and system, the more mechanistic the change is on its nature. In the preceding kind of changes a system-based approach to implement the change is recommended to be used. On the contrary, in case the change environment is relatively complex and variable, and there is relatively a lot of interaction between system and people, the change is complex on its nature. That kind of change should be managed by utilizing organizational approach.

In this thesis, the changes under the discussion are related to changes in existing products or customer orders. Consequently, changes studied this research are to a great extend technically oriented. The systemic nature of the preceding kind of changes is confirmed by Vilko et al. (2012, p. 476.). These changes are placed to extreme hard –end of a change spectrum so the approach is mechanistic or in terms of Paton, hard.

According to Paton et al. (2000, p. 20) management process of technical changes is simplified because the impact is limited to a clearly identifiable and the semi-autonomous component of a technical system. Need for a change is possible to rationalize with systematic analyses and calculations. In this kind of cases change can be implemented according to Paton et al. (2000, p. 20) with no remarkable managerial conflicts.

In case of product related techno-economic change, the change would be under the control of ECM. The determination of the change includes for example identifying the impacts of the change for the products that are already released for manufacturing or the impacts for purchased parts and sub-products in own warehouse as well as for those that still remain at the supplier. Also the impacts related to products that are already delivered for the end customer must be under examination. In case needed, customer must be notified about the possible updates related to product and its specifications.

Paton et al. (2000, p. 17) mentions also that at an early stage of the change cycle, a successful determination of the nature of the change should indicate the most appropriate means of managing the change. For the changes that are technical on their nature, the preceding means for example determining the change so that it is possible to indicate the departments needed to participate into change process. In order to start implementation of change as effectively as possible, it is crucial that all the departments and persons involved into forthcoming change, are informed already at the very first steps of the process, for example on proposal phase. Paton et al. (2000, p. 187) mentions, while writing about organizational change and change resistance, that all relevant people must share information relating to the need for change, plans for change and consequences of change. The preceding rule is totally applicable in engineering changes as well.

2.4.2 Reasons for changes

Changes and modifications in existing product offering are requirement for development (Keller et al. 2007, p. 2). However, it is also a challenge especially for companies producing complex products that are highly customized according to numerous different customer requirements (Wasmer et al. 2011, p. 533). The more complex entity is, the more often there is a need to clarify details and modify specifications for example on the item level, which in turn can lead to major changes in the end-product. There are multiple methods in order to lessen changes after production release such as concurrent engineering and quality function deployment. However, once a product has released to production some changes are unavoidable (Tacvar & Duhovnik 2005, p. 205).

Initiatives for a change are in many cases done by the customer as a new or an additional requirement, or by the supplying company as a manufacturing changes or modification of product specifications (Wasmer et al. 2011, p. 533; Bhuiyan et al. 2006, p. 6). In case the change is initiated by the customer, there is always a risk that change is highly difficult and expensive to implement. This would be situation for example when customer does not have relevant or knowledge deep enough related to the product or its technology, and due that customer is requiring something that is basically impossible to realize with existing technology or within available time. Jiao & Chen (2006 p. 176) confirms the preceeding by mentioning that commonly customers are not aware of the underlying coupling and interrelationships among various requirements with regard to products performance.

On the other hand, if the change is proposed by the company supplying the product, in some cases implementation of the change requires customer's acceptance, which might as well make implementation process more complicated or at least slow it down significantly. Issues related to customer order changes are emerging especially if it is not clear which party has responsibility of carrying the costs of changes. In case internally issued changes are not requiring customer acceptance the particular change should not cause any interruptions on customer interface. On the contrary, the change should benefit customer through for example improved quality or additional functionalities which again could be seen as higher value for invested capital in point of view of the customer.

In general, changes having influencing for example on products cost structure or on delivery time, require in most cases negotiation and settlement between customer and supplier. Finding a solution and agreement quickly is important for that particular customer order to be delivered on time. Furthermore, it is essential for the healthy long-lasting customer relationships. In a long-term, capability to manage changes is certainly appreciated by the customers and therefore that could be used for example as one of the competitive factors.

According to Philpotts (1996, p. 7) product changes are inevitable. However, what is important is the time they occur. Product changes might be ruinously expensive and disruptive if they emerge late in the product lifecycle. The impacts of change are discussed in more detail next part.

2.4.3 The impact of change

Engineering changes can basically occur at any stage of the products lifecycle. Typically, the later a need for a change occurs, the more expensive it will be to execute it (Tacvar & Duhovnik 2005, p. 205). Often the cost of an engineering change increases by a factor of five to ten as product moves from early design phase to manufacturing (Wasmer et al. 2011, p. 534). Figure 6 below illustrates the increase of estimated total cost for an engineering change in the different phases of the order delivery -process.

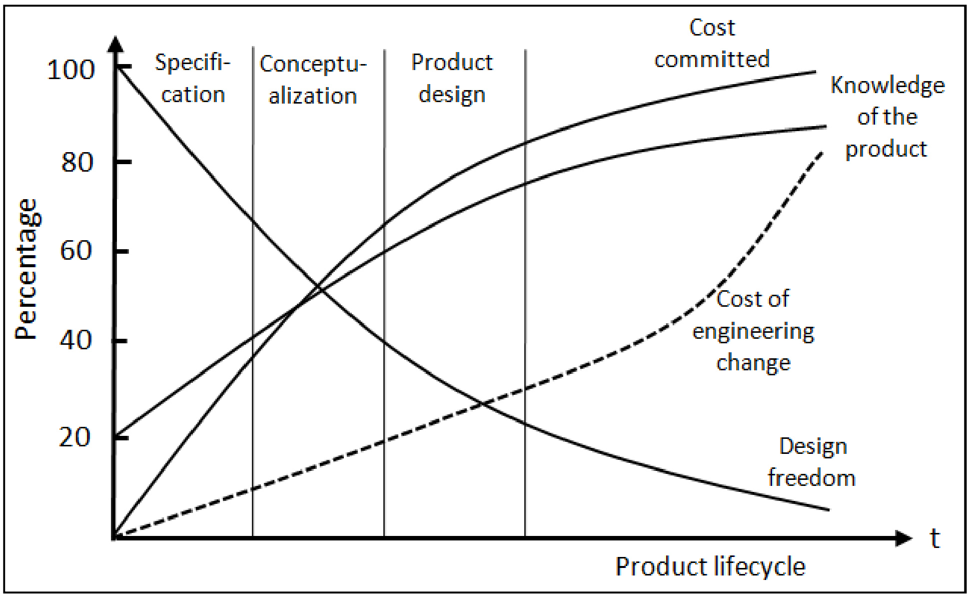

Figure 6. Increase of costs during early stages of product lifecycle (adapted from Ullman 2010, figure 1,4 & figure 1,11).

Like illustrated in figure 6, appropriate time for changes is at the early stages of product's lifecycle. Stevenson (2009, p. 715) mentions that engineering changes, that are commonly concentrating for example on processing instructions or BOM, are one of the most expensive transactions during the order delivery process. Consequently, need for those changes should be recognized latest at the product design phase.

When considering the impacts of changes it is necessary to understand how the changes affect to different types of product and what are as for the impact for material management. The major product types could be divided for example to assemble-to-order, make-to-order, purchase-to-order and engineer-to-order products. One of the most remarkable differences between the preceding product types in the point of view of material management is the point in the supply chain at which customer demand is allocated for the end -product.

Hoover et al. (2001, p. 102) call the point where an order is allocated to the product as an order penetration point (OPP). That point individualizes customer orders for different types of products. OPP works as a link between demand and supply. Each OPP has cost benefits for both the supplier and the customer and economics of value chain can be modified by moving order penetration point. For example in case of engineer-to-order products, the penetration point is engineering in order to be able to supply tailored end – products. In this case, there needs to be balance between customization and process efficiency. On the other hand, if it is about make-to-stock products, OPP is in distribution. In this case, products are finished and it is important to find right set up between product range and reasonable inventory levels. Figure 7 shown below illustrates how OPP is positioned into different functions; engineering, fabricating, assembling and delivering depending on the type of a product type.

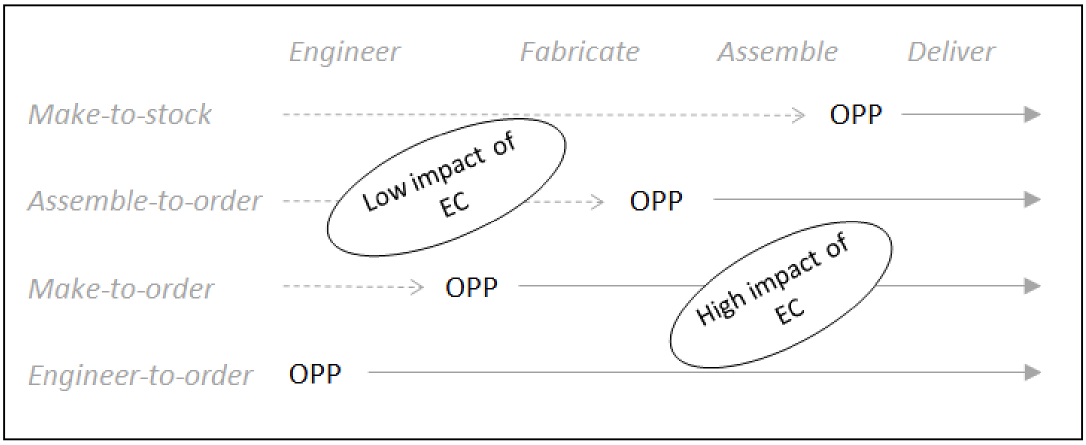

Figure 7. Positioning of OPP and its relation to EC's harmfulness in order delivery process.

Like mentioned earlier, allocation of the customer order to the end –product is dependable of the product type. In case OPP is postponed to the later functions in the supply chain the changes in customer orders have only minor impacts into material flows. On the other hand, if OPP is positioned at the very first steps of the order delivery process, changes in customer's requirements are like to cause problems. Difficulties are faced especially when customer is willing to cancel the order. That is because once order has been tailored to fulfil individual needs and parts are engineered according to special requirements, it's unlikely that parts could be used in some other orders.

Above direct capital impacts of engineering changes are described. Those will always realize and the question to be asked is only how big the costs are. In addition of direct capital impacts engineering changes have other impacts, especially in case the change fails. Elezi et al. (2013, p. 567) and Keller et al. (2007, p. 2.) mentions that in case management of EC fails, in addition of costdirect cost impact, the failure will cause loss of time and lack of control over the product configurations. Accoroding to Ou-Yang & Liu (2001, p, 11) EC's influences also material planning. From inventory point of view the aforementioned impacts are especially notable because those are likely to cause excess and useless material.

2.4.4 Management of engineering changes

Like mentioned earlier, dominating approach method for engineering changes is system-oriented approach. In order to manage changes in that way, the meaning of system should be well defined. According to Paton et al. (2000, p. 76) system may be defined as an organized assembly of components, which are related in such a way that the behaviour of any individual component will influence the overall status of the system. Hence, the essential point of the preceding definition is that changing one part is like to require implementing changes to other parts as well. The preceding reflects to cost side as well, because the costs are likely to accumulate when a change in the design of one component results a change in the design of other components (Karniel & Reich 2011, p. 20; Tacvar & Duhovnik 2005, p. 206).

Proper management system is important in all types of changes. Anyway, especially in case of changes that has impact to current BOM's, management is crucial. In case the preceding changes are made in order to update BOM's to meet current requirements by replacing older versions of items with newer ones. As a result, old versions might be left without any use, and due that, those are like to remain in inventory for relatively long periods of time. From inventory management standpoint, disposition of old design parts is in the ballpark. That is because once items are left useless in the shell, and once those are finally recognized as a problem, it will be, in all likelihood, the inventory department that is going to face the problem.

There exist various models and techniques to manage engineering changes. Similarities from the models could be found and thus the main points summarized. It is suggested that change management is supported in collaborative manner by material planning, procurement and production planning and scheduling (Shiau 2011, p. 2). Huang et al. (2003, p. 483) adds that in some cases it is beneficial to have also marketing involved. Consequently is can be said that management of engineering change is an effective manner requires seamless cooperation between multiple functions and that communication is one the cornerstones for successful change management.

In practice, engineering changes are often executed through documentation sharing. There basicly three kind of engineering change documents. The first is normally used at the inital stage of ECM lifecycle in order to propose the change. The second group of EC documents are used to evaluate the change and its impacts. The last group of EC documents concern to notify all the necessary parties about the change and is consequently used in the end of ECM lifecycle Huang et al. (2003, p. 483).

Watts (2012, p. 245) points out the importance of handling items separately on ECO form by mentioning that companies that do not make a conscious decisions on each old designed part are unconsciously increasing their excess and obsolete part inventory.

Watts adds that companies that do not address the issue change by change have in most cases relatively huge amount of down-level material that has no planned disposition actions.

2.4.5 Cross-company collaboration

It is already stated in this thesis that collaboration between different operations of the company is required in order to handle changes successfully. Information sharing is essential, not only at company level, but at the supply chain level as well in order to minimize negative impact of changes. Effective information exchange is one of the fundamental requirements for well-functioning supply chain (Vilko et al. 2012, p. 476; Mangan et al. 2008, p. 150; Delfmann & Klaas-Wissing 2007, p. 85). Share of information is important because through effective information sharing supply chains level of visibility could be increased. The higher the level of visibility is in the chain, the better companies recognize the risk outside of their own visibility zone. Thus, the information sharing provides companies an opportunity to be prepared for the change.

Ryu et al. (2008, p. 162) highlights the preceding by mentioning that no matter whether it is about demand or supply uncertainty, collaborative information sharing could be used to eradicate the uncertainty and reduce risks related problems like excess inventory and poor service. Dejonckheere et al. (2004, p. 746) mentions as for, that through collaborative information sharing bullwhip effect can be decreased. That could be seen for example as less excess and obsolete inventories. In point of view of change management, once a need for a change is recognized in any part of the supply chain, the information should be shared among all the other members of the chain that might benefit of it. But this is exactly what makes share of information complicated. For which partners the information should be shared, and at what level of details?

2.4.6 Challenges in change management

Change management is a complex process with multiple steps requiring involvement of numbers of people. Current literature indicates that there are various challenges to be solved. For example Huang et al. (2003, p. 481) mentions that engineering changes are significant problem that cannot be underestimated and that and that in the current manufacturing industry more efforts are need in order to process EC’s effectively and efficiently.

In previous part importance of information sharing for change management is brought out. Though information sharing is essential at the supply chain level in order to deal with changes, it does not happen by definition. Hoover et al. (2001, p. 30) points out issues related to collaborative information sharing at the supply chain level by describing example about changes in demand on high-tech business. On that area, the temptation for the supplier is often to push products that have risk to become obsolete. For the customer as for, the temptation is to withhold demand information in order to secure higher shares of products in short supply. The optimal solution for the supply chain as a whole would be that both supplying and customer company would collaborate to ramp-up and ramp-down products together in a controlled manner. Hoover et al. (2001, p. 30) In case the preceding does not happen, material flows in the supply chain are in balance with the demand which could seen as excess and obsolete inventories.

However, implementation of solutions that support collaborative way of working is difficult (Wasmer et al. 2011, p. 534; Hoover et al. 2001, p. 30). According to Wasmer et al. (2011, p. 534) that is because global engineering environment, in which product data is handled in distributed networks involving multiple parties, everyone of those using their own engineering change process, languages and practices, makes things complicated. Consequently, every time when engineering change occurs, cross-company communication requires additional efforts. That would be solved by having a universal language for engineering changes, which anyway is still waiting for its time (Wasmer et al. 2011, p. 534).

Another source for problems related to of information sharing is that companies are reluctant to share information with their trading partners. That is often because of a lack of thrust (Tuli & Shankar 2015, p. 2458). In many cases the main concern is that partner will the using information unfairly and against the company sharing the information. Ryu et al. (2008, p. 162)

In addition to problems the definition of the change has to be added. According to Keller et al. (2007, p. 2.) it is often the case that companies are not able to identify all the items that are affected as a result of the change.

Pince & Dekker (2011, p. 83) clarify the negative impacts of uncontrolled or failed changes for inventory by mentioning that generation upgrades are likely to result excess inventory and obsolete material. In order to highlight the problem Pince and Dekker introduces example from airline business. At that moment, when an airline announces the sale of old version of its aircrafts, the airline’s service providers are likely to face a sudden drop in demand for relevant parts. In case the prior actions are not taken in the preceding kind of situations, the excess stock that has no demand will become obsolete. Pince & Dekker (2011, p. 83). Problem at the above described example is related to uncontrolled phase in of a new product and phase of an old product.

The above described problem related to information sharing is the reason why all the companies in the supply chain should share a similar supply chain oriented way of thinking. In case any company is trying to gain benefits by the cost of overall performance of the supply chain, that is likely to have negative effect to whole supply chain’s performance. This problem could be compared to optimization issue. The optimized value is unlikely be found through partial optimization. In case of supply chain, value to be optimized is the performance of the supply chain and companies of the chain are the factors.

2.5 Material management

Material management, concentrating managing both cross-company and company-internal material flows, has a great influence to company's overall performance and thus consist great improving potentials (Chen et al. 2006, p. 2519 ; Wagner & Enzler 2006, p. 201). Consequently, from slow moving inventory point of view, it is reasonable to investigate opportunities in material management as well it relation to inventories.

2.5.1 Management modes

Commonly, different material management policies are divided into distributed mode, centralized-distributed mode and centralized mode (Chen et al. 2006, p. 2521). The different modes have their own features and effects. Thus, every mode has its own kind of impact into inventories as well. The essential difference between distributed and centralized modes from inventory point of view is that in distributed mode different offices are managing their own inventory and making order decisions separately as in centralized mode inventory is physically in one location where also decisions are made (Zhang & Zhang, 2007, p. 44). Table 2 presents the comparison between the material modes.

MODES / CONTENTS	DISTRIBUTED	CENTRALIZED-DISTRIBUTED	CENTRALIZED
THEORY FOUNDATION	Traditional material management	Synthetizing management theories and information technologies	Synthetizing management theories and information
CHARACTERISTICS	Absolute distributed management	Centralized purchasing, distributed serving, centralized-distributed	Centralized purchasing, distributed serving
SUPERVISION MECHANISM	Hard	Convenient for supervision	Very efficient
RESPONSE SPEED	Very fast	Fast	Slow
STOCKS	Large	Little	Least
RISK OF SCRAP	Large	Little	Least
STORAGE OF IDENTICAL MATERIAL	Large	Little	Least
OCCUPIED FUNDS	Large	Little	Least
THE NUMBER OF PERSONNEL	Many	Few	Fewer
INFORMATION SHARING	Bad	Good	Better

Table 2. The comparison of three material management modes. Adapted from (Chen et al. 2006, p. 2519).

As shown in table 2 each of the modes has some different advantages and disadvantages of themselves. From inventory point of view, the difference in the amount of stock between distributed and centralized mode is notable. That as for, has relation to risk of scrap, storing same kind of materials as well as to capital tied up into inventories. The aforementioned are contents that have direct influence to inventory. Consequently, in order to ease the problem of slow moving inventory, a centralized mode offers notalbe advantages compared to other modes. Benefits of centralizing material management related operations from inventory standpoint are also confirmed by Stevenson (2009, p. 521), Malone (2007, p. 138), Delfmann & Klaas-Wissing (2007, p. 312), Copacino (1997, p. 48) and Zenz (1994, p 84).

Selection of material management mode is related to product portfolios between factories. In case products between factories are highly differentiated and distributed materal management mode has been selected, benefit of centralized material management mode could be achieved by improving factory to factory material flow. According to Kukreja et al. (2001, p. 1373) lateral transhipments are practical manner to improve overall material management. At firts the preceding requires recognized the items could be used at multiple plants, secondly the system that facilitates the lateral shipment needs to established.

2.5.2 Material control policy for items subject to obsolescence

In order to cope with slow moving inventory Pince & Dekker (2011, p. 84) introduces a model that focuses on slow moving items for which the demand rate drops to a lower level at a known future time. That is generally the case for example when old products are being replaced with updated versions or completely new products. Pay (2010, p. 69), Pince & Dekker (2011, p. 84) Drop in demand is confronted by setting the control policy of items in advance so that the demand process takes away the excess stock. The model is used to understand the outlines of the impact of the timing of control policy change on operational costs and to define the optimum time that balances the tradeoff between the risk of obsolescence and backordering. In practice model could be used to identify the time for control policy and to estimate changes impacts on costs incurred.

In the model it is considered a single item, a single location, and continuous review inventory system for items that are about to become obsolete and that has fixed lead times and non-stationary demand. The model assumes that demand follows a stochastic Poisson process. The preceding means that every demand occurred in a certain time interval is individual. That is, a particular demand does not affect to any other demand and there is no relations between the demands occurred. The model assumed that at time $t = 0$ demand rate equals to λ_0. Demand stays at the same rate λ_0 up to pre-determined time point T after which the demand rate drops to a lower state λ_1. It is assumed in the model that demand will not achieve the original rate λ_0 after it has started to decrease and that decreasing is continuous until there is no demand at all, that is, $\lambda_0 > \lambda_1 \geq 0$. In the model's first period, time between the moments $t = 0$ and $t = T - X$, inventory position $IP(t)$ is kept at level of the original safety stock S_0 by releasing replenishment orders according to demand. The model is represented below in figure 8. Pince & Dekker (2011, p. 94)

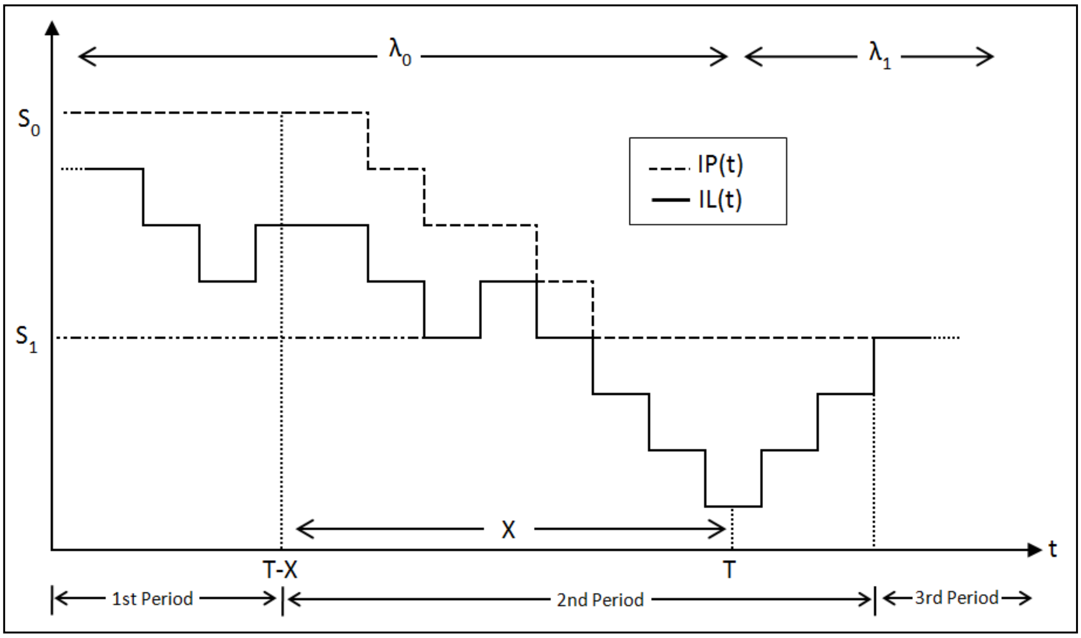

Figure 8. Inventory reduction model for items subject to obsolescence. Adapted from Pince & Dekker (2011, p.84).

