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POTENTIAL OF KANBAN IN THE MANUFACTURING PROCESSES OF CUSTOMIZED PRODUCTS

Master's Thesis in
Operations Management and Logistics

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LIST OF ABBREVIATIONS

ABB's Motors and Generators Business Unit in Vaasa (ABB MoGe)

Asea Brown Boveri (ABB)

Assembly Line 1 (AL1)

Assembly Line 2 (AL2) etc. in ABB MoGe

Association Core Components (ASCC)

Bill-of-Materials (BOM)

Chief Executive Officer (CEO)

Electronic Data Interchange (EDI)

Enterprise Resource Planning (ERP)

First-in, First-out, FIFO

Framework Order (FO)

Information Technology (IT)

Just in Time (JIT)

Made-To-Order (MTO)

Manufacturing Execution System (MES)

Material Requirements Planning (MRP)

Materials Management (MM)

Production Instruction Kanban (PIK)

Production Withdrawal Kanban (PWK)

Purchase Requisition (PR)

Radio Frequency (RF)

Radio Frequency Identification (RFID)

Re-Order Point (ROP)

Return on Investment (ROI)

Supplier Managed Inventory (SMI)

Supply Chain (SC)

Toyota Production System (TPS)

Ultra High Frequency (UHF)

Value-Added Tax (VAT)

Warehouse Management System (WMS)

Work in Process (WIP)

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ABSTRACT:

The thesis is researching the advantages and disadvantages a Kanban system implementation might cause to the material management processes of a manufacturing facility and define the theoretical and/or practical reasons behind these results. On an empirical level the research question is analyzed by participating to a Kanban implementation project at the ABB, Motors and Generator's business unit in Vaasa. Another research problem is to define the possibilities of improving the Kanban system with Radio Frequency Identification (RFID) technology. Since the company utilizes an Enterprise Resource Planning (ERP) system, its functionalities are also considered during the whole study. Research strategy is to collect the data by utilizing academic articles, publications, case studies and material obtained during the employment at the case company and the Kanban implementation project. Research methods are a combination between structural, qualitative, and quantitative approaches.

The key findings of the study are concluding that all the resources were complimenting the Kanban system as a part of operations and inventory reduction, and RFID technology enables the enhancement of the Kanban system currently being implemented. The company's ERP system is able to perform automatic Kanban calculations in order to define parameters for improved production control. These calculations can also be done without the system and appropriate mathematical formulas are introduced and utilized. The Kanban system is not a magical solution for all the problems related to manufacturing customized products, but with a pull system and the Lean concept, it offers a significant improvement for the production operations and inventory management.

KEYWORDS:

Kanban, Manufacturing, RFID, Lean, In-house Logistics

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TIIVISTELMÄ:

Lopputyö tutkii etuja ja haittoja, joita Kanban-järjestelmän käyttöönotto saattaa aiheuttaa materiaalinhallinnassa tuotantolaitoksen prosesseissa sekä määrittää teoreettisia ja/tai käytännön syitä näihin tuloksiin. Empiirisellä tasolla tutkimuskysymystä on analysoitu osallistumalla Kanbanin käyttöönotto-projektiin ABB:n Moottorit ja generaattorit liiketoimintayksikössä Vaasassa. Toinen tutkimusongelma on määritellä mahdollisuudet kehittää Kanban-järjestelmää hyödyntäen radiotaajuustunnistus-teknologiaa. Koska yrityksellä on käytössä laaja toiminnanohjausjärjestelmä, sen toiminnot ja rajoitteet on myös huomioitu tutkimuksen aikana. Tutkimusstrategia on kerätä taustatietoja käyttämällä akateemisia artikkeleita, julkaisuja, yritystapaustutkimuksia ja toimeksiannon sekä Kanban-projektin toteutuksen aikana kohdeyrityksessä kerättyä aineistoa. Tutkimusmenetelminä on käytetty yhdistelmää konstruktiivisesta, kvalitatiivisesta ja kvantitatiivisesta lähestymistavasta.

Keskeiset tutkimustulokset paljastivat yhtäältä, että kaikki lähteet tukivat Kanban-järjestelmän hyötyä osana tuotannon toimintoja ja varastotasojen vähentymistä sekä toisaalta, että radiotaajuustunniste-teknologia mahdollistaa projektin aikana käyttöönotetun järjestelmän kehittämisen. Yrityksen toiminnanohjausjärjestelmä pystyy suorittamaan Kanban laskelmia automaattisesti ja määrittelemään parametrit parantamaan tuotannonohjausta. Nämä laskelmat voidaan tehdä myös ilman järjestelmää ja asianmukaiset matemaattiset kaavat esitellään ja niitä hyödynnetään. Kanban-järjestelmä ei ole taianomainen ratkaisu kaikkiin mukautettujen tuotteiden valmistukseen liittyviin ongelmiin, mutta tuotannon imuohjaukseen ja Lean-konseptiin yhdistettynä, se tarjoaa merkittävän parannuksen tuotannon prosesseihin ja varastonhallintaan.

AVAINSANAT:

Kanban, Tuotanto, Radiotaajuustunnistus, Lean, Sisäinen logistiikka

1. INTRODUCTION

The Kanban system is one of the Japanese manufacturing methods created by Toyota (Olsson 2012) Motor Corporation. It is part of the Lean concept that aims to optimize production processes. These methods create most advantages, when they are applied to a manufacturing facility that operates according to a pull control. Thus the production is phased according to the actual demand in the right time (Slack, Chambers, Johnston & Betts 2009: 362). The motivation for the research was created within the employment organization that had demand for a Kanban implementation project. An additional benefit for the author was being able to deepen the knowledge of Lean manufacturing concept and different kinds of Kanban systems both in theory and in practice.

1.1 Purpose and Background of the Study

The report researches the actual potential of Kanban system in the inventory management and the manufacturing processes of customized products based on the theory and real business life case studies. The aim is to objectively outline the advantages and disadvantages of implementing the Kanban system and define the theoretical and/or practical reasons behind these results. The research area includes, but is not limited to, Industrial Management, Operations Management, Logistics and Kanban. The literature review consists of academic articles retrieved via EBSCOhost and ScienceDirect, publications available at academic library of Tritonia, eBooks and case studies from various Internet sources and additional classified business materials of the employer company involved.

The purpose of the study is to support a Kanban system implementation project at the ABB Group, Motors and Generator’s business unit in Vaasa (ABB MoGe) by offering feedback and improvement suggestions during the weekly project meetings based on the practical knowledge gained during the employment periods at the company and theoretical research being conducted from various resources during the thesis employment. An additional goal of the study was to design an application model for upgraded version of the Kanban system being implemented during the current project by utilizing RFID technology.

1.2 Research Challenge and Problem Definition

ABB MoGe aims to optimize the materials management, order replenishment and/or inventory control management processes to achieve lower inventory levels, improved material receiving efficiency and faster stock turnaround times, the chosen research problem is to define a type of Kanban system that is able to reach these goals. In order to be able to solve the problem, it is vital to operate according to the research questions defined below:

- What potential advantages and disadvantages a Kanban system implementation might cause to the material management processes of a manufacturing facility?
- Could the defined Kanban system be improved with RFID (Radio Frequency Identification) technology?

The proposed outcome of the research is that a Kanban system, if implemented properly, will assists in materials management related processes at ABB MoGe and plays an important role in further developing the Logistics functions related to the production. An additional hypothetical end result is that RFID technology is able to reduce human errors and improve efficiency during the order replenishment and inventory control management processes. Toyota revolutionized several production practices and created a highly efficient manufacturing environment with its Toyota Production System (TPS) (Bergenwall, Chen & White 2010: 374). Therefore, it can be expected that these principles are efficient also in other facilities regardless of the products.

1.3 Structure of the Study

The structure of the study is following the general guidelines of academic writing, it can be divided into four central sections: Introduction, Methods, Results and Discussion. (Luokkakallio 2012: 2). The research paper consists of six main chapters. In addition to Introduction and Conclusions these include: Kanban and Kanban System(s), Kanban Case Studies, Kanban Implementation at ABB MoGe and Future Kanban Application Design for ABB MoGe. Main chapters and numerous subchapters are carefully chosen for achieving a balanced entity and to reach a better understanding of Kanban and the Kanban implementation case project and the system modifications, such as SAP Kanban installation.