As described earlier and as shown in figure 8 inventory position $IP(t)$, that contains both quantity on-hand in inventory as well as quantity on orders, is kept at safety stock level equal to S_0 between time $t = 0$ and time $t = T - X$. From figure 8 it is possible to see that critical component of the model is X. According to Pince & Dekker (2011, p. 89) in case of full obsolescence X is relative to expected on-hand inventory carried during the period 2, stock remaining after the period and expected backorders. Is always company sensitive, how the preceding factors are set in order to find to optimal X. However, according to Pince and Dekker (2011, p. 93) the impact of advance policy change on the expected total cost is remarkable. That is because in case if policy is not changed in advance the holding cost of inventory will increase since the natural attrition of the remaining excess stock takes longer.

When the time for the demand drop is known in advance, X is used to define the certain time for the items control policy chance. That is the time when it is optimal time to initiate the excess stock removal process. Once the change of control policy is made from $(S_0 - 1, S_0)$ to $(S_1 - 1, S_1)$, adaptation to the new safety stock level is achieved by not giving any replenishment orders earlier from time T. In case excess stock removal process is started too early, all the excess stock is removed too early and the inventory system returns to its regular operation before the drop in demand takes place. That is likely to lead into situation where inventory system operates under a safety stock level S_1 until the drop occurs and results more backordering costs.

Pince's and Dekker's model is based on continuous review of control system for slow moving items that demand is going to drop at a know future time and on changing the control policy of slow moving items at a certain time before the drop in demand occurs.

Focus is on the behavior of the net inventory level during the transient period and target is to approximate the optimal time to switch to new control policy. Properly timed policy change results in remarkable cost savings once excess material will be consumed due natural attrition instead of any external efforts put in the process. Thus, in case of items that are in the end their lifecycles, the timing of the control policy change primarily determines the tradeoff between backordering penalties and obsolescence costs. Pince & Dekker (2011, p. 94)

Practical importance of Pince's and Dekker's model is at its most when it is a question of high cost items. That is because the model is based on continuous review policies rather than periodic review. For slow moving items with high downtime cost continuous review policy is more preferred due to relatively low safety stock requirements compared to medium or low cost items. Pince & Dekker (2011, p. 94) In case of high cost items that are about to become obsolescence efficient management of inventory is notoriously challenging.

The key to solve the abovementioned problem is to know a right time to change the control policy in order to reduce obsolete and excess inventories while balancing availability. In case the change is made too early the risk of backordering increases and stockouts might be detrimental to a company's operations (Pince & Dekker 2011, p. 94). On the other hand, if change on control policy is made too late, the risk of obsolescence increases and obsolescence inventories are like a dead weight loss that weakens a company's competitiveness and decreases the amount of working capital available (Pince & Dekker 2011, p. 94).

In Pince's and Dekker's model it is assumed that inventory system is controlled according to a one-for-one replenishment policy and that the lead time for replenishments are fixed. Like it is mentioned earlier, the model aims to provide support for inventory management of items that demand rates drop down dates are known. Therefore it could be possible to utilize model for example to phase-in - phase-out situations. In those cases the demand for one particular item is determined by the date when the end product's BOM is changed. After that and if items are still used in already delivered products, demand is derived from service business. Demand could occur also as from some random needs that are generated for example due to manufacturing mistakes leading to a requirement for an emergency replacement items. Anyway, the model assumes that drop-down date for item is know in advance, which is not always the case. Hence, the model is not able to cover all the problems of slow moving inventory, but party utilization of the model could provide support in order to control situations that are foreseeable.

Pince and Dekker (2011, p. 94) points out that their model is based on several assumptions in order to simplify the analysis. Because of that the model cannot be adapted exactly as it is represented in Pince's and Dekker's study. In case any company would like to utilize the model, it is required that model is reviewed and amended so that it considers exactly and only parameters that are needed in case of that particular company. It also necessary to review the estimed values frequently in order to decrease the risk of overestimations, which according to Dolgui & Pashkevich (2008, p. 713) are one of the reasons for obsolete inventory. However, the model offers further understanding of the transient behaviour of inventory systems facing obsolescence (Pince & Dekker 2011, p. 94).

2.6 Slow moving inventory management

Slow moving inventory management aims to reduce level of inventory that is not selling. Reduction is partly done by activating currently existing obsolete and excess material. That is done in order to release capital tied up to inventory so that capital could be utilized in profitable manners. The preceding could be seen as a first aid for the slow moving inventory.

Like Pay (2010, p. 69) mentions, the most important question is not how to get rid of the inventory, but how to avoid it in the first place. Thus, the main target of slow moving inventory management is to prevent build-up of excess and obsolete material. Preventative actions are highly valuable because once slow moving inventory accumulates it will be difficult, or in some cases impossible, to consume the inventory due normal daily material requirements. In the following part disposition actions in order to reduce slow moving inventory are presented.

It is not always possible to know in front that some particular item is becoming obsolete. In these cases it necessary to recognize obsolete and excess inventory, and execute actions in order to get rid of that inventory. Actions presented in this chapter are especially beneficial in case the actions are executed before inventory becomes slow moving.

In order to prevent accumulation of obsolete items in stock, Watts (2012, p. 245) provides guidelines for disposition of old versions of parts. According to Watts each obsolete item should be dealt with separately on the engineering change proposal form. By adding every item separately on the form, and having a well-coordinated system to manage changes, the risk of excess inventory due engineering changes is minimized. Person responsible of proposing options for disposition actions should be the engineer responsible of the item (Watts 2012, p. 245). That is reasonable because he/she is likely to have the best knowledge and understanding about the best possible and available manners to utilize the item.

Watts (2012, p. 245) focuses on engineering changes and controlling for example phase in phase out process through engineering change forms. He mentions the most typical actions to dispose old version of parts. Actions are illustrated in figure 9. Actions could be adapted for all kind of excess and obsolete inventory regardless of the root cause for material being useless.

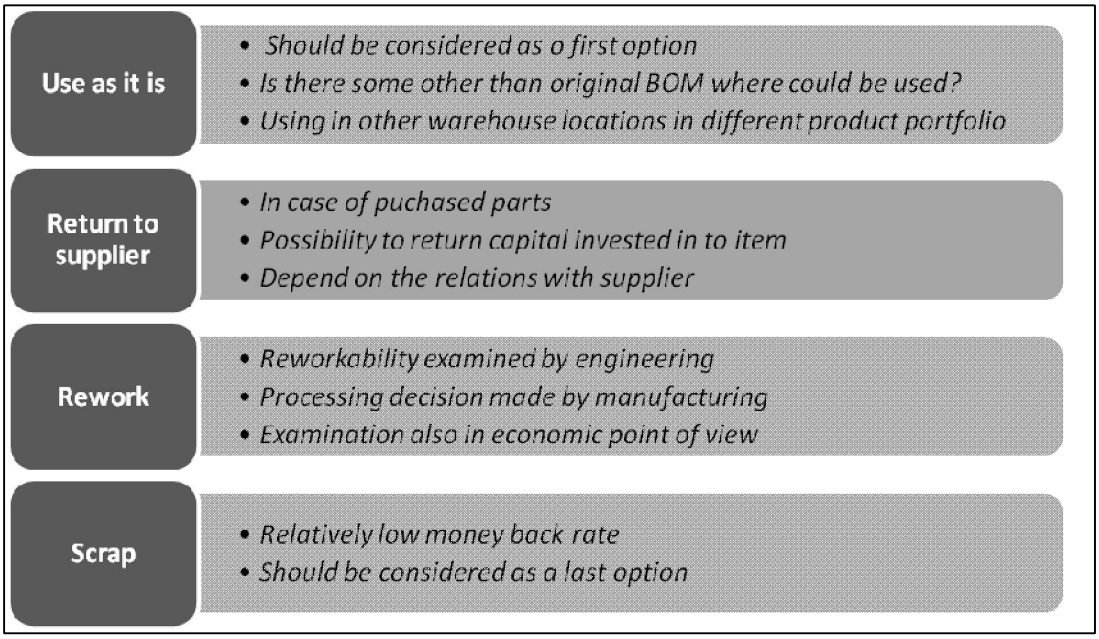

Figure 9. Disposition actions for obsolete and excess items (Watts 2012, p. 245).

The most economic way to activate obsolete item is sell it back to supplier or find a way to use it as it is. According to Watts (2012, p. 245), returning parts to supplier is rarely included as a disposition choice. Watts highlights the problem related to purchase parts. In case a purchased part is the reason for other part to become obsolete, it will create a owning problem. Who will be responsible to the take care of the phase out one? According to Watts general way of thinking in companies is that someone will take care of the obsolete items. Often the preceding means that, in practice, no one is taking the responsibility.

In case the item is obsolete due the fact that it was replaced by newer version, activation by using it as it is might be difficult or impossible. It that case, it is required to figure out if item could be processed so that it can be used. According to Watts (2012, p. 245) confirmation, whether or not item is reworkable and if it is, a proposal for reworking, should come from the engineer responsible of the item but the actual decision whether or not to rework, should be made by manufacturing department. That is because manufacturing has detailed information about the economics of rework. In some cases total costs of newer part is below the costs of processing the older one, thus use of older one would be unreasonable in the point of view of economics. In addition manufacturing might have some cases of urgency where obsolete item could be used once processed.

According report made by Cattani & Souza (2003, pp. 217) scrapping of obsolete and excess inventory can reduce company's profits by up to 1% of revenue each year. In CaseCompany has especially high pressure on margins at that very moment when it has problem with inventory actions like scrapping are not favourable at all. Thus scrapping should be considered as a last option for disposition of inventory. Unfortunately, according to Jaarsveld & Dekker (2011, p. 424), in most cases when demand is totally gone, scrapping is the only way to get rid of the stocks.

Scrapping, as the last disposition option, might be at the same the most difficult one the get executed. Eventhough scrapping would reasonably thingking be the only disposition option after all the other options are already considered it often has to be reasoned for the managers. According to Muller (2003, p. 32) decision makers might be against scrapping because the product has been paid for or they are state that there will be the day when that particular product will sell. Consequenlty it is often necessary to reason scrapping decisions for example with recaptured inventory space or reduced capital tied up to inventory.

2.7 Synthesis

In this chapter literature review of thesis was represented. Subject covered were related to slow moving inventory, product data and lifecycle management, change management and material management.

Literature review shows that PDM/PLM does have connection to slow moving inventory accumulation in case there are deficiencies in current processes. The importance of PDM/PLM especially in the beginning of product's lifecycle was highlighted. Importance is due to the fact that most remarkable lifelong decisions are made at the design phase. It was noted that main challenges in the field of PDM/PLM are related to information and data sharing. Problems occur due to various PDM/PLM systems and applications that are not compatible with each other. Interoperability challenges emerge between different companies as well as between different departments as an inter-company issue. Additionally, problems occur when PDM/PLM related data is dispersed into multiple systems and formats that make it difficult to manage the data as whole.
Due to the aforementioned issues PDM/PLM processes cause excess inventory for example as result of duplicate item creation at the new product development phase.

Change management in this thesis concentrates both engineering changes and customer order revisions. Literature review shows that collaborative way on working is the key factor for success in change management. It was found that the main issues of change management are related to information sharing which has direct impact to level of collaboration. Problems occurred for example due incompatible change management systems. The application -related problem was also brought out in PDM/PLM related issues. Additionally, for example lack of trust was mentioned as a problem for cross-company information sharing. In the end, in case changes are not handled in controlled manner, those were identified as sources for excess and obsolete inventory.

In the field of material management different material management modes were examined. Literature review shows that different material management modes have different impacts to inventories. Additionally, research was done for example in the field of material planning. Material planning model for items subject to obsolescence was examined. It was stated that properly timed policy changes in material plans are likely to reduce risk of excess and obsolete inventory. Conversely, policy changes are not done for example due information share-related issues, item subject to obsolescence are likely to become slow movers.

In the field slow moving inventory management research was focused on inventory disposition. It was brought out that at first it is required to find alternative use for items. As a second option, items are returned back to supplier, or failing that, converted to other items that could be used. As a last option items are scrapped. However, whatever is the disposition decision that will be better that keeping useless item in stock.

3 RESEARCH METHODOLOGY

3.1 Nature and strategy of the research

According to Saunders et al. (2007, pp. 135) focus in strategy selection should be in strategy's suitability for the research; it should be thought out whether or not the strategy will enable researcher to answer to particular research questions and meet the objectives. Farguhar (2012, pp. 31) also discusses about strategy's relationship to research question and objectives and describes strategy creation process as a search for a "fit" between what researcher wants to accomplish and how it is going to be accomplished. Thus, research questions formulated in chapter 1 are used in order to build strategy for this research. The research questions of this study tend to answer what is causing the problem of slow moving inventory as well as how and why the problem is caused. Strategy is derived from the questions and of how those are framed. Strategy is selected also in respect of resources available and already existing knowledge about the subject.

This thesis is implemented as a mix of action oriented research and a single case study because it aims to figure out backgrounds and facilitate a certain problem offered by a particular industrial company. Benefit of a case study is that it emphasises the real-world context where the phenomena occurs (Iacono et al. 2009, p. 40; Eisenhardt & Graebner 2007, p. 25). Case study approach in this thesis is used to figure out the backgrounds of the phenomena. Case study approach is also selected because fundamental solution to the problem of this thesis cannot be adapted directly from previous scientific researches. Action oriented approach as for, is commonly used to execute and promote the change (Saunders et al. 2007, pp. 141) and it is used in researches where collaboration between researcher and organization under examination is required (Worthington etl al. 2011, p. 220). Action oriented approach in this thesis is used in order to achieve capital targets set for inventory capitalization.

As this thesis aims to solve a problem of a particular industrial company it presents a typical study in the field of industrial engineering (Olkkonen 1994, pp. 23). The aim of thesis is to gain udertanding of research context and processes related to the subject. It is suggested that problems described in this thesis is approached through logical inference based on quantitative or qualitative analyses as well as founding a theoretical background for the solution (Olkkonen 1994, pp. 23). Consequently, in this research objectives are supposed to be achieved by using both qualitative and quantitative technique as well examining literature related to subject.

Int this research mixed-model research is utilized. That is because the problem under examination is multidimensional. Consequently, the information is dispersed into multiple sources resulting that various data collection and analysis techniques are required to use. Using mixed-model research in the abovementioned situation is reasonable, as it allows researcher to combine and mix different methods. For example, qualitative data can be analysed by using quantitative procedures, and conversely, quantitative data could be analysed by using qualitative procedures (Saunders et al. 2007, pp. 145-146). Once same result are obtained by using different data collection and analysis procedures level of triangulation of the results is increased (Saunders et al. 2007, pp. 139; Farguhar 2012, pp. 24).

3.2 Data collection

In this research multiple data sources has been utilized. The preceding is common for case studies (Farguhar 2012, pp. 65). As mentioned earlier, in this research observation was selected as a one of the methods in order to gather qualitative data. At the design phase of the study, the researcher considered collecting qualitative data by using interviews and observation. Finally, the researcher chose to use observations only. The main reason for the decision was researcher’s current role in the company. In addition to position as a researcher, the researcher worked for the company as a project owner. Consequently there was lot of communication with CaseCompany’s personnel. After a few meetings and discussionss, it was clear that observations are more natural way to gather information and thus arranging interviews was not considered anymore.

As it came out that observing was more natural way to gather information, observations qualitative data was collected all the way during of research process. Some of the discussions were more formal than others but what turned out to be beneficial, was that it was possible continue observing naturally among other daily tasks over 6 months period. That made possible figure it out for example if the personnel’s way of thinking changes over time. During the preceding period it did not.

The aim of observations was to gain knowledge about reasons for accumulation of slow moving inventory. Qualitative data was collected through discussions which might have occurred basically wherever. Examples of observing situations are daily discussion related to work, meetings, for example in CEP program’s biweekly meetings, phone calls, e-mail conversations and workshops. Normally, when discussing about slow moving accumulation, it was not necessary to steer the conversation in order to cover subjects like customer order revisions and engineering changes.

In addition to observing personnel, qualitative data was gathered from CaseCompany’s engineering change notices (ECNs). Notices are word documents, where change and items impacted are informed in qualitative form. There were two factors that affected to selection of ECN’s. At first, it was required that ECN was sent to factory in location F, not for example only to CaseCompany’s factory S. Secondly, it was required that ECN was created in 2012 or 2013. The aforementioned rules were set in order to see possible impacts in factory’s F slow moving inventory. In respect of these rules, the ENC’s were selected randomly. The data form ECN’s was collected by reading the document and transferring critical item related data into Microsoft Excel table. Purpose for the ECN related data collection was to gather data in order to analyse engineering change’s relation to slow moving inventory.

Simultaneously with collection of qualitative data, quantitative data was collected. Quantitative data is based on CaseCompany’s enterprise resource planning (ERP) system. Data is downloaded from CaseCompany’s data warehouse. For the purchase order (PO) cancellation purposes purchase order related data was downloaded daily. Inventory level related data as for was downloaded biweekly. PO related quantitative data was collected in order to find concrete examples of slow moving sources. Inventory related data was collected in order to make inventory review and design activation actions for slow moving items.

3.3 Data analysis

Qualitative data from the meetings and discussion was mainly collected as hand-written notes or by creating Microsoft Word -documents with computer during or right after the observation occurred. Documentation was always done during or right after the observation in order to ensure the quality of the documents. In most cases, especially in the end of the research process, the analysis of observation data started already at the documentation phase. It was for example compared whether data indicated new possible slow moving inventory root causes.

Once data collection for qualitative data was done, the notes were reviewed and main points, from slow moving inventory standpoint, were looked through. All the notable findings from qualitative data were then examined in more detail and categorization for the result was formed. Finally results were summarized in order see what, according to personnel of CaseCompany, is the main reason behind slow moving inventory problem.

As described earlier, essential data from inventory standpoint was transferred from engineering change notice -documents to MS Excel table. That was done in order to analyse multiple ECN and to convert qualitative data to quantitative. Items, that were affected so that those should not exist anymore where searched from inventory report. In case item was found from the inventory, it is a sign that there are deficiencies in the ECN process. The preceding kind of cases where marked and inventory value of impacted items was brought from inventory data to ECN analysis table. Finally it was possible to analyse quantitatively the impact of ECN’s in this sample group.

Quantitative inventory data is used in order to follow up the level of slow moving inventory, make inventory review and current state analysis. In the beginning of the study, content of the inventory was studied and grouping for example items that could potentially be activated was formed. In current state analysis inventory data was used in order to gain general view of the inventory content. Quantitative data related to purchase order collected as a daily basis was in the beginning of the research used in order to establish B7 -follow up, which is a follow up done in order to aling incoming material flow with real material requirements. Currently PO data is used as raw data for B7-follow up and order cancellation process.

As described earlier, data collected is mostly analysed corresponding to used collection technique. However, for example in the analysis of CaseCompany's ECN's, qualitative data is converted into quantitative data in order to analyse the data by using quantitative procedure. Current state analysis as for, is an example of case where both quantitative and qualitative data is used in order to generate information and gain knowledge of the subject. Consequently, this research is, in research choice point of view, a mixed model research (Saunders et al. 2007, pp. 145-146).

3.4 Internal benchmarking

As this thesis is strongly connected to CaseCompanys Capital Efficiency Program and as the researcher owns a project related to CEP it was required to participate to 5 workshops related to CEP. Workshops were arranged between July 2014 and January 2015. Two out of five workshops took place in CaseCompany's factory T located in location H.

A high level agenda for all the workshops was related to material planning, inventory reduction and inventory accumulation prevention. Main topics discussed were how to utilize Application A inventory database and implementation of Global Data Center (GDC) to factories in location F, location W and location E

As the topics covered in workshops had strong relation to the subject of this research, those provided good opportunity to gain understanding of the problem. Especially the first workshop arranged in July 2014 in factory T widened researcher's knowledge of CaseCompanys inventory problem.

During the workshops qualitative data was collected by using previously described methods. Data was looked through after the each workshop day and most important things were written into separate memo. Data collected from workshops is used for example in order to learn how to utilize Application A in inventory prevention. Data was also used in order to compare inventory activation methods' utilized in CaseCompany's other factories.

4 PRESENT STATE ANALYSIS

4.1 Present state of slow moving inventory

This present state analysis serves a need to have a proper general overview of the content of CaseCompanys slow moving inventory. Analysis is executed in the beginning of this study and it is based on inventory data downloaded from CaseCompany's Enterprise Resource Planning system. In addition, discussions with persons having inventory related knowledge are used to gather information related to backgrounds of slow moving inventory.

Present state analysis provides overall picture of those particular items in inventory that has inventory turnover rate near zero or zero. By having knowledge of the inventory content it is possible to define actions to activate items as well as to design processes to prevent emergence of new inactive items. Present state analysis is also used to build up requisite performance indicators to ease measuring and following up of impacts of executed inventory reduction actions.