A rough timetable for the thesis employment is from the beginning of September, 2012 until the end of March, 2013. The literature search and analysis, collection of empirical material and analyses of the empirical material were conducted gradually, but also according to the project schedule and the requirements of the In-house Logistics team.

1.4 Research Methods

A research strategy is to collect the data by utilizing academic articles, publications, eBooks, case studies and additional materials obtained during employment at the case company and weekly meetings held during the Kanban implementation project. Analyzing methods within the Kanban implementation project include defining: relevant bill-of-materials (BOM) components, demand frequency of materials, categorized ABC materials, optimal batch and/or order sizes, production work center areas, assembly lines' structure, warehousing infrastructure and potential key suppliers for Kanban system implementation. Prior to the current project, ABC materials have been defined based on ABC analysis that is explained in a subchapter of the thesis. BOM materials are also known previously and Kanban materials are selected from them. Part of the project are also employees' training, changes related to the infrastructure, hardware, software and warehouse area organization, implementation in practice, piloting stage, application launching, final results and possible modifications. All of the activities are not described in detail in the thesis for protecting the company's confidentiality and because they are not entirely within the core scope of the thesis. Moreover, the study is mainly structured around Kanban and only the key elements are defined and included.

The research methods of this study are a combination between structural, qualitative, and quantitative approaches. Lukka (2013) describes structural research method as innovative and practical, since it creates and molds knowledge via individual thinking process based on researched findings and analyses between theoretical and empirical information. Its main goal is to define solutions for actual, real life research problems. Case studies are one form of structural research. (Lukka 2013.) Qualitative research approaches problems via empirical methods and quantitative research is conducted based on statistical data and figures. The empirical method is to analyze the case studies objectively and to define, whether the Kanban system generally improves the overall production processes and inventory management in manufacturing facilities based on the theory and experiences of selected companies. Quantitative research is based on data obtained from the sources and the ERP system of ABB MoGe. Additional calculations are completed with figures of actual components used in the company's manufacturing.

2. KANBAN AND KANBAN SYSTEM

As a side comment: The term Kanban is quite freely used both as a card and as a system, thus in this thesis they are differentiated by using kanban, when referring to a card (or other type of kanban signaling form) and Kanban with a capital K, when a system or the whole concept is meant. However, at times these might be mixed because of capitalization rules or other grammatical reasons.

Kanban is a Japanese term meaning card or signal. In manufacturing its purpose is to signal the demand of components for different stages of production processes and thus operate as an ‘invisible conveyor’ between them. Kanbans are used to trigger the movement, production, or supply of fixed amount or batches of components required for manufacturing operations. The Kanban system is used to operationalize a pull control, which main idea is to synchronize the production exactly with real customer demand. It is a vital feature for lean concept, since the amount of ‘waste’ created during the production processes is minimized. (Slack et al. 2009: 362.) According to Lean thinking, waste has several forms, such as inefficient labor time, malfunctioning machines or equipment, overproduction, and high inventory levels. If something wastes time, money, or resources, it is considered to be a waste for the production processes and thus needs to be eliminated or at least minimized. (BusinessKnowledgeSource.com 2010).

Naufal, Jaffar, Yosoff and Hayati (2012: 1721–1722) define Kanban system as an inventory stock control system. Its main function is to trigger a signal of a product for production, thus instructing a correct action needed to proceed according to customer requirements. Kanban system is not a traditional manufacturing strategy based on customer forecast, such as ‘Push System’. On the contrary, it aims to minimized inventory levels and is actually a type of pull manufacturing system. By transforming operations from push into pull method, it is possible to prevent high WIP (Work in Process) inventories, unsynchronized production processes and unnecessary production of excess stock. Most researchers support a statement suggesting that lead time reduction and manufacturing excellence could be reached via Kanban system implementation. (Naufal et al. 2012: 1721–1722.) Kanban can also be described as Japanese production principle that utilizes fixed quantity boxes for controlling raw material procurement via using the empty boxes as ordering signals. (ABB Inc. Press Release, RFID Lab Finland ry 2005: 5.)