4.2 Item management

Due to CaseCompany's strategy, it is distinctive for its final products that most of those are customized to a large extend according to various different customer specifications. In order to fulfil various customer specifications a large number of different type of sub-products and parts are used. This leads to great number of individual item codes that makes for example both production data coordination and engineering change management challenging.

Presently total count of item codes is increasing at the CaseCompany. Situation has been like this as long as company has existed. Increasing amount of item codes is due to practices of how different requirements for the item are supposed to be indicated. Item codes are based on character strings. The preceding strings consist mainly of numbers and letters. The length of the characters string is not standardized and thus various lengths and forms exist.

Basic item code is a string of characters without any particular or additional information. Once customer order includes special requirements for the final product, these requirements needs to derivate from the final product to sub-products. To ensure derivation of special requirement of final product to sub-products a tail-code -system is utilized. By adding a requirement specific tail-code to the end of the basic code, item with special requirements is created. Once there can be tens of different individual requirements, it means that there are thousands of different combinations of those. Consequently there are thousands of different tail-codes to add in the end of the basic codes, which leads to increasing amount of total items codes

In general, tail code -system is an effective and explicit way to indicate special requirements for the item. Anyway, the policy related to new tail codes in CaseCompany does not encourage taking the advantage of already existing items. Eventhough there would not be remarkable differences between already existing one and the one which is about to be created. It is easier just to create new tail code than use the old ones (O7; O12). This is because comparing the already existing tail codes and requirements indicated by those to the new requirement combination is more complicated that just building a new tail code to describe new requirement combination. In practice, this means that whenever there is a need for a new combination of special requirements, new tail code is created to indicate exactly, and only, that particular requirement. Item code policy like this is likely to increase total count of items considerably in a long run.

When total count of item codes is increasing continuously and new tail codes are created without first comparing them to existing ones it sets challenges for managing and coordination of items. Issues with product and item data are as for related to inventories. Once new item codes are created and old ones are still remaining valid and having stock it is likely that the older ones will never be used. This could be seen in CaseCompany for some of the items, which has stock for basic item as well as numerous different tail codes (O7). In many cases inventory turn for the standard item is at an acceptable level. Acceptable inventory turn might apply for some of the basics items tail coded versions as well.

Problem is that in some cases there are also numerous tail-coded versions in stock that has no demand at all. Those are remaining as useless parts over extended periods of time only tying up capital and reserving storage space. That is waste because of those rarely, or never, used tail coded versions might fulfil very similar kind of special requirements than what those with better inventory turn does. In fact, tail-coded items are normally surpassing the requirements of the basic ones (O7). Therefore, it is often possible to use slow moving tail-coded items as an alternative option for the basic item.

However, because of the specific tail -code items are never allocated to the orders, even though items would be fulfilling all the requirements. This is because of logic build in CaseCompany's ERP system. ERP system does not automatically compare required item to the similar ones existing in stock.

In case there is a demand for basic item and even though there would be tail-coded items in inventory, ERP system creates a new planned purchase so that new standard item is acquired. This happen even though the basic body of the item's code for the one to be purchased and for the one existing in stock would be the same. At the moment CaseCompany's ERP system is not able to recognize that alternative option exists in stock. Due to the preceding ERP-related problem many tail –coded item have ended up to slow moving inventory.

To fix the problem related to tail code items ERP system should check automatically if there exist some alternative options to be allocated for the demand. Currently, all the checking for alternative options needs to be done manually by the planner or buyers. However, that is not included into the buyers or planners daily responsibilities so checking for use of alternative items is not performed regularly.

4.3 Activity analysis

Currently various parameters are used in CaseCompany in order to categorize items. In point of view of this study an important one is ABC Class Contributional. The aforementioned parameter is one of the four ABC parameters used. ABC Class Contributional is used to indicate in which of the 6 lead time groups item belongs. Value A refers to item that do not belong to any fixed lead time groups. The preceding items often are generally used in customized products. The rest of the values vary from E to I indicating fixed lead time from 1 week up to 16 weeks. The lead time for the item level is derived from the end product. The reason for ABC Class Contributional's significance for this study is that it is used as a parameter in item activity analysis. Division of items to active and slow moving through inventory report is presented below in figure 10.

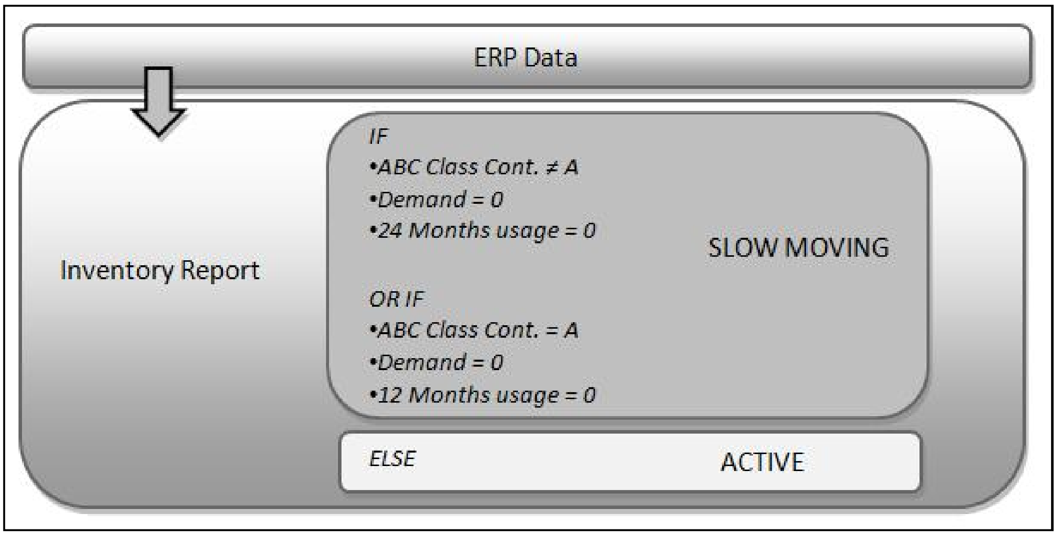

Figure 10. Item classification to active and non-active.

In CaseCompany main purpose of activity analysis is to divide inventory items into active and non-active category. Currently analysis is done as monthly basis in the beginning of every month. Analysis is based on consumption data collected from CaseCompany's ERP system and ABC Class Contribution -value. With the preceding ERP data Inventory report is created. On inventory -report items are classified as active or slow moving. Division to the preceding groups is based on item's frequency of use and item's value of ABC class contribution.

Figure 10 illustrates the division. All items that has A as a value for ABC Class Contribution and that do not have any activity in the past 12 months and do not have any existing demand shown in ERP system are considered as slow moving items. Also all items that have anything else than A as value for ABC Class Contribution and do not have activity in the past 24 months and do not have any existing demand in ERP system are considered as slow moving items as well. The rest of the inventory is considered as active.

4.4 Present slow moving inventory

In the beginning of this study count of different slow moving item ID's in the CaseCompany's inventory were X. Capital tied up into the slow moving items is worth of X Euros. At the same moment, total amount of different item ID's in the active inventory were X. These active items had monetary value worth over X million Euros. Accurate inventory values are presented below on table 3.

Table 3. Count of item numbers and monetary value of non-active and active inventory.

ACTIVITY STATUS OF INVENTORY ITEMS				
	ITEM NUMBERS		MONETARY VALUE	
	Count	% from Total	EUR	% from Total
SLOW MOVING	X	X %	X	X %
ACTIVE	X	X %	X	X %
TOTAL INV.	X	X %	X	X %

As shown in table 3 a percentage count of slow moving item ID's is larger than percentage monetary value. This indicates that the average monetary value tied up into a single slow moving stock keeping unit (SKU) non-active is lower than the average value tied up into a single active SKU. Average value for slow moving SKU is X euros whereas average value for active SKU's is X euros. Consequently, slow moving inventory includes relatively more low cost items than the active inventory. The reason for low-cost items ending up to slow moving inventory could be because of inventory control related aspects. The case could be for example that low-cost items are not controlled like high-cost ones because of their lower value. Low cost items could be for example under less supervising in phase-in phase-out situations.

As shown in table 3, currently slow moving items represent approximately X % share of total count of SKU’s in inventory. Table 3 shows as well that almost X % of overall capital tied up into the inventory is due to slow moving items. In order to understand how the value is fragmented in slow moving inventory it is necessary to make analysis, which compares the count SKU’s and the value tied up into those. Making difference between the high and the low costs SKU’s provides useful information in order to support for example decision making process for further actions. In order to gain for example result for CEP project, it is reasonable to start inventory capitalization with high-cost items. In order to gain knowledge about capitals dispersion between SKU’s in slow moving inventory a Pareto diagram can be utilized. Pareto diagram shown below on figure 11 illustrates the cumulative value of capital tied-up in slow moving inventory.

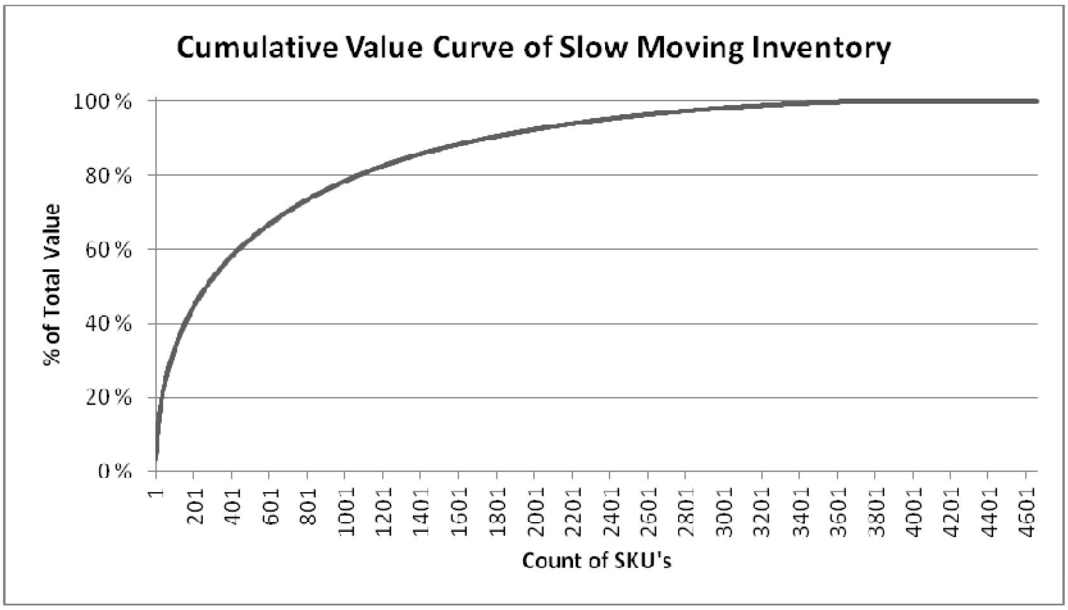

Figure 11. Cumulative value of slow moving inventory.

Like presented in figure 11 the capital tied up into the slow moving inventory is highly dispersed. In the beginning of the curve the angular coefficient is relatively high compared to the end of the curve where the slope is close to 0. The preceding indicates that most of the stock keeping units in slow moving inventory are tying-up relatively small amount of capital. Those might be single items or multiples but in any case, the quantity of a particular item is not important in the cost point of view.

The aforementioned is because total value of that particular stock keeping unit is always relatively low because of its extremely low unit price. In general, these low cost items are for example screws, bolts, and nuts in order mention couple examples. What the preceding items have in common is that those are not the core components in the end products. In order to have more detailed image of how capital tied up into slow moving inventory is dispersed items can separated into groups. Groups are illustrated in table 4.

Table 4. Classification of Slow Moving Inventory to A, B and C items according to monetary value.

<table>
<tr><th>GROUP</th><th>SECTION OF CUM. VALUE</th><th>COUNT OF ITEM NUMBERS</th><th>CLASS</th><th>COUNT OF ITEM NUMBERS</th><th>TOTAL VALUE (k€)</th></tr>
<tr><td>1</td><td>0 %-10 %</td><td>X</td><td>A (10 %)</td><td>X</td><td>X</td></tr>
<tr><td>2</td><td>10 %-20 %</td><td>X</td><td rowspan="2">B (20 %)</td><td rowspan="2">X</td><td rowspan="2">X</td></tr>
<tr><td>3</td><td>20 %-30 %</td><td>X</td></tr>
<tr><td>4</td><td>30 %-40 %</td><td>X</td><td rowspan="7">C (70 %)</td><td rowspan="7">X</td><td rowspan="7">X</td></tr>
<tr><td>5</td><td>40 %-50 %</td><td>X</td></tr>
<tr><td>6</td><td>50 %-60 %</td><td>X</td></tr>
<tr><td>7</td><td>60 %-70 %</td><td>X</td></tr>
<tr><td>8</td><td>70 %-80 %</td><td>X</td></tr>
<tr><td>9</td><td>80 %-90 %</td><td>X</td></tr>
<tr><td>10</td><td>90 %-100 %</td><td>X</td></tr>
</table>

As shown in table 4, each group represent 10 % share of overall value tied-up into slow moving inventory. By using this grouping stock keeping units can be classified into A, B and C class. Stock keeping units that are tying-up relatively great amount of capital, belong in A class. Like shown in table 4 only X stock keeping units belong in class A that has monetary value of X Euros. Class B as its part includes in total 70 stock keeping units that represent in total X Euros of s slow moving inventory. The rest of the items belong in C class that includes in total X items numbers tying-up X Euros of inventory.

In addition of table presented above, where monetary value of stock keeping unit is used to classify items, it is useful to analyze what kind of items has ended up into slow moving inventory. In order to do that, it is required that there exists information type that is commonly in use for all the items. It is also required that information is valuable so that results of the classification can be used when designing further actions for slow moving inventory. Item description is a type of information that most of the items have. That is also type of information that can be used when selecting group of parts that are taken under examination and activation survey. Categorization according to item description is shown in table 5 represented in appendix 4.

On table 5 it is represented 10 most remarkable item descriptions measured by monetary value. First group named as “BODY PARTS” includes all items that are either bodies or body halves. BODY PARTS -group is as its part divided into different types of body related parts like shown in table 6 represented in appendix 4. Results in table 6 show that body parts, on total of X stock keeping units worth of X Euros, represent X % of total value and X % of the stock keeping units of slow moving inventory. The rest of the groups are relatively small compared to body parts. However in total these 9 groups, consisting of item X, item Y, item Y parts, and raw materials represent in total X % of total value. Thus, this examination group of 10 most significant item descriptions cover in total X % of the of CaseCompany's slow moving inventory.

Further investigation of the BODY PARTS category shows that X % of the parts have A as a value for ABC Class Contribution. Thus, these items are used in products that are tailored according to individual customer orders. The reasons why this kind of items end up in slow moving inventory could be customer order cancellations or revisions, item was not ordered against demand but as a pilot order, or excess quantity of an item was ordered in order to cover for example quality issues. One reason for the preceding kind of excess and obsolete inventory is also new product ramp-ups. When phasing-in new item and phasing-out old ones, it is possible that some of the old items are left in stock.

At this point, when big picture inventory content has been formed, it is good to make more detailed analysis in order to support practical inventory review. In order to start reviewing inventory to support design process for activation actions further analysis of inventory items is needed. To support decision making process it is good to take at few information types included in CaseCompany's inventory report.

Essential parameter for the inventory analysis is acquisition code. The code indicates whether item purchased or manufactured. Manufactures items are marked as number 1 and purchased item with number 2. In case the inventory consists of items that are purchased, one solution in order to stop accumulation of inventory could be building up an order cancellation process which would be the end for excess material receipts. As a result of inventory analysis is noted that X % of SKU's are purchased items. Those represent X % of total inventory value.

Also item description could be used in order to analyse CaseCompanys Slow moving inventory. It is earlier described that items that special requirements are marked with tail codes. Tail-coded items could be used as standard and thus activation of those requires only allocating item to demand of standard part. When analysing the share of X tail-coded SKU's, the result is that those represent X % of SKU's and X % of total capital tied up into slow moving inventory. In addition, no weld -items was possible to use as standard. Those presented X % of SKU's and X % of overall inventory value.

In addition to information types to be looked at, it is necessary to examine item's warehouse location. That is because in case item is in external warehouse CaseCompany is paying for the warehousing of slow moving inventory. Keeping item in CaseCompany's own shelf is a cost of course as well. However cost of outsourced warehousing is notably higher. Thus, warehouse location could be used as prioritization parameter for example when deciding scrapping priority for items that are identified as useless. Analysis of warehouses location shows that X % of SKU's and X % of total slow moving inventory value is stored in outsourced warehouse.

On CaseCompany's inventory report, there is a link between the item and the buyer responsible of the item. In addition to above-mentioned, an analysis of how slow moving inventory is distributed among personnel need to made. Result show that three responsible persons out of 36 covered X % of slow moving inventory's SKU's that represents X % of overall slow moving inventory value. Consequently, is should be the most profitable to start inventory review with these three persons.

As a result of this inventory analysis, it is possible to name couple main subjects that should be covered in order design actions that in long term are likely to decrease the level of slow moving inventory. At first, because slow moving inventory includes mainly purchased items, it is reasonable to start designing actions in order to stop receipts of excess purchased material. It is relevant that purchase orders can be cancelled or modified on time if necessary. In general, the focus will be on change management, material management and product data management. In the field of change management, it is tried to find support to handle customer order changes and revision. In the field of change management, focus will be also on examining new product development and phase-in phase-out situations. In the field of product data management the focus will be on product data coordination and new product development process. In the field on material management, study related to material flows is required.

4.5 Present slow moving inventory management

In the beginning of this study, CaseCompany did not apply any continuing development actions related to slow moving inventory. There did not exist any documented or standardized processes or practices deal with excess and obsolete items that would have actually aimed to reduce inventory level in the long term. It could be said that as a daily basis there was no made any difference between active and slow moving inventory. No continuously running efforts for inventory clearance were made.

However problem related to slow moving inventory was obvious and it was recognized in CaseCompany. Something had already been done to get rid of the problem. There had been couple separate initiatives to reduce capital tied up in slow moving inventory. The main focus of those initiatives where to recognize useful items from slow moving inventory and active them. Items were analyzed with the person responsible of the item and after that items were divided into certain categories according to result of analysis (O7).

Non-active items, that were recognized to be useless or obsolete, were suggested to be scrapped or moved to the other CaseCompany's locations. In case item was likely to have demand at some other location, it was send away to be used there where the demand existed. Items that were recognized to be useless globally were recommended to be scrapped. Those items were put on the scrap list, which was later on approved. Items on approved scrap list were thereafter scrapped in predetermined time determined by finance department. Scrapping date was determined to control and allocate certain amounts of scrapped material to a certain period of time. Certain amount of material was disposed at certain quarter of the year. In order to scrap items, it is required in CaseCompany that the items have inventory provision. All the slow moving items have 50 % of the provision automatically. Figure 12 illustrates how the provision for items is accumulated to 100 %.

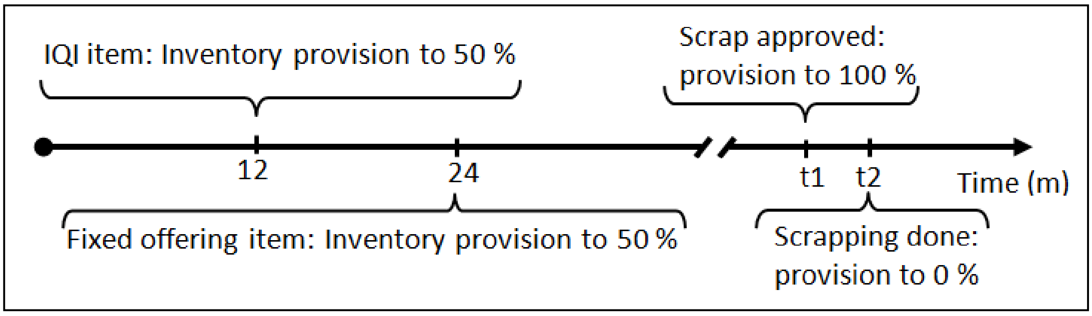

Figure 12. Slow moving inventory provisioning for scrapping.

In order to scrap items, finance approves scrapping and increases inventory reservation from 50% to 100 %. At the same time, the decision of actual scrapping time is made. Once it is time to scrap items, provision is decreased to 0% and the value of inventory is wrote off

Slow moving items that were identified as potentially usable were tried to utilize in numerous ways. Items were tried to activate by using them as alternative items for the ones that had demand. This is the solution for example when there is demand for standard item and there is tail-coded version available in the warehouse. Using storage item as alternative requires that inventory employee verifies that tail-coded version really exists at the stock and that it is in qualified condition. In addition it is necessary to find out special requirements behind the tail code and make sure that it is possible to replace basic item with tail coded one. After aforementioned confirmations tail-coded item can be allocated manually to the demand. By allocating slow moving item to existing demand it will change item’s status to active on inventory report.

In case non-active item were not tail-coded there was still possibility to use it. In some cases the reason, why non-active item ended to slow moving category in a first place, was that there was new version released from engineering or new item creation process had produced duplicate items. Due that, no demand allocated for the old item or in case of duplication, for the duplicate item. In this kind of situations it is possible to transfer on-hand balance from slow moving item to active items.

Using non-active item as blank for an upper level item has been one way to activate inventory as well. This has been the case when there exist some of the lower levels of the item at the warehouse remaining useless and there is demand for some of the levels of that particular item. Lower level items can be used as raw material for upper level items by allocating the lower level item manually to the demand in ERP system. Lower level items are remaining useless at the warehouse for example in case that some of the upper level items has their acquisition type defined as purchased instead manufacturing. Purchased parts are the lowest level of BOM for which ERP system allocates demand.

It is possible that there are also items in slow moving inventory that could be used without any further or additional processing. Those items are totally valid and are in slow moving category because of that particular product group those belong in has had a downturn in sales. CaseCompany's solution to deal with this kind of items was to put those on special stock sales list. The list contained final products as well as spare parts with exceptionally short delivery time. Try out of special sales list did not meet the expectations put on it and many valid items and products remained useless in the inventory. (O7)

4.6 Engineering change management

In CaseCompany, engineering changes are changes made in to active products, items, or for example assembly instructions. Engineering change process is divided in to three main parts. The process begins with engineering change request, which is followed by engineering change proposal. Third part is engineering change notice. (D1; O4) The process is illustrated below in figure 13.