According to Naufal et al., Kanban systems function by utilizing cards (2012: 1722). Based on vision of the author of this thesis, Kanban card is operated as a similar type of ‘tool’ in production than a dam in a river. Dams are used to regulate the flow and amount of water in different river sections to prevent flooding or draught, if the adjustments are done correctly the flow is smooth and even in each section. As a comparison to manufacturing, once material flow operated with Kanban cards is as synchronized, production bottlenecks and inventory stock-outs will be prevented, which in turn leads to increased efficiency and productivity in different processes or assembly line sections and work centers.

Naufal et al. (2012: 1722) proceed to explain that there are two types of Kanban systems; single card and two card. Single card Kanban system operates by using a Production Instruction Kanban (PIK) card that triggers upstream production based on the downstream demand. Two card Kanban system utilizes also an additional Production Withdrawal Kanban (PWK) card, which is for withdrawal of required components based likewise to PIK on downstream demand from the stock of manufacturing facility itself or suppliers’ inventory. (Naufal et al. 2012: 1722.)

However, the author of this thesis is slightly disagreeing with Naufal et al. relating to the theory described in the previous paragraph. The author believes, it should also be noted that single card Kanban system does not necessarily have to be based on PIK card. Moreover, it could actually be argued that implementing a single card Kanban system for PWK card is a better option for manufacturing facilities that have a vast supplier network and a nonexistent or trivial internal component production.

Basically, Kanban is a rather simple parts movement system depending on cards and boxes or containers. Only these will trigger the movement, order, or production of the required components because an empty storing unit and a Kanban card are signaling that the specific parts have a quite urgent demand at an informed assembly line. The Japanese Kanban management system is more complex, and the previously described ‘visual record’ procedure is merely a sub-process. (Olsson 2012)

Olsson (2012) states the following advantages of the Kanban process in production:

- A simple and understandable process
- Provides quick and precise information
- Low costs associated with the transfer of information
- Provides quick response to changes
- Limits over-capacity in processes
- Avoids overproduction
- Minimizes waste
- Control can be maintained
- Delegates responsibility to line workers (Olsson 2012.)

Furthermore, Kanban can be effectively used for continuous improvement of the manufacturing process and to define the bottlenecks and problems behind them. Rationalizing the production operations via Kanban will assist in reducing waste and therefore, supports the Lean concept as well. (Olsson 2012)

The roots of the Kanban system are at Toyota and its assembly line based automotive manufacturing. The Kanban as a materials management tool of production was created already in the 1950s. More recently during the last thirty years, the Kanban has developed rapidly and is nowadays a significant part of optimized manufacturing environment, which has a major effect on competitiveness of the companies even on a global scale. (Olsson 2012.) According to Bergenwall et al. (2012: 382–383), TPS process design is based on seven key principles and practices:

1. Create continuous process flow to bring problems to the surface.
2. Use pull systems to avoid overproduction.
3. Level out the workload (heijunka).
4. Build a culture of stopping to fix problems, to get quality right the first time.
5. Standardized tasks are the foundation for continuous improvement and employee empowerment.
6. Use visual control so no problems are hidden.
7. Use only reliable, thoroughly tested technology that servers your people and processes. (Bergenwall et al. 2012: 382–383).

These practices are gradually able to provide highly improved operation, if the principles are implemented correctly to complement each production facility's current situation and processes. According to Slack et al. (2009:297) two-bin and three-bin Kanban systems are rather straightforward. In the simplest case, there are two storing bins that each have same amount of parts for production. The second bin is used to store the reorder point quantity and the safety stock quantity, while the first bin's content is being used for production. After getting emptied, it operates as a kanban signal for the next reorder quantity replenishment order. This type of system can be modified and two or three bins can be replaced by one, if the content is differentiated and it is clearly visible, when the reorder point is reached. (Slack et al. 2009: 297.)