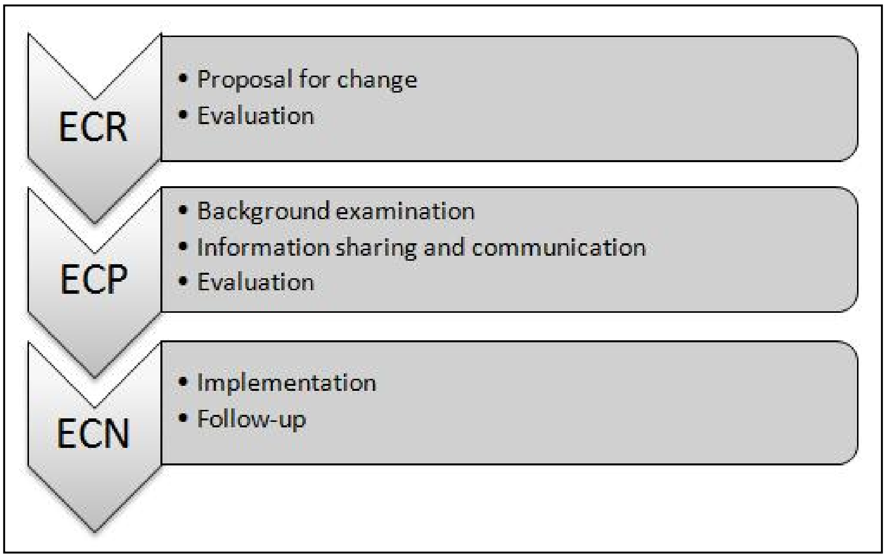

Figure 13. CaseCompany's engineering change process (D1; O4).

A request for engineering change can be made by anyone of CaseCompanys employees by fulfilling engineering change request -form in PDM -tool Aton. Fulfilled request form is sent to Engineering Change Manager, who will either approve or deny the request. Engineering Manager will for example figure out whether or not the requested change is necessary or if there has already been similar requests. In case denied, there will be discussion of the subject. (D1; O4)

In case the request is approved, next step is to create an engineering change plan. At this point it is decided whether or not the change will be implemented as a Fast Track -change. In Fast Track -changes the change is implemented immediately. Fact Track -changes are only allowed in case the production is stopped because of the reason for the change, or the change is about fixing an error. In addition Fast Track is allowed if change does not have impact to inventories, spare parts, product offering or performance of the products or processes. (D1; O4; O26)

In case Fast Track is not utilized, next step is to create detailed plan for a change and communicate and discuss through the plan with all the necessary departments. The plan includes information about parts or processes that are affected by the change as well as instructions of how to react to the change. Once engineering change plan is made, it needs be approved by product home. (D1; O4; O26) From inventory point of view, item affected by the change are interesting. Items affected are indicated in the form and further actions are advised depending on where item is in order delivery process. Coding to inform further actions could be seen in appendix 5 and appendix 6 where copies of engineering change documents are represented.

Once engineering change plan is approved by product home, next step is implementation of the change. Implementation begins by updating ECR to ECN in PDM -tool Aton and then notification about the change is send for all the departments necessary. ECN informs departments about what have been changed and how different departments are expected to react. Responsible of different departments receive ECN's into their e-mail. After that, is department-sensitive, how change is handled. After a department has reacted to the change, departments responsible person responds for change manager that actions required are done (D1; O26).

Above CaseCompany's engineering change process is described. Change management is complex process that requires collaboration between multiple people over different departments. It is important to verify that change plan is comprehensive and that information included is correct. From inventory point of view, engineering change processes plan creation -phase is especially important. In case the information or listing related for example of parts affected is incomplete, the change is likely to cause obsolete inventory. That is simply because persons responsible of implementation are not aware of all the items that should for example be scrapped. In addition it necessary to follow-up that all changes will be done according to plan.

4.7 Customer order revision process

CaseCompany's order revision process aims to handle all the changes that affect to customer orders. Revisions are controlled by revision management. Revision management takes responsibility of handling the changes related to customer order's internal supply chains in CaseCompany's ERP system and shares information for example between the factory and customer order handling. Next, the process for order revisions in described.

Customer order revision process starts when customer order management sends revision inquiry to revision management. Inquiry is sent in the first place in order to figure out whether or not the order can be cancelled and at what cost. Once change management receives the inquiry, a current supply chain of the customer order is stored from ERP system. The supply chain is stored in order to secure the information about the initial state and requirements of the order. Initial state information is used to figure out items that affected by the change. Once supply chain is stored and item affected are figured out, next step is to determine the cost and lead time impact of the revision. (O3)

In case the preceding cannot be determined by revision management, an inquiry to factory is sent. Once revision inquiry at the factory, purchasing communicates with suppliers in order to determine the costs and lead time impacts. Required actions to figure out the impacts are done also in manufacturing. Once the impacts are known, those are sent through revision management and customer order management all the way to the customer. In case customer is willing to keep the order untouched the process ends and customer order remains as it is. (O3)

In case customer decides to implement the change, basically the same process for information sharing is used. Order management informs revision management which as for informs purchasing which again informs suppliers and the other way round. In addition, the above described process of information flow, the actual changes are implemented and the internal supply chain in ERP system is configured by revision management. Newly revised supply chain of the customer order is seen in manufacturing and purchasing as a change in material requirements. As employees in manufacturing and purchasing were aware of the change to be implemented, they know how to react to changes. (O3)

Above order revision process in described. What is critical in the process from inventory standpoint, is storing initial supply chain of the customer order and information sharing between parties participating to the process. Initial state information is required in case the change and costs are approved by the customer and change will be implemented. At that phase, old and revised supply chains are compared in order to find parts that became excess due to the revision. Comparing revised order and initial order is essential from inventory standpoint because revision is likely to cause excess item that are no longer needed and those need to be figured out. Once those are figured out, another critical phase is to informing all the required people. In case there occurs interruptions in information sharing, the implementation of the change is likely to cause excess inventory.

5 SLOW MOVING INVENTORY REDUCTION

5.1 Actions for slow moving inventory

In this chapter actions in order to reduce slow moving inventory are described. As a result of present state analysis of CaseCompany's slow moving inventory presented in chapter 4, it is noted that there is potential to activate the inventory. Despite of the fact that notable part of the inventory consist of make-to-order or purchase-to-order items, it is recognized that many of those are tail coded or blanks. While doing inventory review with buyers, it is also recognized that many slow moving item could be added as alternative item into currently active BOM's. Thus, as a result of present state analysis and observations made during this research certain practices and processes were established in order to solve the inventory problem. In this Chapter, slow moving inventory reduction actions are presented as well as are the results gained during 6 months period from June 2014 to December 2014.

Activation of slow moving inventory was started by reviewing items in inventory with one buyer at the time. Review was done with the buyers because they have needed knowledge about the items and whether or not it could be possible to utilize them (O1). In some cases buyers were also able to explain why item has ended up in slow moving inventory. However, that was really rare and thus the main objective for reviewing items was to make decisions about future the actions.

5.1.1 Alternating and substituting

In this research alternative use of item means that item is utilized as it is, thus no additional modification is needed. Items that can be used as alternatives are in many cases some sort of duplicates. In practice, the preceding means that there is multiple item identification numbers which all refer to exactly similar parts. That alone would not cause inventory problem, as long as all of the item identification numbers are linked in to active BOM's. It is not even necessary that BOM's are the same, but those all need to be active.

However, one notable group that needs be brough out were no-weld items. For these item supplier is not allowed to make welding repairs. The welding restriction is actually the only thing that separated the now-weld item from standard item. However, when no-weld items were created it was decided that those will have their own item identification numbers, even though there were no structural difference with standard items. The preceding is an example if items that could be used as alternative items.

Another group of slow moving items that were identified to be used as alternatives are tail-coded items. As explained earlier in this thesis, tail-coding is used to indicate special requirements for standard items. Thus, the only difference between tail-coded and standard items is that tail-coded items have for example gone through more strict quality inspection.

In practice the activation of slow moving tail-coded items is done by following-up the demand of standard items. At the moment when demand for standard item emerges in CaseCompanys ERP system, the buyer responsible of the item is informed so that he or she will not buy the standard item proposed by the ERP system. Simultaneously planner responsible of the item is informed that he or she should allocate tail-coded item for the demand. Once planner has done the allocation and material requirements planning (MRP) run is made in ERP system, the purchase order planned (POP) for standard item will be gone and tail-coded item will be used.

At first the follow-up of the demand for standard items was made manually in Microsoft Excel by the researcher of this thesis. That caused a lot of additional work. Due to the preceding it was decided in one of biweekly CEP -meeting that follow-up needs to be automated. Consequently an automated report was designed and build-up. Automated report compares material requirements for standard items to the tail coded items in slow moving inventory. Currently the researcher needs to control the information flow for the buyers and planners as well as keep up the record for capital reduced from inventories.

5.1.2 Converting

During slow moving inventory review it was noticed that many of the items in inventory are blanks. This came out from present state analysis of slow moving inventory. The analysis is shown in appendix 4 in table 5. The analysis shows that slow moving inventory value for example for blank balls is X Euros. Thus, there was seen notable activation potential in blank items.

In order to identify convertible items those were sorted out by using Microsoft Excel. Common prefixes used in item description to indicate blank in CaseCompanys inventory report are for example “precmach”, “blank” and “cast”. Once sorted out, the consumption of the upper level item was reviewed. In case there was regular consumption or current demand for the upper level item, CaseCompany’s machining center was informed and advised to convert the blank to the upper level part.

According to observations made during this thesis, the main reason why blanks end up to slow moving inventory, is that the upper level part has been changed from manufactured item to purchased item. (O2; O7; O22; O28) As a result of that change, ERP system proposes to buy ready item instead of proposing to manufacture the ready item from the blank. The result is that demand is never allocated for the blanks that are in stock. The above-described is change management related issue and could be solved by controlling the change so that inventory of the blanks is used in a first and then the acquisition type for ready item is changed. The solution for this change management related issues is discussed in more detail later in activation practices and tools chapter.

5.1.3 Factory to factory material flow

As result of inventory examination it was found that part of the slow moving inventory at CaseCompany's factory in location F could be sold to other factories. This came out when studying inventory reports of CaseCompany's other locations. By comparing inventory turns it was possible to indicate items that were slow movers in factory F but that have relatively good inventory turn at other factories.

The preceding kind of inventory turn cross-checking between other factories was done as a monthly basis. Before offering items to other factories it was first ensure with product line, that items do not belong to fixed offering of factory F. Once it was clear, which items could be transferred, transfer was arranged with person responsible of the warehouse at the receiving factory.

5.1.4 Scrapping

In case any of the previously presented capitalization actions did not work, items were identified as scrap or it was decided to keep the items in inventory. Scrapping decisions were always evaluated at first with buyer responsible of the item. Items recommended for scrap were listed and list was sent to CaseCompany's Product Line, where additional examination was made. Product Line compared items to current product promising and either accepted or denied scrapping. In case scrapping was denied, and there was no additional instructions for proceeding suggested by Product Line, items remained in inventory.

Items that were approved to be scrapped by Product Line were prioritized for scrapping according to the warehouse location. Items that were stocked in external warehouse were identified as high priority scrap items. Consequently, those were to be scrapped in the first place. After setting scrap priority for the items, list of the scrap item was sent to finance department. Finance department's responsibility was to identify appropriate time for the scrapping. When it was time to execute the scrapping, finance department informed logistics. Logistics took responsibility of scrapping item in ERP system as well actually collecting items from the warehouse and sending them out.

5.1.5 Other actions

Previously the main action in order to capitalize slow moving inventory were presented. In addition of those, multiple other actions were done. Partly inventory was activated as a result of identifying BOM related issues. Those came out mostly during inventory review. In case a BOM related issues was noticed, engineering was informed about that. Common case was that item was in slow moving category because it did not have connections to active BOM. In the preceding kind of cases, engineering was asked to add ad item in BOM.

It came out during the review that slow moving inventory balance contains tools. Those should not be in operational inventory. Consequently, it was decided that always when tools are recognized, those are excluded from the inventory value in ERP system. Another action that could be brought out is correcting the value of the item. While doing the inventory review it came out that there is faults in the price's of items. This was relatively rare. However, errors were corrected when found.

5.1.6 Results of slow moving inventory capitalization

Previously inventory reduction actions were looked through. In this part, the result gained due executing the actions are presented. The results of slow moving inventory capitalization during six month period between July 2014 and December 2014 are shown below in figure 14.

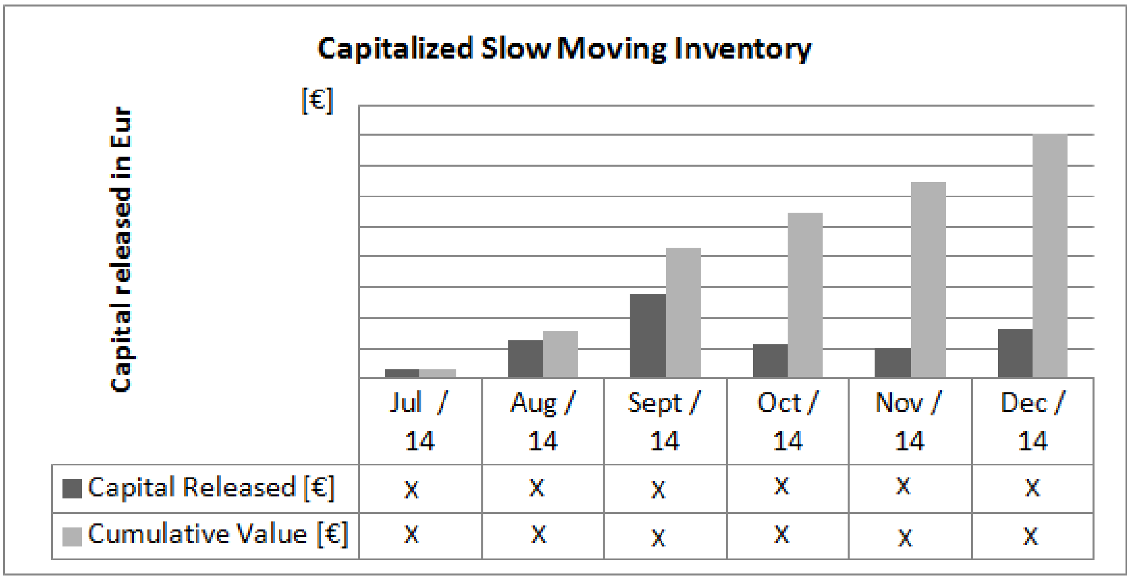

Figure 14. Results of slow moving inventory activation actions: capital released from slow moving inventory between July 2014 and December 2014.

As this thesis is strongly linked to CaseCompany's Capital Efficiency Program, some of the objectives of the thesis are derived from CEP targets. High level targets for CEP were set in CEP Inventories -kick of meeting in June 2014. As a target for CaseCompany's factory F it was decided to set target for slow moving inventory capitalization to X Euros. Capitalization in this matter refers to allocating demand to slow moving items. Consequently, as researcher of this thesis participated in CEP slow moving inventories as a project owner, it was decided that the preceding CEP target would also be one of the targets of this thesis. Thus, simultaneously with all the research made during this thesis, some of the actual activation actions were designed and started already at the very beginning of the research process.

Durign the above-mentioned six months period average of capitalization as a result of slow moving inventory activation is X euros per month. As shown in figure 14 capital released in July is X euros less than the average. That notable difference is due to fact that at that time most of the activation processes were just about to be established. During July and in the beginning of August, manners to activate inventory were still under examination, like were the inventory review and the current state analysis as well. However, by the end of August, there was X euros of inventory identified to be activated due inventory review and analysis. Simultaneoysly with the review and current state analysis activation methods described earlier in this chapter were developed.

Results shown in figure 14 illustrate the progress as results of August and September are notably better than the result of July. Compared to average activation per month, result of Septermber is significant. That is because one of the factors affecting to inventory review was the value of SKU in euros. Thus, the most valuable items were activated in the first place. Figure 14 shows that slow moving inventory capitalization target of X euros was achieved during October 2014. In total, during six months period capital released from slow moving inventory is X euros which is 161,6 % of the overall target.

Capitalized value of slow moving inventory was, due to CEP, the most important meter for this thesis. Before getting into total reduction of slow moving inventory balance between July and December, it is necessary to explain the difference between the value of inventory capitalization and the value total activation. As mentioned above, capitalization refers to inventory value that is allocated to customer orders, whereas total activation of slow moving inventory is a sum of capitalized inventory value and value of the inventory which status has been changed to active as a result of capitalization but which does not actually have demand. Lets say there is 10 pieces of item A in slow moving inventory, each worth of 1 000 euros resulting total of 10 000 euros of slow moving inventory. At that moment, when 1out of these 10 items is allocated to demand, inventory status for the rest 9 pieces will change to active as well. That is more a negative than a positive consequence of inventory capitalization beacuse the activated items that were not allocated to demand are only causing inaccuracy to real values of active and slow moving inventory. In addition, those ite are likely fall back to slow moving category after 12 months or 24 months depending on item type.

Now, as result of slow moving inventory capitalization total value of slow moving inventory activation during 6 months period was X euros. Total value for new slowing items emerged during the period was X euros. In addition, sum of scappred items and items that left from slow moving category, but that were not real slow movers, was X milloin euros. As a summary of the aforementioned, slow moving inventory balance decreased from X million euros to X million euros.

5.2 Changes in material requirements

Purchasing related operations have their own influence on inventory levels and material flows. Therefore, purchasing processes should be examined when studying backgrounds of slow moving inventory. At the beginning of this study, it was already found in CaseCompany that some of the POs that were released against demand derived from customized products lost the demand during supplier's delivery process (O1; O24). In the preceding kind of cases purchased item, which is engineered according to specific requirements, is likely to end up in inventory as a useless part, unless the PO is cancelled. By the time, that particular purchase to order (PTO) item will become obsolete because it does not have connections to active BOMs with continuing or even occasional demand. PTO items in inventory are problematic, because thos are engineered according to specific customer requirements.

One way to prevent accumulation of unnecessary inventory is to improve correctness of the purchase orders. Correctness of PO in this matter means that purchase price, supplier, quantity, delivery terms, delivery time and delivery address are as required and that PO is made in accordance of the rules agreed between the parties involved. In the point of view of slow moving inventory build-up prevention the quantities are the ones that count. In this matter, it is the most important that purchased quantity of a particular item is in align with the real demand of the item. To ensure correctness of released POs requires observing and monitoring possible emerging changes in demand as well as immediate actions in case of a demand changes in order to modify the order so that it corresponds with required quantity.

5.2.1 The need for purchase order cancellations

Customer order changes, that have direct influence into needed parts and quantities of those, are supposed to be covered by customer order revision -process. Currently revision process is managed by customer order revision -team. The team manages the change and informs purchasing department in case there exist purchase orders that needs to be cancelled or modified. Buyers should be informed about the changes, however it was discovered that the current process between revision team and purchasing department may not be effective enough to cover all the emerging changes (O1). Once in a while it is noticed that customized items are received at the warehouse with no customer demand. Some of those PO's are left unnecessary because of customer order revision related faults and difficulties.

However, whatever is the root cause behind PO with no demand, in a first place it is the most important that the PO can be cancelled in order to prevent accumulation of excess material. Consequently cancelling process for unnecessary PO's, especially in case of PTO items, is supported by CaseCompanys CEP -program.

In order to cope with the preceding problem with unnecessary items it is possible to utilize CaseCompany's ERP system. There is a feature in the system that indicates items that excess according to material plan. Once item becomes excess, ERP system creates a note for the PO. The note is marked in the system as "B7". B7 is one of the PO related activity messages in CaseCompany's ERP system and is shown for example on MRP -window and on the PO -report, that provides detailed information for example of all the open PO's. B7 -activity message was not utilized before this study, however, it usefull for order cancellation process because it indicats purchased items that might not be needed.

In order to develop accuracy of PO's and to block accumulation of unnecessary items possibilities to utilize B7 -message was studied. Data for B7 messages are found from CaseCompanys Purchase Order -report. Report can be downloaded from CaseCompany's reporting system by anyone. Thus, the data is easily accessible and B7 activity messages can be sorted out from the report by using Microsoft Excel. Once it was confirmed that data to support order cancellation process was adequate, it was time to design the follow-up process in order to cancel PTO item that has has no demand.

5.2.2 Purchase order cancellation -process

Currently the roles and responsibilities in the process are material review and disposition (MRD) analyst, who is responsible of managing the process, buyer responsible of PO, system specialist and customer order revision -team. The process is started by MRD Analyst, who gives a first view for the purchased item that according to MRP is no longer needed. At first item's type is reviewed. In general, it could be said that only PTO items needs to be taken under more detailed review. Generally items that belong in some of rest of the types, for example to vendor managed or to safety stocked, has normally steady and frequent consumption, but at least random consumption. Depending on a frequency of the consumption, in many cases it is acceptable to let the PO remain as it is.

Once item's type is checked and if it happens to be purchase to order item, it is taken into next step of the process. Item is examined in the consumption point of view by reviewing its historical use. In case the consumption history indicates that item is likely to be used, despite of the fact that at the moment item is excess, PO can remain as it is.

Anyway, and what is characteristic for the PTO items, consumption in the past has been extremely low or there has not been consumption at all. In this kind of cases backgrounds for losing the demand needs to be figured out. In case the actual root cause cannot be identified, it is crucial to know backgrounds for losing the demand even at some level. That is because the better the backgrounds are figured up, the more reliably the decisions about whether or not to cancel the order can be done.

Currently analysis for root cause and background of recently emerged B7 -message is started by figuring out which order's have been requiring that particular item. Most of the order can be seen from CaseCompany's Whatchdog -application. The application monitors statuses of items that are allocated for configured customer orders. Basically the application seeks for customer orders and collects items from each order for status monitoring. By checking items connection history to customer orders from Whatchdog, it is possible to have a listing of customer orders and their statuses. From purchase order cancellation point of view, the problem with listing available in Whatchdog is that the listing has no connection to purchase order numbers. That is a problem because when figuring out the root cause for redundant PO, it necessary to know what caused the proposal for PO. In the other words, it is necessary to find out the customer order that required purchased materials in the firts place.

The preceding means that purchased item's link to demand needs to be found somehow. Information in Whatchdog does not offer that link so it needs to be figured out from some other sources. In some cases, the connection between the excess item and the demand which is gone is possible to find by examining conversations stored in CaseCompany's Electronic Order Handling -application and Bernie -application. Both are basically used in information exchange and conversation. From the aforementioned applications it is possible to search backgrounds for customer order cancellation or other reasons for losing the demand. Search from applications is basically done by using either customer order number or by CaseCompany's internal purchase order -number. Previuoysly described process in order to find information is time consuming and inefficient way to handle the problem. Anyway, this is the only way currently.

Once figuring out the backgrounds for excess item, customer order revision -team and system support specialist are involved if necessary. Those parties are able to provide additional information and support for root cause -analysis of B7 -message. Revision team is responsible of accuracy of revised supply chain data and BOMs in ERP system in case of customer order changes. Correctness and timeliness of the preceding data is crucial in order to have valid material requirements. Because the revision team has the best knowledge of the recent changes in customer orders, they are able find out effectively, if B7 -message exist due to some of the recently revised customer orders and whether or not there is changes in required parts or the quantities of those.

System support specialist as for, supports in ERP related matters. In some cases, B7 -message is due for example supply chain related error, caused by ERP system. Though, in this kind of cases the actual root cause is relatively challenging and time consuming to find out. In ERP related problems short term focus is more on the question whether or not the part is really needed, than on the root cause analysis. That is due the fact that IT based problems require sometimes relatively remarkable amount of time and effort to get solved, whereas actions for the PO needs to be decided as soon as possible.

Once backgrounds for the B7 -activity message are know at acceptable level, it is time to decide what to do with purchased item. Item and its relations to BOM's are studied in order to figure if the item could be utilized for example in some other end -product than where it was originally supposed to be used. That would be the case for example when purchased item is tail-coded special item. In most cases tail -coded parts could be used as alternative parts in the end -products that are normally using non-tail -coded standard items. In the preceding kind of case it is not necessary to execute any actions for PO.

In case item is excess and if there is no way to utilize it as alternative part, PO needs be modified so that item could be allocated for some other demand or PO needs to be cancelled. At this phase MRD Analyst informs buyer responsible of the PO about the situation. The buyer is asked to figure out whether or not cancelling the PO is possible and at what cost. Once buyer has the preceding information he or she cancels the PO and forwards information about cancellation costs to MRD Analyst. In case the item can not be cancelled, it is received like any item, but after that, it is proposed to be scrapped and it will be put on a scrap list. By putting excess PTO items immediately to the scrap list is one of the actions to prevent build-up of slow moving inventory. The B7 -process is described in more detailed as a process flow chart shown in figure 15 on appendix 7.

Due to examination of CaseCompany's purchasing related processes, practices to cancel purchase orders were established. In addition, a process to analyze the backgrounds of B7 messages was developed. Analysis of a particular B7 -message aims to explain a root cause for the existence of the message. The reason for the existence of the message is important to know because that information is used for reasoning the actions related to the PO. Depending on what kind of item type PO includes and the backgrounds of the B7 -message, for example a decision, whether or not the PO should be cancelled, needs to be made. The process should be ran as part of daily purchasing practices in order to minimize amount of capital tied up into excess inventory.

In case the B7 -process would be ran by buyers, additional workload needs to be considered buyer by buyer. Depending on the different item types buyers are responsible of, there would be a remarkable difference between the workload added on normal daily buying practices between buyers. Person responsible of purchase-to-order items would have a lot more work to dealt with due B7 -messages than for example person responsible of safety stocked ones. That is because B7 –message is more likely to lead into time-consuming root-cause analysis in case of a PTO item than a safety stocked one. It does not harm a company to receive a few extra pieces of safety-stocked part with stable and continuing demand, like it harms to receive a customized and relatively expensive item without any expectable demand in the future.

5.2.3 Results of purchase order cancellation process

Like it is mentioned earlier, the most important objective of the B7 -follow-up is to prevent receiving and accumulation of excess raw material and parts. In order to measure the impacts of B7 -process as a monthly basis track about PO related costs was tallied. Once cancellation cost is reduced from confirmed purchase price it gives the monetary simplified savings realized due the process. Savings are called as simplified in this matter, because the other costs, for example the ones due inspection of receiving material, material handling or warehousing, are not taken into account. However, the aforementioned costs would naturally realize in case the cancellation is not made, and thus cause greater harmful capital impact than what would be expected only by considering the purchase price.

PO related cost information was gathered between July 2014 and December 2014. Information gathered included confirmed purchase price of the purchased part, cancellation cost if one occurred, and difference between confirmed purchase price and cancellation cost. Monthly results were also used a as part of that CEP -programs monthly factory report which was focused to report reduction of capital tied up into inventory. During the research, and CEP project, monthly results of the follow-up were always represented in biweekly CEP meetings. Summarized result of B7 follow-up between July 2014 and December 2014 are presented in table 7.

Table 7. Results of B7-follow-up between July 2014 - December 2014.

MONTH	SUM OF CANCELLED PO VALUE [€]	SUM OF CANCELLATION COSTS [€]	SUM OF DIRECT SAVINGS [€]
Jul	X	X	X
Aug	X	X	X
Sept	X	X	X
Oct	X	X	X
Nov	X	X	X
Dec	X	X	X
TOTAL	X	X	X

As shown in table 7 cancelled value of cancelled PO's during the 6 month period is X Euros. Without the B7 -follow-up, that capital would have been tied up to inventory. When counting in total of X Euros of cancellation costs total savings due purchase order cancellations is X Euros. That is the capital which CaseCompany could now invest in something profitable. During the follow-up period total of cancellation costs represent X % of total cancelled PO value. As the costs cut the savings it is required to cancel orders as soon as possible.

Thus, one further development point in B7-follow-up could be to speed up the process. During the follow-up period it took 1 to 3 days in order to figure out whether or not the order should be cancelled. However, the potential of this development is not remarkable because time needed for B7-process is relatively short compared to delivery times of engineer to order items. Instead the focus in the future is further development of root cause analysis related to B7 -messages. That is because the analysis is a core part the process and currently it requires a lot manual work and is partly based on qualitative research. Additionally in many cases the original customer order which created the demand in a first place, cannot be identified and that is a notable deficiency. The preceding is due to fact that it is not possible to see historical material requirement. It was already mentioned in the beginning of the research, that in case there is no proper MRP -history data, it will be really difficult to examine root causes for slow unnecessary PO's (O3).

5.3 Backgrounds of slow moving inventory

In previous chapter monetary result of B7 follow up are presented. In order to gain further knowledge about the backgrounds of slow moving inventory root cause analysis for slow for excess and obsolete inventory was made. During data collection and examination period from July 2014 to December 2015 in total 82 root-causes where identified. Cases examined are found mostly as a result of B7 follow-up. In addition some example cases came up through other sources like e-mail conversations related to slow moving inventory. Table 8 shown below illustrates the categorization for the sources of slow moving inventory.

Table 8. Slow moving inventory root causes indicated by case examples.

ISSUE SOURCE	COUNT OF ISSUES	PROPORTION
BOM	x	x %
ERP -related	x	x %
Purchasing	x	x %
Claiming	x	x %
Material planning	x	x %
Product data issue	x	x %
New item creation	x	x %
Customer Order Handling	x	x %
TOTAL	x	x %

As shown in table 8 customer order handling is the most remarkable source for accumulation of slow moving inventory. The category includes both revisions of order and order cancellations. Also BOM related issues are strongly linked to inventory problems. Next some example cases from the categories shown in table 8 are looked through in more detail.

5.3.1 Customer order handling

In the field of customer order handling, notable from inventory standpoint is that current revision process is not able to cover all the items affected by the revisions. For example, not all the connector parts are covered in the current revision process. In order to fix that problem actions are in progress and that should not be a remarkable factor in the future (03).

Another example case found for excess material accumulation was that both revision manufacturing order planned (MOP) and the original MOP generated material reservations. As a result, parts for that particular order are required twice. It was figured out, that the preceding situation can occur for example if manufacturing order for the end-product, Top-Work, is released in ERP system while manufacturing ordes for sub-products, for example subproducts, are stil in planned status as MOP and in revision. In the other words, ERP system creates material reservations for the MOP which is in revision, and in case the Top-Work gets released while revision is still in progress, then for the Top-Work as well. As result of this finding CaseCompany's revision process was fixed so that the aforementioned situation should not happen again.

Analysis of case examples indicates also that one of the problems is information sharing between purchasing department and revision team. The preceding came up also in the results of qualitative observation data analysis presented in chapter 5.6. However, according to results of qualitative analysis, a common problem was that once purchasing or manufacturing has responded to revision team's request about revision costs, revision team never got back to the subject. In the other words, revision team did not inform purchasing or manufacturing whether or not the customer has accepted the revision costs and if change would be implemented.

However, concrete example shows that there are deficiencies at the puchasing side as well. In one case, buyer was informed about the duplicate purchase by researcher as well as by the revision team. After 17 days and multiple reminders duplicate items were cancelled. Lesson to be learned about this example, is that in addition of informing responsible persons about actions required, it is also necessary to monitor that actions are actually done.

5.3.2 Issues related to the bill of materials

Another notable category is BOM -related issues, where BOM is simply built wrong. In one example, there were two parts in products's BOM instead of one, which leads into duplicate purchasing of the parts. Another example revealed that there were phased out items in subproducts's BOM. That was a result of error, which occurred when transferring changes from PDM sytem Aton to ERP system. That error results purchasing phased out items that may not be usable.

Accumulation of inventory is also caused by items that are not linked to active BOM's. Consequently, consumption of these items do not appear in ERP system and items become slow movers. Some of the preceding kind of items have already been changed to RFID controlled instead of purchasing those manually. Managing items by RFID reduces stock out risk but does not help with consumpion data problem. Consequently, at this point some of the items are also changed to zero cost items, and thus value of inventory decreases. In case zeroing the cost is not done inventory value will increase every time when a new batch of items is received.

Special situations have increased likeliness to cause issues. That was also the case in an ecxample of special delivery. A deal was that CaseCompany's supplier would deliver a part directly to CaseCompany's customer. In the other words, the part never appeared physically into the CaseCompany's warehouse. However, it was needed mark the part as received in CaseCompanys ERP system in order to mark the final product as completed and delivered so that ERP system would allow invoicing the customer. That led into an error in inventory balance: the item was received in ERP system, but it was never marked as collected from the shelf and used in the ERP system. As a result the part remained in the inventory balance until its physical existence in the warehouse was questioned due the to inventory data review with buyer responsible.

5.3.3 Product data changes and issues

Product data issues are most often engineering faults or uncontrolled changes in product data. From inventory point of view, faults are critical in case those are noticed after the purchasing or manufacturing of items has been started. There is multiple examples were new item is created, and purchased, after that items atributes are changed in a way that new item ID is required. Buyer or planner may be notified or the information is received too late and thus both new old and revised item is purchased.

Also new item creation has impact to slow moving inventory. During the research an example of duplicate item creation was captured. The reason for duplication was simply that engineer at CaseCompany's factory in location E could not find similar item what he/she was about to create from the PDM-sytem. Sourcing was already been started and the model for casting was made with supplier before the duplicate was captured. Total capital impact was X Euros.

5.3.4 Enterprise resource planning -related issues

ERP -related issues include user errors related to ERP's use as well as situations in which ERP system is bypassed. Always when system is bypassed, it is likely to cause unnecessary questioning and wondering because system is not synchronized with events of the real life. The preceding kind of example occurred when there was an engineering mistake which lead into revision of items that were already purchased. Because of the rush, standard new item creation and purchasing processes in the ERP system were bypassed. Purchase order proposal for the newly designed item was hand-written on paper and left on buyer's desk. Buyer ordered new items and also the ones that were ordered in the first place were received. The root in this case was engineering error. However, the way how newly designed item was ordered caused unnecessary questioning and investigations.

5.3.5 Other sources

Analysis of examples show, that one source for slow moving inventory accumulation is material planning changes. Some of the regularly used items are safety stocked. In case consumption of item decreases safety stock should be removed. During the data collection of this research, there were cases in which item was purchased to safety stock before the safety stock was removed. At that very moment when decision to remove safety stock was made, there was no need for items purchased anymore. Consequently, items purchased were considered as excess and potential slow movers.

In order to find new suppliers there needs to be trials in order to evaluate potential candidates. Sourcing makes pilot orders in order to figure the quality and performance of the supplier. Some of the pilot items are never used and thus they remain in shelf tying up capital. In addition, if pilot -item is aproved in quality inspection it will come up as a new item to inventory balance. In case there is another similar item coming from another supplier, that item is no longer needed because pilot item could be used for customer order. Consequently, sourcing could be named as one of the sources of slow moving inventory.

5.3.6 Results of engineering change analysis

In addition to analysing individual cases, slow moving inventory backgrounds were examined by analysing the relation of engineering change process and inventory accumulation. In order to analyse CaseCompanys engineering change process 35 randomly selected ECN -documents were taken out of CaseCompanys ECN data base. It was decided to examine ECN's that were created during 2012 and 2013. The preceding span was selected so that possible inventory causing faults of ECN's could be seen in slow moving inventory. ECN's were red through in order to identify items that were likely to be left as obsolete or excess as a result of engineering change. After identifying items, it was checked whether or not the affected items were still in CaseCompanys inventory. Engineering changes that caused slow moving inventory problem are shown in table 10 in appendix 10.

As result of ECN analysis, X ECN's out 35 was identified as sources of slow moving inventory. Total value of these slow moving items was X Euros. Consequently it can be estimated that approximately X % of ECN's cause inventory problems. In table 10 Disposition -column indicates researcher's interpretation of the qualitative information that ECN contains. Consequently in three cases the inventory should have been scrapped immediately. In four cases there would have been possibility to use items affected by engineering change as alternative items. However none of these actions where never done and thus items ended up into slow moving inventory.

5.3.7 Slow moving inventory sources according to personnel

During this research multiple observations in order to figure out backgrounds for slow moving inventory. Data for the observations was collected during workshops, meetings and daily conversations with employees of CaseCompany. Once an observation related to slow moving inventory accumulation was made, it was written down immediately, or right afterwards the situation observation occurred, in the hand-written memo or in to a Word -document. Observation data collected is qualitative form. Thus, in order to analysis the data it was necessary to convert the data into quantitative form. Conversion was done by reading the memos and highlighting the reason's mentioned for slow moving inventory accumulation. After that a categorization for the reasons was designed. Table 9 shown in appendix 9 illustrates the results of observations.

As shown in table 9, it is possible to identify 5 primary areas where the sources of slow moving inventory accumulation are. In the field of purchasing, source is related to purchase of excess material. However, the difference compared to other categories is that the actions are under control. That is done consciously in order to cover quality issues of suppliers in case of critical projects.

Change management related issues came up in all observations. It was always mentioned that there is issues in customer order revisions. Like mentioned in chapter 4.8 one of the core factors in revision process in communication and information sharing related to implementations of changes. According to observations, there exist defects in information sharing. In was stated that for example a final decision about items affected by the revision and instructions of how to proceed with the affected items was not always delivered for the buyers and planners (O21; O8; O25). Consequently there is uncertainty related to material requirements which reflects as excess acquisitions.

Another sub-category in the area of change management is engineering changes. As a result of observations it is noticed that for example phasing in and phasing out new products and items is likely to cause slow moving inventory. Again it was mentioned that especially information sharing is the problem (O18; O20).

Product data management related issues are related to existing BOM's and creation of new items. It came out that there are items that are used regularly but those are not linked into BOM's. Consequently the consumption does not appear in CaseCompany's ERP system and item becomes a slow mover.

Another PDM related issue is due new item creation process. Consequently, there are duplicate items which lead into difficulties in item and BOM relation management. Figure 17 illustrates the problem. Items XX and XY have fully congruent attributes with each other, conversely product A and B are different products. Items XX and XY are created as a result of creating parts for product A and B. In ideal world item XY would not exist because congruent attributes with item XX would have been recognized and thus item XX would have been linked to both BOM's of product A and B. However in, congruent within attributes is not always recognized and duplicate item XY is created and linked in to BOM of product B. Let's say that demand of product B decreases or it gets for example phased out resulting that item XY remain useless. That is the initial situation in Figure 17. Current situation show in figure 17 as its part, illustrates the new linkage to BOM of product A as a result of item activation.

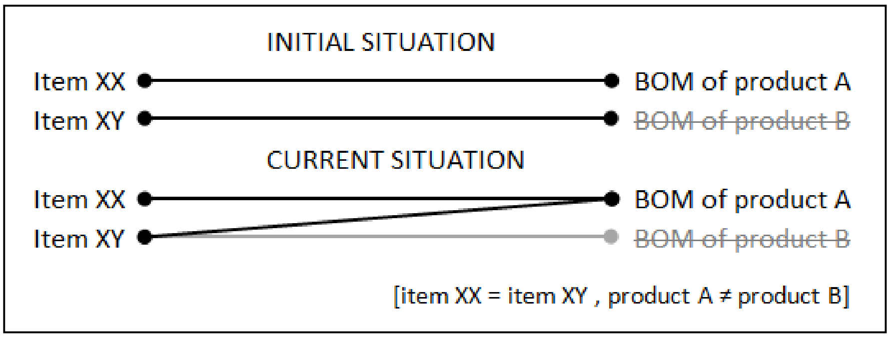

Figure 17. Changes of item XY's connections as a result items activation.

The initial situation in figure 17 is an example of product data related issue which has developed as a result of new item creation process. As a result of observations it came out that current product data management system makes it difficult to compare attributes of the parts (O16; O18; O24). Consequently, when there is a need for a part, it is easier to create new item than what it is to find exactly a similar one from the product data management system. In the long run that that increases the amount of item numbers which as for makes it more difficult to manage items.

As a result of observations it is noted that inventory management is one source of slow moving inventory as well. It was mentioned that every once in a while items are not used, but those are lost. In these cases it is necessary to buy one items to replace the ones that cannot be located. Afterwards, once the items lost are found, for example as a result of stocktaking, those are excess.

Also use of CaseCompany's ERP system was mentioned as one of the possible sources. It was mentioned that there has been problems in supply chains of customer orders. It was stated that for some reason supply chains just disappeared from the ERP system. The preceding is likely to cause distortion in the material requirements which again is likely to cause inventory problems.

As shown in table 9, analysis of observation data indicates that the major source behind CaseCompany's slow moving inventory is customer order revisions. It was mentioned above that according to observations main problems are in information sharing. Consequently, the revision process needs to be examined in more detail. In order support the results of observation's data analysis it is necessary to collect and analyse quantitative data as well. Data to be collected is related to purchase order that have lost the demand after those were created. Data is collected from the preceding area because that has direct relation to customer order revisions and order cancellations.

5.3.8 Summary

Previously some of the root causes for slow moving inventory accumulation have been presented. Root cause analysis based on case examples indicates that background for slow moving inventory is highly intricated. The results show that there is various smaller sources that do sum up in a long run and cause notable capital impacts. However, two sources were above the others. By the virtue of results, there are improving potential in customer order handling and product data management. Thus further actions in CaseCompany should be aimed into these areas.

What many examples discussed above have in common is issues related to information. Either information was not delivered or the receiving party did not react to information on time or at all. Consequently, it could be beneficial to make further examination for example of information flows between purchasing department and revision team. Information flows of engineering changes should be studied as well.

Examples looked through reveal also that in most cases there is human factor involved. The preceding is not surprising and as long as human is part of the process, there will be human related errors as well. Mistakes are, and will always be done. The question is, how capture mistakes before those turn into losses. As there is multiple sources for slow moving inventory and is has been recognized that most slow moving items are purchased parts prevention of inventory accumulation could be started by developing effective order cancellation process.

5.4 Factory to factory material flow

Currently at the global level CaseCompany is using distributed concept of purchasing. Every factory is responsible of its own operational procurement. Using distributed concept, at some degree, for procurement is reasonable due the fact that product portfolios for the factories are differentiated. Consequently, material requirements are mainly factory specific. However, items that have consumption at several locations exist as well. There is also material and items that used to have consumption at one factory but at some point, consumption decreased and finally ceased. In some cases consumption just moved to another location, due factories product portfolio adjustments (#O7; O18). However, items that were at the original location, where there was no consumption anymore, never got shipped to the other factory where the consumption was. Due to the multiple aforementioned-like cases, CaseCompany has increased the level of slow moving inventory year by year.

The preceding is partly because of distributed procurement, and the rules designed to support buyer's daily purchasing practices on each factory. Buyers are responsible of that right quantity of the required material is at the factory at the right time. Sourcing as its part, takes responsibility of the decisions where the items should be purchased. Sourcing does not have strong involvement on daily operational buying. Thus, it would be preferable that buyer's were able to take responsibility of material flow between CaseCompany's own factories.

In order to boost factory to factory material flow, appropriate methods and systems needs to be established. It is crucial that system used to view material requirements and create purchase orders support buyers work related to material transactions between factories. Currently, and by default, purchase orders are released to predefined supplier in the ERP system, according to demand and without checking that particular material's availability at the other factories of CaseCompany. The availability checking is not executed by default because it increases time needed to create a PO. Once multiple items are bought, doing additional availability check for every item will increase workload substantially.

The above mentioned issue could be solved by having global material requirement view for buyer in CaseCompany's ERP system. Current default view for the buyer shows only material requirements for the factory buyer is buying for. By having a view that combines material data for all the factories would facilitate to notice that it is not required to purchase more that particular material from external suppliers, but it could be transferred internally from location to another. The above described functionality would require modification of CaseCompanys ERP system or a change of that. Both are high cost solutions and thus not considered as an options at this points.

However, as result of observation made during this thesis, it was found that it is possible to add notes for the items in ERP system. Possibility to add notes came up when having an ERP related discussion with one of the CaseCompany's buyers. The field where the note is possible to be added was not utilized before. That is because the field is not actually for notes, but to indicate supplier's name for the item. The functionality of the field was examined and a test was made. In the test, a note was simply added for an item that had purchase order proposal, and then it was checked how the note appears for the buyer responsible of the item. In addition, it was ensured that the field is not used in any other factories. The preceding was done because the information type of the field is global, which means that when adding something to the field, that information will be shown in every CaseCompanys location. It came up that the field was available and could be used. As result of the aforementioned, an instruction was made in order to utilize Supplier's item name -field as a note -field.