2.1 Designing Kanban System

Gross and McInnis (2003: 86) state that it is a common misconception to assume, it is enough to define the size of Kanban and become prepared to implement. In fact there are four (4) main steps for successfully implementing the Kanban system. Firstly, one needs to set container quantities, secondly, develop the design, thirdly, utilize the design and lastly, train the design for employees involved in the operation. The design itself ought to be considered based on three factors: selection of the signaling mechanism, definition of the rules for operation and creation of the visual management plans. All three of these should be defined based on the Kanban viewpoint of the planned application for the company's needs. (Gross et al. 2003: 86.) Naufal et al. (2012: 1722) offer more theoretical viewpoint and suggest developing Kanban system based on a method with three key elements. Firstly, relevant parameters are gathered, secondly, total number of kanbans is calculated and lastly, pull mechanism and rule are established (Naufal et al. 2012: 1722).

Kanban calculations define the optimized quantity of kanbans in the planned system. Relevant production parameters required for these calculations are:

- Cycle time
- Withdrawal time
- Kanban waiting time
- Replenishment time
- Part variance
- Safety stock amount
- Container capacity
- Customer demand per material.

These parameters are gathered from sources, such as company's production department, 'shop-floor', history record and customer forecast. For example, the number of PWK cards can be computed based on a formula (1):

$$PWK=(D+K_w+\alpha)/c \quad (1)$$

The variables used in the above calculation, are quantity of customer demand (D), kanban waiting (K_{w}), safety stock (α) and container capacity (c). After the calculations, Kanban flow is visualized and Kanban rule created in order to assist production personnel to adapt the transition into a Kanban system. In this case, the Kanban system implementation is for a manufacturing company that operates based on a push system, thus the customer demand is gathered from a forecast and not from an actual data. (Naufal et al. 2012: 1722–1723.) Another formula for calculating optimized number of kanbans is presented below. In formula (2) d is average demand per hour, L is lead time in hours, S is safety stock amount and C is container quantity of material. D and L do not need to be hours, however, they have to be same time unit or the formula does not function. (Lean Sigma Supply Chain 2013.)

N=(dL+S)/C (2)

In the case of a standard Kanban solution, the SAP is utilizing the formula (3) below for counting the number of kanbans for materials within the system. Most of the data is defined into the control cycles of the Kanban materials. (SAP AG. 2013). RT is replenishment lead time per kanban, AC is average consumption per time period, Cont is contents per kanban (quantity of material units in a container), SF is safety factor (or Z factor that most commonly is 1.64 for 95 percent standard distribution) and C is constant (SAP's default is 1). (Lean Sigma Supply Chain 2013). Another formula that SAP uses is for counting the best fixed quantity of components in one kanban box or other container. With this formula (4) on the next page, the kanban quantity needs to be available beforehand. The variable descriptions and acronyms are similar to the formula (3). (SAP AG. 2013). For defining a safety stock or safety factor, a coefficient C is needed. It is calculated based on service level percentage that is selected based on the required security level against stock outs. Example percentages are 90.0, 95.0, 99.0 and 99.9; their corresponding coefficients are 1.28, 1.64, 2.33 and 3.09. (Baudin 2012.)

K=((RT*AC)/Cont)*(SF+C) (3)

Cont=((RT*AC)/(K-C))*SF (4)

Figure 1 below illustrates the Kanban startup phases according to Gross et al. (2003: 138). Determining the current state of the process at the company is emphasized and a vast research is made of the present process. The information of process description, amount of scrap (raw materials, component or product wastage), production rate, changeover time, and process downtime is gathered and analyzed. Based on the current state, the most suitable kanban quantities are calculated. After the calculation stage is complete, designing the Kanban takes place. It is an important step that needs to be planned carefully according to the company's requirements and possible limitations. Before implementing the Kanban system, everyone involved must be trained of the new materials management tool and its operation in practice. (Gross et al. 2003: 138.)