Instruction was introduced in CaseCompany's purchasing related meetings and accepted as an official instruction. Afterwards the instruction was shared to CaseCompany's other factories in location W and location E. Instruction works as a foundation for factory to factory material transaction development. Instruction is represented in more detail in figure 16 shown in appendix 8.

5.5 Enabling applications and tools

In the beginning of this research, inventory activation required lot of manual work. Identifying potential activatable items requires its own effort, however commissioning the actions and following that persons responsible of the actions are actually completing the actions is even more time consuming. In order to make daily activation practices more effective it was required to build-up a system which supports the activation. In addition, and like mentioned earlier in this thesis, slow moving inventory activation has earlier been project type of activity with no perseverance. Consequently, it was required to establish a solid foundation in order to boost and standardize slow moving inventory activation so that it will serve inventory reduction in long-term.

Over time, it had come up in CaseCompany that currently used ERP system has significant limitations as a material planning tool. Limitations were partly due to ERP systems features and partly because of how it was used in different factories (O12; O19). Consequently, there was done preliminary research related to suitable tools for material planning and inventory activation at CaseCompany's location W factory.

Application A, which fundamentally is inventory data management application, and previously used for example for forecasting purposes in CaseCompany, was identified as a suitable tool for slow moving inventory reduction as well. Usefulness is due to ability to build customized ranges using various logics. Ranges are used to run searches from inventory data. Thus application A could be used in various ways as a supportive tool in order to develop CaseCompany's material planning and inventory management. However, what makes application A especially beneficial from slow moving inventory reduction point of view is that items that are not yet slow movers, but are about to become ones, can be identified. (O12; O15 O19) Thus, the inventory clearance and activation can be done earlier than normally and before items end up into slow moving category.

Application A, enabling slow moving inventory accumulation prevention actions locally, has also remarkable potential at the global level. Previously item planning data has been used differently in different locations of CaseCompany. Same information types have been meaning different things. That has caused confusion and made comparison of inventory performance between different locations problematic and measurement of inventory at the global level basically impossible. By creating rules for item planning data and segmenting items according to the rules in application A, it is possible to establish standardized item planning policy for all the warehouses. Standardized item planning enables measurement of inventory performance globally, and makes it possible to compare inventory performance between each location and between different item categories.

In order to manage potential slow movers in Application A those are marked as MRD -candidates. MRD is an acronym for Material Review and Disposition and when it is a question of items it refers to slow movers or items that subject to slow moving (O5) MRD items are recognized and marked as a monthly basis. As result of this research the preceding has become continuous work in order to indentify problematic inventory also in CaseCompanys location F factory.

Application A fulfils the need to effectively identify excess and obsolete inventory. Once the problematic inventory is identified it needs to be taken under review and activation. Previously it was mentioned that in the beginning of this research especially following -up that activation actions are completed required lot of efforts. In order to make activation more efficient is was required to have supportive system for that as well. There was a need to ease measuring of inventory activation, establish a global reporting system and make information flows more effective. Consequently the main requirements for the global system were that it would facilitate monitoring assigned inventory activation tasks and see whether or not those are completed (O12; O22; O28). In addition it was required that factory-specific projected activation results as well as realized result could easily be seen (O12; O28).

From the above-mentioned requirements specifications for the MRD application were derived. Scketch for the end-user layout and high-level desing of funtionalities of the application were in agenda of Workshop 1, which took place in CaseCompanys location

W factory in city P. Participants of the workshop 1 went through the requirements of the MRD application with GDC specialist in order to ensure that the application could be incorporated into Global Data Center -software. GDC is software that CaseCompany had desided to implement as part of the CEP in order to facilitate for example customer order management (O12). Flexibility and transparency of the software provided suitable base for MRD -application as well. As a result of Workshop 1, 2, 3 and 4 MRD -application was designed and builded-up. The application was tested during fourth quarter of 2014 and officially introduced in January 2015. How the application supports inventory activation practice, is explained next.

Earlier it is explained how potential slow movers are identified and marked in Application A. In the beginning of every month, all the MRD -marked items are transferred from Application A to GDC as result of monthly update run. The preceding update run and other information flows are illustrated in figure 18 shown in Appendix 12. GDC recognizes the MRD -marked items and automatically moves those into MRD table. From MRD table items are taken under a review and activation actions are decided and assigned for particular persons. Once actions are done the result are reported into GDC. Activation process in MRD application is described in more detail in figure 19 shown in appendix 11.

In addition to normal MRD process shown in appendix 11, it was decided to add phase-in phase-out functionality into MRD application. That was because phase in- phase out -process is a complicated process including various steps. In addition it requires involvement of multiple individuals from different locations. By designing the process in GDC is possible to utilize GDC's network of global users. That enables more efficient communication and planning for work down inventories as well as for in bound inventories.

The idea is that all the essential information related to phase-in phase-out situation will be put in GDC database. Once information is in the system, it easily accessible for all the global users. GDC allow users to determine, urgency of the phase out, inventory levels and all the other required values related to phase out. When required values are in the system, phase-in phase-out situation can be coordinated in collaborative manner.

5.6 Slow moving inventory reduction -framework

As a result of this thesis a slow moving inventory reduction -framework was developed. The framework could be divided into four main parts. The upper part illustrates the vision where there is no place for slow moving inventory at all. In a manufacturing company inventories does not add any value for the final product in point of view of the customer. Consequently, in an ideal world, inventories should not exists, at least not slow moving inventory. However, that would require seamless and flawless cooperation among participants of the supply chain in order achieve a perfect just in time flow of material as well as of information.

The second part is a long term objective of continuous decrease of the slow moving inventory level. Now, as the vision might sound unachievable, the target should not. As already shown in the results of activation, the level of slow moving inventory has been constantly decreasing. The preceding is due the third part of the framework where actual actions are represented. Actions, which are described in more detail previously in this chapter, are here divided to activation and prevention category depending on their nature. Activation actions are direct efforts in order to find use for items in slow moving inventory. Prevention actions as for, are efforts in order to block the accumulation of slow moving inventory.

The lowest part is a foundation of the framework. That is a solid base build of enabling tools that are making long term slow moving inventory reduction possible. Without continuous development and standardized utilization of these tools, activation actions are likely to end-up project type of executions with no continuity. That as for would be seen in slow moving inventory so that the level would continue to increase like it was increasing before this research. Slow moving inventory reduction -framework is presented below in figure 20.

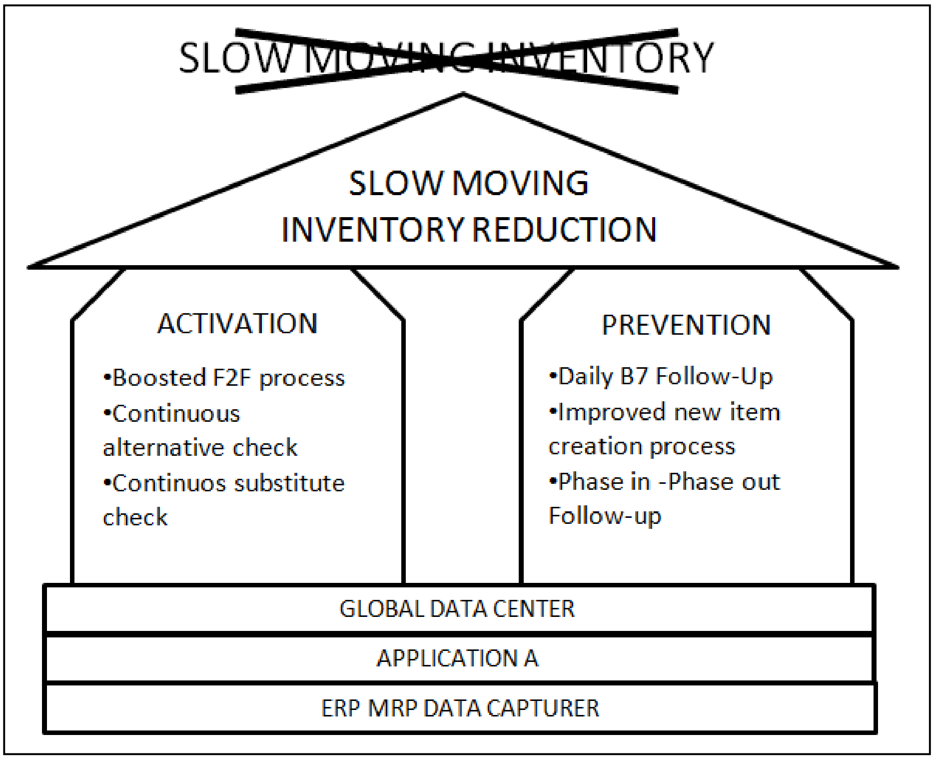

Figure 20. Slow moving inventory reduction framework.

In the beginning of slow moving inventory reduction both activation and prevention actions are needed. However, when the time goes by and the inventory has decreased, the results of activation are likely to decrease as well. That is a natural result of activation thus the potential to be activated has decreased. Consequently, the focus need to be shifted more and more to slow moving inventory build-up prevention. Only by doing that effectively, the vision illustrated in figure 20 can be achieved.

6 DISCUSSION

6.1 Study for slow moving inventory backgrounds

This research concentrated on slow moving inventory reduction and causing mechanisms behind slow moving inventory accumulation. Literature related to PDM/PLM, change management and material management where examined in order to find out current challenges in the subjects. It was studied if the challenges of the aforementioned subjects could have relation to accumulation of excess and obsolete material.

In the field of PDM/PLM main problems are product data and information sharing -related (Feng et al. 2009, p. 49; Demoly et al. 2012, p. 559). Issues emerge mainly because companies manage their product data with their own methods and applications Yang et al. (2008, p, 1043). Incompability between applications used makes information sharing technically challenging due various data formats. In addition information is distributed into various locations which make finding particular information difficult.The aforementioned difficulties are especially harmfull at product's design phase, where relations and similarities between already existing products should be recognized (Demoly et al. 2013, p. 834). Failing in the preceding leads to less standardized products (Demoly et al. 2013, p. 842), which as its part, is likely to cause increase of inventories (Vrat 2014, p. 14; Philpotts 1996, p. 10). Chens's et al. (2006) research as its part shows that the higher is the overall inventory level, the higher is the risk for storing duplicate parts and scrap material.

As it is shown in literature that deficiencies related to PDM/PLM have relation to the problem of slow moving inventory. Findings of the literature are supported by the concrete examples presented in chapter 5.3 In addition the results of observations made in CaseCompany and presented in chapter 5.5 support the aforementioned statement that that faults in PDM/PLM are one factors behind the the accumulation of the slow moving inventory in CaseCompany.

Like in the field on PDM/PLM, also in the field of change management its current challenges were examined through literature review in order to find out change managements possible relations to slow moving inventory accumulation. For managing EC's CaseCompany utilizes similar model of shared documents than what is described by Jarrat et al. (2011) and Huang et al. (2003, p. 483). Challenges in management of EC's are similar to challenges related to PDM/PLM, which is logical because these both are product related functionalities. As change management is complex process (Elezi et al.

2013, p. 568), it requires collaboration between various functions (Hoover et al. 2001, p. 30). That is what makes things difficult. Solutions that would support collaborative approach for change management have not been implemented perfectly, partly due to issues of global engineering environment (Wasmer et al. 2011, p. 534). Challenges of change management are also partly due complexity, which lead into difficulties when defnining the impact of change (Keller et al. 2007, p. 2) As these challenges are not straighten out, the result could be seen as excess and obsolete material (Pince & Dekker 2011, p. 83) This is exactly what have come out as result of engineering change analysis made of CaseCompanys change data. The analysis show real-world examples of how complex process of engineering change is partly behind the slow moving inventory problem of CaseCompany. Findigs brings out also change management importance related to customer order revisions. Additionally, the result of observation data analysis presented in chapter 5.5 support the findings.

In addition to abovementioned subject material management's relation to slow moving inventory accumulation was examined. Current litetature related to subject shows that different material management modes have notable differences from inventory point of view. According to Chen et al. (2006, p. 2521) inventory levels and this warehousing of duplicate item and scrap items are remarkable lower in centralized material material management mode tha in distributed mode. CaseCompany utilizes distributed mode. Hence, it can be stated that CaseCompany's slow moving inventory problems are partly due to its selection of material manament mode. Partly because the research made by Kukreja et al. (2001), it was started to figure out, how distributed material management could obtain similar benefits than centralized mode has.

6.2 Development of slow moving inventory reduction framework

In previous part literature findings related to CaseCompanys slow moving inventory problem were described. There were three main factors that have affected to selection of the subjects covered. Partly selection is made according to the result of current state analysis of CaseCompany's current slow moving inventory. Early observations made in CaseCompany have also been affecting to the final selection. Both, results of current state analysis as well as observations, pointed out that change management and product data management should be covered. Third factor effecting to selection was subject recommendations made by the examiner of this research. Challenges and diffiulties of the aforementioned subjects were examined from slow moving inventory standpoint.

In addition to literature review observations have been made from unstructured conversations. Observations were made in order to support triangulate the findings of literature review and root cause analysis. During the research there were various sources for data collection. Participants to be observed were selected according to their backgrounds.

Especially in the beginning of the study observations from discussion with CaseCompany's product management representative has been useful in order to build a general view and big picture of the slow moving inventory problem. Discussion with the instructor of this thesis as its part, offered some perspective how the purchase processes might affect to inventory problem. Many productive discussions have also held with systems specialist related to revision management. Conversations have provided an insight into customer order changes and revisions as well as how those might impact into excess and obsolete material accumulation. Notable source for observations are also inventory reviews made with buyers. Additionally, many of the observations are pulled out of the daily discussion for example with production planners. During the discussions it was noticed, that slow moving inventory as subject of discussion, it now always the most pleasant. Due that, for example while doing inventory review, it was necessary to explain the backgrounds for inventory review.

In order to find concrete examples behind slow moving inventory accumulation CaseCompanys purchase order related data was examined. Data was used to capture PO's with no demand in CaseCompany's ERP system. PTO item that were bought agains customer order, but that had lost the demand where examined. It was noticed that there was a gap in data required and thus an IT initiative was made in order to fill the gap. In addition, CaseCompanys engineering change related data was examined. Sample of 35 engineering changes was examined in order to figure out if engineering changes have relation to slow moving inventory accumulation.

In the end of the research process findings of the literature were compared to results of observations made in CaseCompany. Additionally, the aforementioned findings were compared with root-cause analysis based on real-world examples collected during the research. The findings supported each other and showed that there is improving potential especially in change management and produt data management. What came out from current state analysis was that slow moving inventory consisted mainly of purchased parts. Consequently, actions in order to stop receives of purchased parts were designed. Observations indicated that there was a need for standardized slow moving inventory activation and prevention actions. Additionally inventory inventory review was started and activation actions were planned. In order to achieve standardization, tools and applications to support daily practices were designed and implemented. It has to be mentioned that design and implementation of the tools to required notable portion of the overall time used for this research. The preceding was because the researcher was not familiar in advance for example with Application A. Thus, it took its own time to learn how the applications could be utilized. What comes to Global Data Center, it was in addition required to implement the application and teach use of the application for particular group of personnel. Based on all the aforementioned, a framework for long-term slow moving inventory reduction, presented in chapter 5.8, was established.

The purpose of the framework is to provide required actions and tools for CaseCompany in order to get rid of the slow moving inventory. Framework has been already partly implemented in CaseCompany. As disbenefit of the framework, slight increase in workloads of buyers and planners could be mentioned. Benefits as for are seen as reduced capital tied up into slow moving inventory as a result activation and prevention actions as well as improved factory to factory material flow. Applications implemented, GDC and Application A, work as enablers for global level material planning standardization, which as its part is a cornerstone for improved inventory performance both locally and globally. There has also been improvement in factory to factory transactions due use of instructions presented in appendix 8. Additionally, receipts of useless material have already been decreased due to development of purchase order cancellation process. Also monitoring progress of phase-in phase-situations has improved due utilization of the certain application built in Global Data Center. Abovementioned main findings ans solution as are summarized in table 11.

Table 11. Summary of main findings and solutions.

ISSUE SOURCE	ISSUE	SOLUTION	IMPACT
Engineering changes	Actions indicated in engineering change notice are not executed	Application to monitor phase-in phase-out situations	Improved visibility and control of changes.
Customer order revisions	Difficulties to align supply of materials with demand of materials	Purchase order cancellation process	End of useless material receipts
Factory to factory transactions	Invisibility of available material on other factories	Instructions to indicate temporary supplier in ERP system	Improved material flow between factories
Material management	Unstandardized methods for material management and planning	Application A and Global Data Center	Enables measurement of inventory performance on global level

Table 11 summarizes the main findings related to slow moving inventory accumulation in CaseCompany. Additionally solutions and impacts of those are described. Not all the solutions where implemented during the research. Consequently, those which are not presented in table 11 are presented as further development recommendations.

6.3 Further development recommendations

6.3.1 Capturing of material requirements data

During this research, a daily follow-up was developed in order to have a better control and view on released purchase orders. Unnecessary POs where examined from the view point of root cause analysis and in order to make decision of whether or not to cancel the order. However, analysis with currently available information is relatively time consuming and inaccurate. From PO cancellation point of view, for some cases it is essential to know for which customer order the material was originally required.

Hence, further development is required at the field of root cause examination. Root cause examination for unnecessary PO's is currently relatively challenging because no historical material requirement data is available. Lack of history data leads to problems, which in many cases means that it is not possible to see what was originally the reason why a purchase order proposal was created and why the purchased item was afterwards no longer needed.

Due the data capturing problem described above, an IT development initiative was made in order to fix the problem. Some preliminary work has already been done, including figuring out possibility to capture and store material requirements data. In case it is possible to capture material requirements data and store it in reasonable manner, it is also required that data can be examined effectively. In case the preceding is possible, it would be a major improvement for the root cause -analysis of redundant POs.

The plan would be that material requirement data is captured from ERP system and saved as a daily basis to CaseCompany's data warehouse. According to development Manager some problems might occur due to great amount of data to be stored (O27). Capacity of CaseCompany's data warehouse is limited which sets its own restrictions for capturing and saving (O27). Due to the preceding limitation current plan is that data will be stored only for two days. Consequently there will be two days, starting from the day the B7 -message was generated, to utilize stored MRP data. The preceding might require special worktime arrangements because of weekends.

Once data would be captured and saved, and a new potential PO cancellation is identified, a query to stored data would be made. As an input for query, an item number that is under examination would be provided. As an output, the query would return information about the material requirements for the day before the demand was lost (D_{C-1}). Once the material requirement's situation of the day before the day the demand was lost is known, that situation can be compared to current situation (D_c). By comparing the differences in material requirements between current day ($D_{C)}$ and situation on D_{C-1}, it is possible to identify the redundant material requirement or the the cancelled customer order. That is because MRP data separates and individualizes customer orders and manufacturing orders that are reserving the item. Figure 21 and related table 12 shown in appendix 13 illustrates the data capturing and utilization as a support of B7-follow up.

6.3.2 New item creation

Literature review of this thesis indicates that new item creation process, in case not working properly, have connection to accumulation of slow moving inventory. The preceding could be confirmed by the result shown in chapter 5.3. The preceding could be triangulated by the findings of observations presented in chapter 5.5. Consequently, and because during this research it was recognized that there is complications in current new item creation process, it is recommend for CaseCompany to make further investigation in the field of new item creation and revise and if necessary also re-engineer its current process.

As this thesis does not focus directly to CaseCompanys new item creation process, solving this problem is not considered as an objective for this study. However, form inventory point of view that is a problem which is necessary to brought out. Consequently new item creation process and especially development of item attribute comparison and checking in the current PDM system is suggested as one of the areas for further investigation. It has been brought out that there are difficulties are especially in comparing item atributes (O7). Consequently it is challenging to find similarities between already existing items and those which are under a process to be created. Thus further invenstigation of new item creation process could concentrate especially on item attribute comparison.

6.3.3 Globalized material requirements

Currently, and by default, CaseCompany's purchase orders are released to predefined supplier in the ERP system, according to demand and without checking that particular material's availability at the other factories of CaseCompany. The availability checking is not executed by default because it would increase the workload substantially. The preceding is likely to interrupt factory to factory material flow. Problem is discussed in more detail and a solution, which is suitable for current systems used CaseCompany, is represented in chapter 5.4

However, the current solution requires manual controlling of items that are slow movers in some of the CaseCompany's factories. Further investigation could be done in the field of material requirements -data management. Focus could be on how material data is shown for a buyer in CaseCompanys ERP system. The idea is, that insted of representing required and available material for one particulat factory, a buyer would the globalized view. The globalized view would show the available on-hand balance of all the CaseCompany's factories. In case there would be excess items on one location, the buyer would make the internal order istead of buing from external supplier.

6.3.4 Prosess development for managing engineering changes

As results shown in chapter 5.6 indicate, there are deficiencies in CaseCompany's engineering change process. As a result of sample analysed, it could be approximated that X % engineering changes cause inventory problems in CaseCompanys. Furhter investigations of result shows that problems are in implementation and follow-up phase because implementation actions that were described in the ENCs where simply not executed.Consequently, further development in the field of engineering changes should be aimed into the implementation phase.

Additionally, it is could be beneficial to start measuring engineering change process. Currently there is no standardized measuring system for the process. In addition there is no quantitative or qualitative data available about the engineering changes process (O26). Currently available data consist of separate engineering change forms and thus, it is difficult to examine performance of the process.

6.3.5 Implementation of further development actions

Previously recommendations for further development were presented. Roadmap presented in table 13 summarizes the main actions recommended and provides short description of estimated impact of the action and proposed timeframe for the implementation.

Table 13. Milestones for further development of slow moving inventory reduction.

ROADMAP TO IMPROVED SLOW MOVING INVENTORY REDUCTION		
MILESTONE	IMPACT	EXECUTION
Material requirements data capturing	High quality data to support purchase order cancellation process	In short-term
Improved new item creation process	Less duplicates items	In medium-term
Improved management of engineering changes	Better measurability and visibility of the process	In medium-term
Globalized material requirements	Improved factory to factory material flow	In long-term

Execution in short-term refers to action which is recommended to implement within 6 months. Medium-term actions are recommended to implement during next 6-12 months depending on resources available. Long-term milestone as for is recommended to implement during next 12-24 months period

Because order cancellation process is essential in order to stop accumulation of new slow moving inventory it is necessary to execute actions that support that process in the first place. Hence, and as shown in table 12, short-term focus shoud be in development of material requirements data capturing and utilization of the captured data.