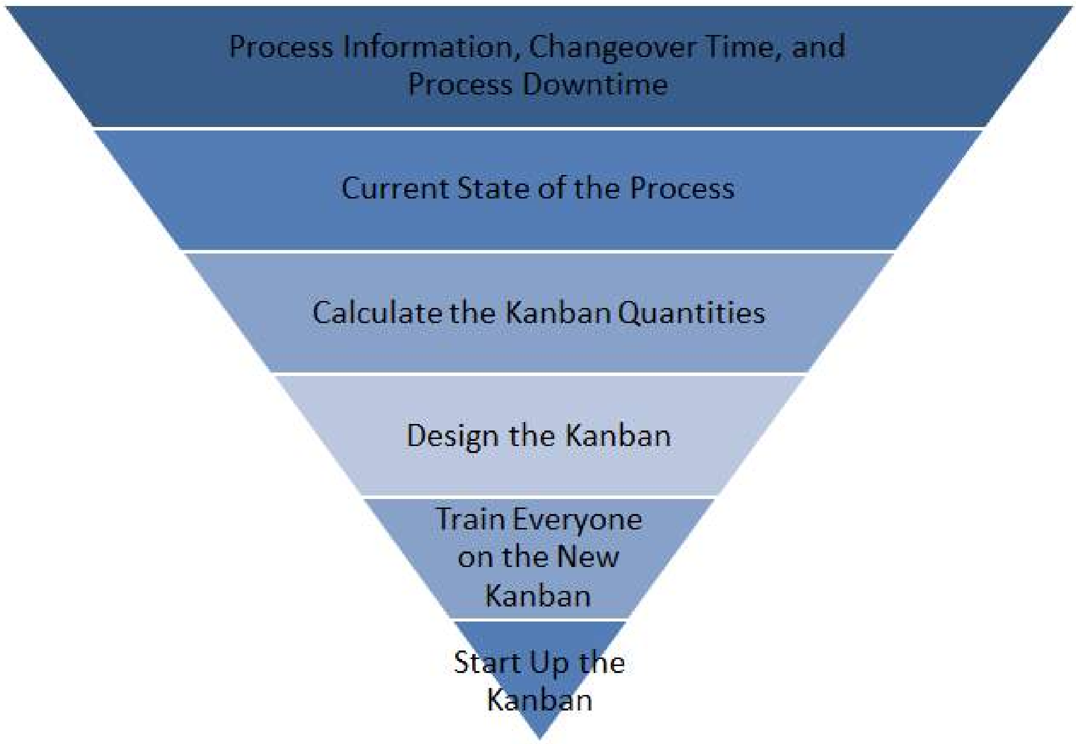

Figure 1 *Modified Kanban Process Flow (Gross & McInnis 2003: 138.)*

A Kanban system can have several forms, but regarding a production operation it has two main functions in refilling the stocks. Firstly, signaling processes to produce components and secondly, informing material handlers to move components. These function types are called production kanban and withdrawal kanban, or make kanban and move kanban. (Lean Enterprise Institute, Inc. 2009) Juntunen (2012: 6) defines Kanban systems under two main categories: Single card Kanban and Dual card Kanban. The first one has two subcategories: Product Kanban and Generic Kanban (Juntunen 2012: 6.) These are described in more detail in upcoming subchapters.

2.1.1 Kanban Cards

The most common form of Kanban is believed to be the use of kanban cards. This is mostly because the founder company of Kanban concept, Toyota, is using kanban cards as their means of signal in the Toyota Production System. However, there are also reported disadvantages related to them that cannot be overlooked. The most obvious ones are losing, misplacing or mismanaging the cards. (Gross et al. 2003: 90.)

Basically, kanban card is a piece of paper, often in a protective sleeve, traveling attached on or placed inside the kanban material container. The card contains information of the part number or material code, and the fixed batch or order amount of the container. It might have additional or more specific information as well. The main function of the card is to signal the interval and form of action that production or material handler operators need to take. The aforementioned signal occurs, when the card is pulled from the container and placed in a cardholder rack or Kaban post to inform of the consumption of the kanban parts, while the container is being moved to an assembly line or other type of production work center for usage. The kanban cards in a cardholder or post are acting as triggers that signal to the In-house production or Procurement of a demand for a restocked container. (Gross et. al 2003: 90–92.) Gross et al. (2003: 90) determines that “The kanban card serves as both a transaction and a communication device." Figure 2 below visualizes an example of a kanban card for ordering parts.