Further development of process to manage engineering changes and development of new item creation process should be possible to start with systems currently in use in CaseCompany. However those not as critical as material requirement capturing is. Additionally, those might require more detailed examination of current processes and possible re-engineering of the processes. The preceding requires both time and resources. Consequently, those categorized as mid-term development recommendations.

Globalizing material requirements is essential in order to use inventories effectively between various locations. However, factory to factory material flow has already been improved as a result of instructions presented in appendix 8. Consequently, further development of material requirements visibility between different factories is consireded as long-term development recommendation.

6.4 Meeting the objectives

Previously research process, inventory activation and its results are presented. Next those are discussed in point of view of the objectives and research questions of this thesis. The research focused on slow moving inventory reduction in CaseCompany's Helsikin factory. In order to develop solution that will help the slow moving inventory pronlem in long term two separet research question was formulated. At fisrt, it was necessary to find ways to activate the inventory, not scrap the inventory. Thus it was requied to figure out what slow moving inventory actually consisted of. Consequently, the fist research question was formulated as:

1. *What is the current state of the slow moving inventory?*

In order to answer to the first research question present state analysis described in chapter 4 was made. There current slow moving inventory management and the most essential inventory and item parameters were looked through. Additionally inventory content was examined. Thus, Chapter 4 as well as table 5 and Table 6 in appendix 4 answer to first research question.

As the first research question was focusing to gain understanding of the current state of the slow moving inventory, it was necessary to formulate another question which would have enabled this research to meet the rest of its objectives. For the purpose, this thesis would not only be a temporary solution through inventory activation actions, it was required to delvelop actions that would stop build-up of slow moving inventory. Hence the second research question was formulated as:

2. *How can CaseCompany decrease the level of slow moving inventory permanently?*

Due to multimidimensionality of the second research question the following subquestions were formulated.

2.1. How can slow moving inventory be activated?
2.2. Which functions or processes are most likely to generate excess and obsolete items?
2.3. How can the accumulation of new slow moving inventory be stopped?

Inventory disposition actions shown in figure 9 as well activation methods adapted and standardized during this research presented in chapter 5.1 provide information about different manners to activate slow moving inventory. Thus, chapters 2.6.1 and 5.1 are the ones that aswer to sub-question 2.1.

Possible root causes for slow moving inventory accumulation are discussed thorugh the chapter 2. Additionally from CaseCompany's perspective, root causes are discusses in chapters 5.3.6 where case examples for root slow moving inventory root causes are examined and in chapter 5.5 where results of observations are looked through. Additionally in chapter 5.6 EC's relations to slow moving inventory is discusses. Consequently, chapters 2, 5.3.6, 5.5 and 5.6 provides answers to sub-question 2.2.

In order to stop accumulation of slow moving inventory B7 follow-up represented in chapter 5.2 was established. Process aims to identify all the purchased and unneeded material before it is received in the CaseCompanys factory. Thus answer to sub-question 2.3. is represented in chapter 5.2.

In order to answer to second research question it was first required to answer to sub-questions. Derived from the answers of sub-question a framework for long term slow moving reduction was designed. The framework and the aswer for second research question are represented in chapter 5.8. In conclusion, the research answered to its research questions.

As the thesis is strongly linked to CaseCompany's Capital Efficiency Program there were objectives derived from CEP also. The main objective derived from CEP was to reduce capital tied up to slow moving inventory of CaseCompany'factory by X euros in six months period between July 2014 and December 2014 (O6). In order to achieve the preceding objective slow moving inventory review and activation was started in the beginning of the research simultnaeuosly with other research work. The main objective derived from CEP was achieved during October 2014. That is presented in more detail in chapter 5.1.6.

6.5 The role of practitioner-researcher

During the research process, the researcher worked for the organisation where the research was concducted. The preceding arrangement has its pros and cons. At first, the research subject for this research was offered by the employer. Consequently, the employer was interested about the research and provided support if necessary. The preceding is one of the main benefits of the role of practitioner -researcher (Saunders et al. 2007, pp. 144; Farguhar 2012 pp. 5). As the organisation and the employer are interested about the outcomes of the research, that is likely to generate a supportive atmosphere. The preceding is good addition for all the practical support that is offered by the employer.

Another advantage for practitioner-researcher mentioned Saunders et al. (2007, pp. 14-144) is the knowledge of the organisation, so the context and research environment is already familiar. However, in these cases researcher has to be aware of assumptions and preconceptions that he or she might make subconsciously. That is because those are likely to interupt the research process and prevent researcher from examining issues that he or she would otherwise examine. In case of this reseach, the researcher has been already working in several positions in the CaseCompany. Consequently, also the disadvantages of knowing the organisation might occur. This might result that the outcomes of this research may differ from the result that would have achieved by using internal or external observer that would not have known the organization in advance.

In addition to abovementioned issue, Saunders et al. (2007, pp. 143-144) states that combining the roles a employee and a researcher is likely to cause cause challenges related to practical research work. During the process of this research, the preceding could have seen for example as schedule-related issues. Sometimes it was challenging to combine the roles of a project owner and a researcher. The preceding is likely to be an issue, which is not perceived by the employer because many of the activities related to actual reseach work are not visible for the employer (Saunders et al. 2007, pp. 144). During this reseach process, the reseacher was repsonsible of the progress of CEP Slow Moving Inventories -program in CaseCompany’s factory E. Occasionally workload related to the CEP resulted in a confict between the schedule of the research and the schedule of the CEP tasks. However, by prioritizing tasks, both short and long term CEP targets were met, and also the thesis was finished in acceptable time.

7 CONCLUSION

7.1 Managerial implication

Results of the theoretical study indicated that all the subjects covered in this thesis, could be behind the slow moving inventory accumulation. In cases of PDM/PLM and change management, it was noticed that share of information is likely to be the most important part of those functions. In case there occurs deficiencies in information sharing that can be seen as inventory problems.

Results of the empirical study show that CaseCompany's slow moving inventory problem is multidimensional.Consequently, improvements on a particular area, for example in the field of PDM/PLM, are not enough in order to stop slow moving inventory accumulation. Hence, comprehensive approach is required and there needs to be improvements at multiple areas. The framework represented in chapter 5.8 makes it possible to facilitate the problem. The framework aims to activate current problematic inventory as well as to prevent accumulation of new slow moving inventory. The framework includes required practices and applications in order to decrease the level of slow moving inventory with persecerance.

Analysis made on CaseCompany's engineering changes provides information of how those affect to accumulation of slow moving inventory. The analysis proved that there is connection between accumulation of obsolete inventory and engineering changes. The analysis points out, that seemles information transferring is a crucial part in engineering change process. It was also noted that there should be practices to monitor that required changes are actually completed, not only in the ECN form and in product data management system, but also in the factory and ERP system.

One important thing to highlight is ownership. During the research, it was observed that no one in CaseCompany is actually responsible of the slow moving inventory. Once problems occur in the areas that are taken care by nobody, who should be one handling the problems? Currently CaceCompany is moving towards less inventory problems and decreased level of slow moving inventory. However, in order to stay on the course, it is required that there is person responsible of slow moving inventory reduction.

7.2 Academic contribution

Accroding to Nenes et al. (2010, p. 313) Inventories might be the most throughly examined subject of operations and production management. Previous research related to inventories is focused greatly on different inventory control systems, inventory management policies and decreasing the level of inventory through various methods. Studies are focused mainly to active and spare part inventories. Scientific studies that would focus exactly to slow moving inventory related problems are relatively rare.

In literature point of view, problem of slow moving inventory was approached in this thesis by examining change managent's, product data managent's as well as material management's relation to slow moving inventory. Relation of the aforementioned subjects to slow moving inventory has already been brought out in the previous studies. However the relation to slow moving inventory has not been the main focus of the studies. In the other words, the studies have not been focusing on the factors behind the slow moving inventory and thus there is not research that would summarize the main factors behind slow moving inventory problem.

As this research is focused to examine root causes and clarify the backgrounds of slow moving inventory, in academic point of view it provides new case study approach by combing change management, PDM/PLM and material management as factors behind slow moving inventory problem. The research brings out how the slow moving inventory is accumulated through varius different sources in CaseCompany. Consequently the problems multidimensionality is brought out. Information related to problems multidimensionality might benefit academic world when designing further studies related to slow moving inventory.

In addition to examining the factors behind slow moving inventory the research recommends disposition actions in order to decrease the level of slow moving inventory. Recommended actions of this study are similar to what has already been brought out in previous academic studies. However, depending of how the actions are used has a great influence to their effectivity. Short term utilization of disposition actions is only a temporary solution for slow moving inventory problem. Hence, in this thesis a framework for long term slow moving inventory reduction is presented. In addition to traditional inventory disposition actions the framework points out the importance of standardizing slow moving inventory activation and prevention actions through use of appropriate tools and applications.

7.3 Limitations and credibility

In this thesis, a framework for slow moving inventory reduction is developed. Findings utilized to form the framework are based on examination of current excess and obsolete inventory and factors behind slow moving inventory accumulation. Backgrounds of the slow moving inventory problems are investigated by literature review and by analysing qualitative and quantitate data collected from CaseCompanys procedures and personnel.

As the findings are strongly attached to this particular company, it lessens external validity of the findings (Saunders et al. 2007, pp. 151; Meredith 1998, pp. 449). Consequently, the framework presented in the thesis may not be generalised and commonly accepted theory shall not be formed. The preceding is characterisical for master's theses because commonly the problems discussed are not universal and thus it is expectalbe that results are not generalized (Olkkonen 1994, pp. 23). However, especially in large manufacturing companies such as CaseCompany, it could be possible to partially utilize the findigs in order to solve a similar problem than what is discussed in this research. Consequently, the findings have some level of transferrability (Wahyuni 2012, pp. 77).

There is a relationship between the results obtained and the techniques used to collect and process data (Saunders et al. 2007, pp. 147). As all the techniques have their own individual effects as well as strength and weaknesses, it was deceided to utilize both qualititate and quantitative data collection and processing techniques. Choice to utilize mixed-model research combining and mixing the aforementioned techniques was done in order to increase the reliability and validity of the findings. Result of qualitative data collected during discussions supported the result of quantitative data analysis for slow moving inventory backgrounds. Hence, observations data could be used to triangulate and improve the reliability of the other findings (Costley & Armsy 2007, pp. 140).

As choice of the research model of this thesis may support the credibility of the research, data used as its part decreases the credibility. In the literature review of this thesis, mainly scientific research papers and books are used. However, also articles that present subjective perspective of an individual author are utilized. Consequently, some of the source material is not scientificly approved. The preceding decreases the credibility and reliability of the theroretical part of this study.

In addition to limitations set by the data used, quality of the observations data has to be mentioned. Qualitative data, used in root cause analysis for slow moving inventory, was collected from e-mail conversations, unstructured discussions, meetings and workshops.The data is based on subjective perspectives of the individual employees. Hence, it is necessary to regard the results of observation data with criticalness (Iacono et al. 2009, p. 45).

In this research, researhers role was practitioner researcher, in addition the organization where research was conducted was familiar for the reseacher in advance. This the preceding relation between the organization and the reseacher entails clear limitations for example due to familiarity and preconceptions (Saunders et al. 2007, pp. 144).

7.4 Future research

In this research slow moving inventory problem is investigated in one particular company. In order to have more realiable and more generalisable findings of the problem related to excess and obsolete inventories of manufacturing companies, there could be a research that includes a sample of multiple companies. By examining multiple companies having similar problem with research setting used in this research would provide more credible insight into backgrounds of slow moving inventories. Consequnelty, instead of utilizing single case study like in this research, as case study includind multiple case companies could be conducted.

The problem discussed in this reseach is approached by examining internal processess of the CaseCompany. Consequently, the external factors are left with less attention. Future research could investigate what are the external factors behind inventory problems. It could be investigated for example how company's positioning in the supply chain affects to its material flows and through that to accumulation of slow moving inventory. It could also be investigated whether or not there is relation between inventory problems and companys leverage over the other parties in the supply chain. Slow moving inventory problem could also be approached by focusing on information flows. The research could examine how disturbances in information flows affect to material flows.

BIBLIOGRAPHY

Balaji, K. & Kumar, V. 2013. Effects of Slow Moving Inventory in Industries: Insights of Other Researchers. International Journal of Trade, Economics and Finance. Vol. 4(4), p. 243-246.

Bhuiyan, N., Gatard, G. & Thomson, V. 2006. Engineering change request management in a new product development process. European Journal of Innovation Management. Vol. 9(1), p. 5-19.

Cattani, K. & Souza, G. 2003. Good buy? Delaying end-of-life purchases. European Journal of Operational Research. Vol. 146(1), p. 216-228.

Chaneski, W. 2003. Are You Keeping Obsolete Inventory? Modern Machine Shop. Vol. (73), p. 52-54.

Chen, A-Z., Cao, Z. & Tang, W. 2006. Centralized-Distributed Material Management Mode of Large Enterprise Groups. International Conference on Machine Learning and Cybernetics. p. 2519-2523.

Copacino, W. 1997. Supply Chain Management. The Basics and Beyond. 2000 Corporate Boulevard. N.W. Boca Raton. St Lucie Press. 204 p.

Costley, C. & Armsby, P. 2007. Methodologies for undergraduates doing practitioner investigations at work. Journal of Workplace Learning. Vol 19(3), p. 131-151.

Crnkovic, I., Asklund, U. & Persson Dahlqvist A. 2002. Implementing and Integrating Product Data Management and Software Configuration Management. Artech House. 95 p.

Cudney, E., Elrod, C. & Uppalanchi, A. 2012. Analyzing customer requirements for the American Society of Engineering Management using quality function deployment. Engineering Management Journal. Vol. 24(1), p. 47-57.

Dejonckheere, J., Disney, S.M., Lambrecht, M.R. & Towill, D.R. 2004. The impact of information enrichment on the Bullwhip effect in supply chains: a control engineering perspective. European Journal of Operations Research. Vol. 153(3), p. 727-750.

Delfmann, W. & Klaas-Wissing, T. 2007. Strategic Supply Chain Design: Theory, Concepts and Applications. Köln, Kölner Wissenschaftsverlag. 400 p.

Demoly, F., Dutartre, O., Yan, X-T., Eynard, B., Kiritsis, D. & Gomes, S. 2013. Product relationships management enabler for concurrent engineering and product lifecycle management. Computers in Industry. Vol. 64(7), p. 833-848.

Demoly, F., Yan, X-T., Eynard, B., Gomes, S. & Kiritsis, D. 2012. Integrated product relationships management: a model to enable concurrent product design and assembly sequence planning. Journal of Engineerig Design. Vol. 23(7), p. 544-561.

Dolgui, A. & Pashkevich. 2008. Extended beta-binomial model for demand forecasting of multiple slow-moving inventory items. International Journal of Systems Science. Vol. 39(7), p. 713-726.

Eigner, M. & Nem, M. 2010. On the Development of New Modeling Concepts for Product Lifecycle Management in Engineering Enterprises. Computer-Aided Design & Applications. Vol. 7(2), p. 203-212.

Eisenhardt, K. & Graebner, M. 2007. Theory building from cases: opportunities and challenges. Academy of Management Journal. Vol. 50(1), p. 25-32.

Elezi, F., Maier, T. & Lindemann, U. 2013. Engineering Change Management Challenges and Management Cybernetics. IEEE International Systems Conference. p. 567-573.

Farguhar, J.D. Case Study Research for Business 2012. First edition, London, SAGE Publications Inc. 134 p.

Feng, G., Cui, D., Wang, C. & Yu, J. 2009. Integrated data management in complex product collaborative design. Computers in Industry. Vol. 47(3), p. 289-298.

Hoover Jr, W. E., Eloranta, E., Holmström, J. & Huttunen, K. 2001. Managing the Demand-Supply Chain: Value Innovations for Customer Satisfaction. Canada, John Wiley & Sons, Inc. 257 p.

Huang, G., Yee, W. & Mak, K. 2003. Current practice of engineering change management in Hong Kong manufacturing industries. Journal of Materials Processing Technology. Vol. 139(1-3), p. 481-487.

Iacono, J., Brown, A. & Holtham, C. 2009. Research Methods - a Case Example of Participant Observation. Electronic Journal of Business Research Methods. Vol. 7(1), p. 39-46.

Jaarsveld., W. & Dekker, R. 2011. Estimating obsolescence risk from demand data to enchance inventory control - A case study. International Journal of Production Economics. Vol. 133(1), p. 423-431.

Jarrat, T. A. W., Eckert, C. M., Caldwell, N. H. M. & Clarkson, P. J. 2011. Engineering change: an overview and perspective on the literature. Research in Engineering Design. Vol. 22(2), p. 103-124.

Jiao, J. R., and Chen, C.-H. 2006. Customer Requirements Management in Product Development: A Review of Research Issues. Concurrent Engineering: Research and Applications. Vol. 14(3), p. 173–185.

Jimenez-Narvaez, L.-M., Dalkir, K. & Gardoni, M. 2012. Managing knowledge needs during new product lifecycle design on quick-term project development QPD: case study of 24 hours of innovation - ETS Montreal. Revised Selected Papers of IFIP WG 5.1 International Conference of PLM, Montreal, Canada. p. 28-34.

Karniel, A. & Reich, Y. 2011. Managing the Dynamics of New Product Development Processes: A New Product Lifecycle Management Paradigm. London, Springer-Verlag. 249 p.

Keller, R., Alink, T., Pfeifer, C., Eckert, C., Clarkson, P. & Albers, A. 2007. Product models in design: A combined use of two models to assess change risks. 16th International conference on engineering design. Vol. 42, 12 p.

Kukreja, A., Schmidt, C. & Miller, D. 2001. Stocking Decisions for Low-Usage Items in a Multilocation Inventory System. Management Science. Vol. 47(10), p. 1371-1383.

Leong, K., Yu, K. & Lee, W. 2002. Product data allocation for distributed product data management system. Computers in Industry. Vol. 47(3), p. 289-298.

Malone, R. 2007. Chain Reaction: How Today's Best Companies Manage Their Supply Chains for Superior Performance. 1st liberty Plaza, New York, NY, Kaplan Publishing Inc. 225 p.

Mangan, J., Lalwani, C. & Buther, T. 2008. Global Logistics and Supply Chain Management. John Wiley & Sons, Inc. 343 p.

Meredith, J. 1998. Building operations management theory through case and field research. Journal of Operations Management. Vol. 16(4), p. 441-464.

Monczka, R., Trent, R. & Handfield, R. 2005. Puchasing and Supply Chain Management.(3.), USA, Thomson South-Western Inc. 733 p.

Möttönen, M. 2009. Requirements engineering: Linking design and manufacturing in ICT companies. ACTA Universitatis Ouluensis. Department of Industrial Engineering and Management, University of Oulu. Oulu Univercity Press. Oulu, Finland. 62 p.

Muller, M. 2003. Essentials of Inventory Management. 1601 Broadway, New York, NY, 10019. American Management Association. 255 p.

Murphy, P. & Wood, D. 2008. Contemporary Logistics. (9.), Upper Saddle River, New Jersey, 07458, Pearson Education, Inc. 393 p.

Nenes, G., Panagiotidou, S. & Tagaras, G. 2010. Inventory management of multiple items with irregular demand: A case study. European Journal of Operational Research. Vol. 205(2), p.313-324.

Olkkonen, T. 1994. Johdatus teollisuustalouden tutkimustyöhön. (2.), Otaniemi, Teknillinen korkeakoulu. 143 p.

Ou-Yang, C. & Cheng, M., C. 2003. Developing a PDM / MRP integration framework to evaluate the influence of engineering change on inventory scrap costs. International Journal of Advanced Manufacturing Technology. Vol. 22(3), p. 161-174.

Ou-Yang, C. & Liu, HC. 2001. Developing a Computer-Aided Environment to Investigate the Influences of Design Schedule Changes on Material Requirement Planning. International Journal of Advanced Manufacturing Technology. Vol. 17(1), p. 11-26.

Papinniemi, J., Hannola, L. & Maletz, M. 2014. Challenges in integrating requirements management with PLM. International Journal of Production Research. Vol. 52(15), p. 4412-4423

Paton, R., A. & McCalman, J. 2000. Change Management: A guide to effective implementation. (2.), 6 Bonhill Street, London EC2A 4PU, SAGE Publications Inc. 280 p.

Pay, R. 2010. Avoiding obsolete inventory. Industry Week. Vol. 259(6), p. 69-70.

Pettersson, T., Chemli, S., Delamare, C., Hoimyr, N., Mallon Amerigo, S. Manola Poggioli, E., Martel, P., Mottier, M., Muller, J., Petit, S., Rousseau, B., Widegren, D. & Puittinen, R. 2000. The CERN Engineering Data Management System - A status report. Proceedings of 7th European Conference, EPAC 2000, Vienna, Austria. p. 2450-2452.

Philpotts, M. 1996. An introduction to the concepts, benefits and terminology of product data management. Industrial Management + Data Systems.Vol. 96(4), p. 11-17.

Pince, C. & Dekker, R. 2011. An inventory model for slow moving items subject to obsolescence. European Journal of Operational Research. Vol. 213(1), p. 83-95.

Prudhomme, G., Zwolinski, P. & Brissaud, D. 2003. Integrating into the design process the needs of those involved in the product life-cycle. Journal of Engineering Design. Vol. 14(3), p. 333-353.

Ryu, S-J., Tsukishima, T., Onari, Hisashi. 2008. A study on evaluation of demand information-sharing methods in supply chain. International Journal of Production Economics. Vol. 120(1), p. 162-175.

Saunders, M., Lewis, P. & Thornhill, A. 2007. Research Methods for Business Students. (4.), New York, NY, Financial Times / Prentice Hall. 656 p.

Shiau, J-Y. 2011. Reducing Cost of Inactive Stock Caused by Engineering Changes. Proceedings of the 2011 Industrial Engineering Research Conference. p.1-8.

Stevenson, W. J. 2009. Operations Management. 1221 Avenue of the Americas, New York, NY, 10020, The McGraw-Hill Companies, Inc. 906 p.

Subrahmanian, E., Rachuri, S., Fenves, S., J., Foufou, S. & Sriram R., D. 2005. Challenges in supporting product design and manufacturing in a networked economy: A PLM perspective. Product Lifecycle Management: Emerging Solutions and Challenges for Global Networked Enterprise. p. 495-506.

Tacvar, J. & Duhovnik, J. 2005. Engineering change management in individualand mass production. Robotics & Computer-Integrated Manufacturing. Vol. 21(3), p. 205-215.

Tuli, P. & Shankar, R. 2015. Collaborative and lean new product development approach: a case study in the automotive product design. International Journal of Production Research. Vol. 53(8), p. 2457-2471.

Ullman, D. 2010. The Mechanical Design Process.(4,), 1221 Avenue of the Americas, New York, NY, 10020, The McGraw-Hill Companies, Inc. 448 p.

Vezzetti, E., Violante, M. & Marcolin, F. 2014. A benchmarking framework for product lifecycle management (PLM) maturity models. International Journal of Advanced Manufacturing Technology. Vol. 71(5-8), p. 899-918.

Vilko, J., Rumpu, A. & Koivuniemi, J. 2012. An information-exchange perspective on supply chain risk management: systemic organisational motives and cognitive barriers. International Journal of Logistics Systems and Management. Vol. 12(4), p. 460-482.

Vrat, P. 2014. Materials Management: An Integrated Systems Approach. Springer. 408 p.

Wagner, B. & Enzler, S. 2006. Material Flow Management: Improving Cost Efficiency and Environmental Performance. Germany. Physica-Verlag Heidelberg. 206 p.

Wahyuni, D. 2012. The Research Design Maze Understanding Paradigms, Cases Methods and Methodologies. Journal of Applied Management Accounting Research. Vol. 10(1), p. 69-80.

Wasmer, A., Staub, G. & Vroom, R. 2011. An industry approach to shared, cross-organisational engineering change handling - The road towards standards for product data processing. Computer-Aided Design. Vol. 43(5), p. 533-545.

Watts, F. B. 2012. Engineering Documentation Control Handbook: Configuration Management And Product Lifecycle Management. (4.), Boston, William Andrew Publishing. 381 p.

Weber, C., Werner, H. & Deubel, T. 2003. A different view on Product Data Management/Product Life-Cycle Management and its future potentials. Journal of Engineerig Design. Vol. 14(4), p. 447-464.

Worthington, E. Miller, A. & Talley, C. 2011. Action-oriented research: A primer and examples. Journal of Psychology & Theology. Vol. 39(3), p. 211-221.

Yang, J., Han, S., Grau, M., Mun, D. 2008. OpenPDM-based product data exchange among heterogeneous PDM systems in a distributed environment. The International Journal of Advanced Manufacturing Technology. Vol. 40(9-10), p. 1033-1043.

Yang, M., Li, Y. Li, S. & Yuan, Q. 2008. Decision-making process analysis of customer requirements driven cooperated product development and cooperated production control. Prodeedings of the International Conference on Information Management, Innovation Management and Industrial Engineering ICII 2008. Taipei, Taiwan. Vol. 1. p. 254-257.

Young, R., I., Gunendran, A., G., Cutting-Decelle, A.. F. & Gruninger, M. 2007. Manufacturing knowledge sharing in PLM: a progression towards the use of heavy weight ontologies. International Journal of Production Research, Vol. 45(7), p. 1505-1519.

Zenz, G. 1994. Purchasing and The Management of Materials. (7,), Canada, John Wiley & Sons, Inc. 718 p.

Zhang, C. & Zhang, C. 2007. Design and simulation of demand information sharing in a supply chain. Journal of Simulation Modelling Practice and Theory. Vol. 15(1), p. 32-46.

Zwikael, O. & Tilchin, O. 2007. Effective customer requirements management using an information based model. Problems and Perspectives in Management. Vol. 5(4), p. 50-56.

APPENDICES

APPENDIX 1: LIST OF DOCUMENTS AND OBSERVATIONS

DOCUMENTS:
D1: ECN -instruction

OBSERVATIONS:
O1: Time: 11.6.2014 10:00-11:00.

O2: Time: 13.6.2014 13:15-14:15

O3: Time: 17.6.2014 14:00-15:00.

O4: Time: 18.6.2014 09:00-11:00.

O5: Time: 19.6.2014 09:00-12:00.

O6: Time: 24.6.2014 10:30-12:00.

O7: Time: 27.6.2014 09:00:10:00.

O8: Time: 2.7.2014 11:00-11:15.

O9: Time: 8.7.2014 10:30-12:00.

O10: Time: 8.7.2014 13:00-14:00.

O11: Time: 9.7.2014 13:00-14:00.

O12: Time: 14.7.2014-18.7.2014.

O13: Time: 21.7.2014 10:30-12:00.

O14: Time: 23.7.2014 14:00-15:00.

O15: Time: 24.7.2014 12:00-13:00.

O16: Time: 1.8.2014 13:00-14:00.

O17: Time: 4.8.2014 14:15-15:15.

O18: Time: 5.8.2014 10:30-12:00.

O19: Time: 18.8.2014-22.8.2014.

O20: Time: 12.9.2014 13:15-13:30.

O21: Time: 19.9.2014 10:00-11:00.

O22: Time: 13.10.2014-17.10.2014.

O23: Time: 29.10.2014 10:00-11:00.

O24: Time: 11.11.2014 10:30-12:00.

O25: Time: 14.11.2014 13:00-14:00.

O26: Time: 17.11.2014 09:00-10:00.

O27: Time: 27.11.2014 14:00-16:15.

O28: Time: 2.12.2014-5.12.2014.

O29: Time: 8.12.2014 10:00-11:00.

O30: Time: 15.12.2014 08:30-09:30.

APPENDIX 2: MILESTONES OF CAPITAL EFFICIENCY PROGRAM

Table 1. CEP Milestones

APPENDIX 3: TROPICS TEST

TROPICS -test		
	Recommended approach / solution methodology	
	A = "Hard", system-oriented / mechanistic	*B = "Soft", ornizational / complex*
TROPICS Factors		
Time scale	Clearly defined: short to medium	Ill defined: medium to long term
	A	B
Resources	Clearly defined and reasonably fixed	Unclear and variable
	A	B
Objectives	Objective and quantifiable	Subjective and visionary
	A	B
Perceptions	Shared by those affected	Creates conflict of interest
	A	B
Interest	Limited and well defined	Widespread and ill defined
	A	B
Control	Within the managing group	Shared outwith the group
	A	B
Source	Originates internally	Originates externally
	A	B

Figure 4. Tropics -test.

APPENDIX 4: SLOW MOVING INVENTORY BY ITEM DESCRIPTION

Table 5. Slow moving inventory by item description

ITEM DESCRIPTION	ON HAND VALUE- €€	ON HAND VALUE- %	COUNT OF SKU's	COUNT OF SKU's - %
ITEM*	X	X %	X	X %
PART 1	X	X %	X	X %
PART 2	X	X %	X	X %
PART 3	X	X %	X	X %
PART 4	X	X %	X	X %
PART 5	X	X %	X	X %
PART 6	X	X %	X	X %
PART 7	X	X %	X	X %
PART 8	X	X %	X	X %
PART 9	X	X %	X	X %
SUM	X	X %	X	X %
OTHERS	X	X %	X	X %
TOTAL	X	X %	X	X %

Table 6. Slow moving inventory by item's.

ITEMS *	ON HAND VALUE- €€	ON HAND VALUE- %	COUNT OF SKU's	COUNT OF SKU's - %
ITEM 1.1	X	X %	X	X %
ITEM 1.2	X	X %	X	X %
ITEM 1.3	X	X %	X	X %
ITEM 1.4	X	X %	X	X %
ITEM 1.5	X	X %	X	X %
ITEM 1.6	X	X %	X	X %
ITEM 1.7	X	X %	X	X %
ITEM 1.8	X	X %	X	X %
ITEM 1.9	X	X %	X	X %
ITEM 1.10	X	X %	X	X %
ITEM 1.11	X	X %	X	X %
ITEM 1.12	X	X %	X	X %
ITEM 1.13	X	X %	X	X %
SUM	X	X %	X	X %

APPENDIX 5: CASECOMPANY'S ENGINEERING CHANGE NOTICE(1)

Copy of CaseCompany's ECN document page 1/2.

APPENDIX 6: CASECOMPANY’S ENGINEERING CHANGE NOTICE(2)

Copy CaseCompany’s ECN document page 2/2.

APPENDIX 7: PURCHASE ORDER CANCELLATION PROCESS

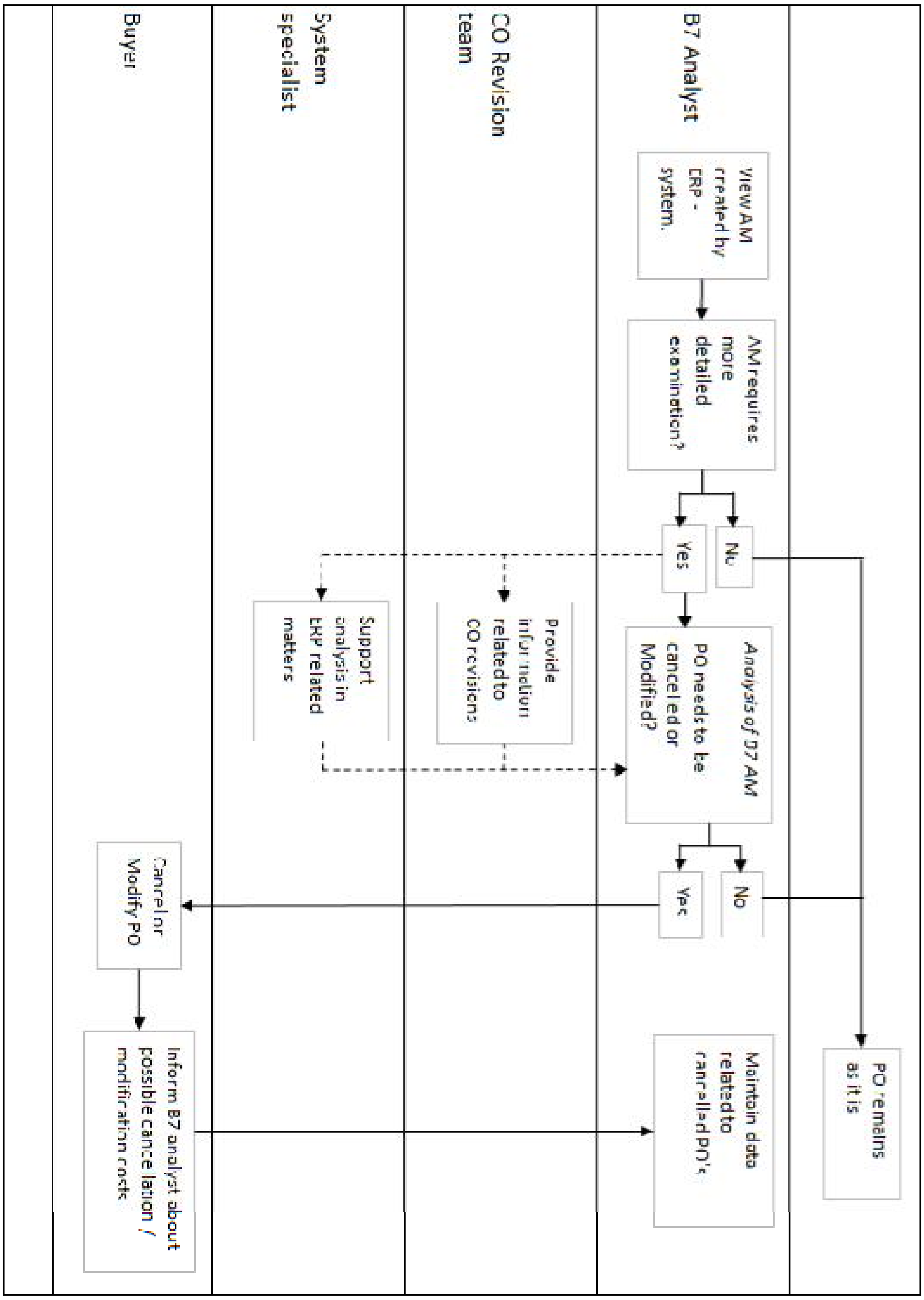

Figure 15. B7- follow up -process in order to cancel purchase orders

APPENDIX 8: INSTRUCTION TO INDICATE TEMPORARY SUPPLIER

Figure 16. Instruction to use M3 PPS040 to indicate a temporary supplier.

APPENDIX 9: RESULT OF OBSERVATIONS

Table 9: Slow moving inventory backgrounds according to observations

	PUR-CHASING	CHANGE MANAGEMENT		PDM		INV. MANA-GEMENT	ERP
OBSER-VATION	Risk Covering	Order's	Product's	BOM	New Item Creation	Lost and founds	SC Issue
W1	x	x	x	x	x	x	x
W2	x	x	x	x	x	x	x
O1	x	x	x	x	x	x	x
O6	x	x	x	x	x	x	x
O2	x	x	x	x	x	x	x
O26	x	x	x	x	x	x	x
O24	x	x	x	x	x	x	x
O23	x	x	x	x	x	x	x
O29	x	x	x	x	x	x	x
O18	x	x	x	x	x	x	x
O19	x	x	x	x	x	x	x
O21	x	x	x	x	x	x	x
O22	x	x	x	x	x	x	x
O3	x	x	x	x	x	x	x
O100	x	x	x	x	x	x	x
O28	x	x	x	x	x	x	x
O69	x	x	x	x	x	x	x
O4	x	x	x	x	x	x	x
Count	x	x	x	x	x	x	x
Frequency	X %	X %	X %	X %	X %	X %	X %

APPENDIX 10: RESULTS OF ENGINEERING CHANGE ANALYSIS

Table 10. Result of ECN **analysis:** ECN**'s that have caused slow moving inventory.**

APPENDIX 11: MATERIAL REVIEW AND DISPOSITION IN GLOBAL DATA CENTER

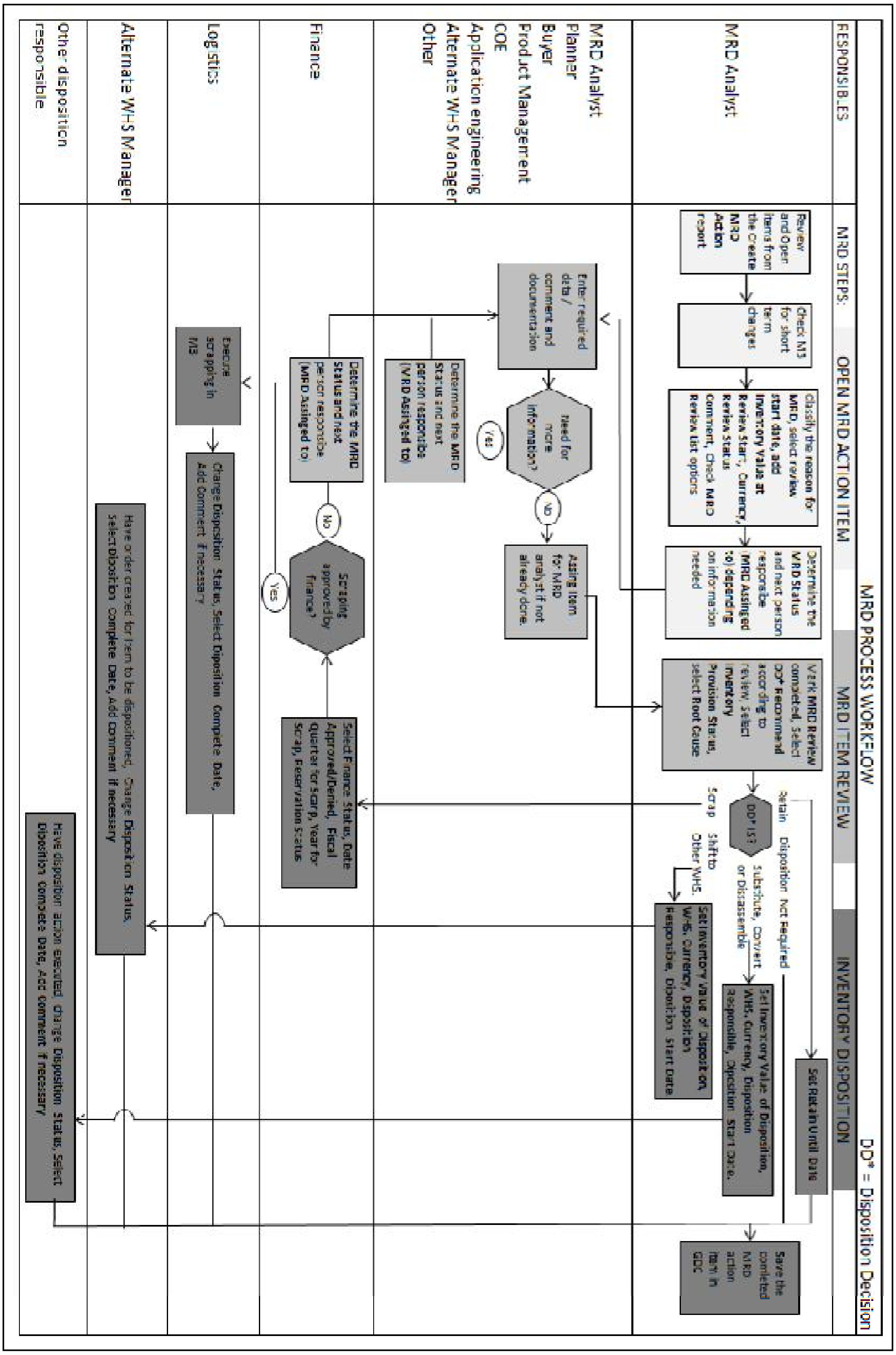

Figure 19: Workflow of the MRD -proces in Global Data Center.

APPENDIX 12: DATA FLOW IN INVENTORY DATA UPDATE

Figure 18. Monthly update cycle between CaseCompanys ERP system, global and local Application A databases and Global Data Center.

APPENDIX 13: MATERIAL REQUIREMENTS DATA CAPTURING AND UTILIZATION

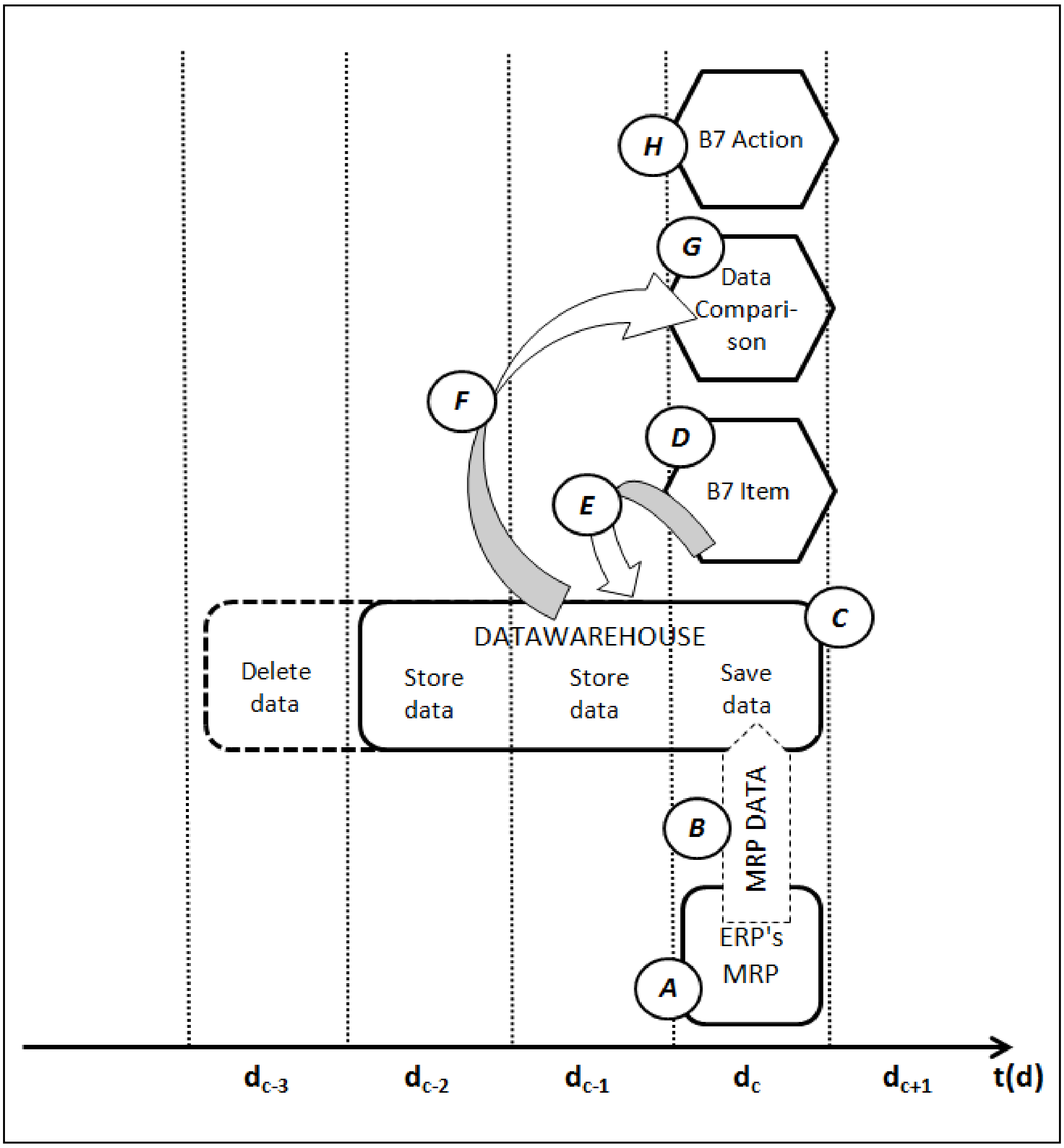

Figure 21: Historical MRP data utilization in order to support dailu B7-Follow-up

Table 12: Description of steps used to utilize historical MRP data to support B7-analysis.

STEP	Description
A	Daily Automated MRP run: Updated data available in ERP system
B	ERP's Data is captured and saved to datawarehouse
C	Data is stored in warehouse for 2 additional days and finally deleted on day Dc-3
D	Due daily B7 -Follow up a new potential cancellable item is recognized
E	Data query for Dc-1 MRP data is made
F	MRP data of DC-1 sent for query initiator
G	Historical and current MRP data data is compared
H	PO is either cancelled or retained