Part Number:	*80800-14898*
Part Name:	10 V Power Supply
Supplier:	Smith Electronics
Vendor Number:	133345
Container Type:	Plastic 12 × 14
Container Quantity:	20
Delivery Interval:	Daily
Storage Location:	Portable Radio Line
Production Operation:	50
Bin Location:	C-3
Delivery Location:	Dock 5

Figure 2 *Kanban Card used for Ordering Parts between Supplier and Customer (Gross & McInnis 2003: 91.)*

Single card Kanban system is the most traditional and popular one to be implemented. This is partly because it is suitable for majority of production facilities that have a stable manufacturing environments and repetitive production. Furthermore, it is relatively easy to implement and adapt. Single card Kanban's two subcategories are Replacement Kanban and Capacity Kanban. The first one follows strictly the pull system principles and component production is authorized only, if there is an actual need and signal or call for the specific component. Similarly with all Kanban systems also the latter operates based on actual demand, however, the component is not specified with kanban, but has another system for more exact information flow. This Kanban system is suitable for a production facility with a wide variation of in-house manufactured components with similar routings and time requirements between different workstations. As a conclusion, generic (or capacity) Kanban has less WIP inventory than product (or replacement) Kanban, but the response time to the signals is longer. (Juntunen 2012: 6)

2.1.2 Look-See

Look-see is a form of Kanban that relies on visual signals in replenishment. There are several types of variations from floor markings and signs to flow lanes and racks. The main idea is to be able to detect at a glance via eyesight, when the kanban materials need to be replenished. It is recommendable to implement a Kanban system that is at least partly dependent on visual characteristics. Similarly than with kanban cards, a container can be used as a kanban signal. In this case, however, the queues formed by the containers in a Kanban loop are evaluated based on the fixed quantity and the alarm limits, which determine the signal color. Figure 3 on the next page clarifies the operation of a Look-see Kanban system with container lines used as the signal. Yellow is an impulse to start operations to restock and works as a scheduling signal. Red means that a stock-out is occurring shortly and the situation requires immediate attention and action. Logically, green indicates that the inventory level is on a satisfactory level. (Gross et al. 2003: 94–95.)

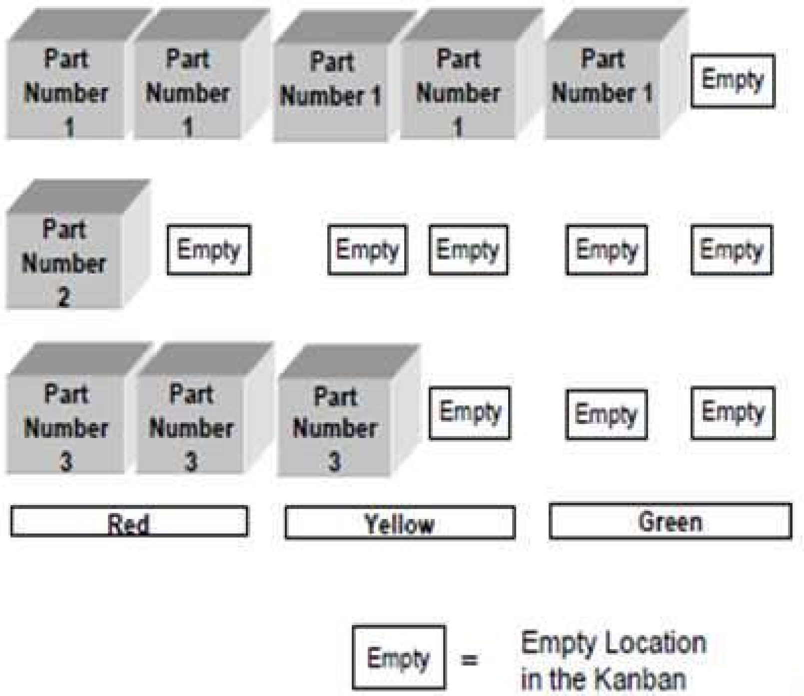

Figure 3 *Look-See Kanban as a Scheduling Tool (Gross & McInnis 2003: 94.)*

2.1.3 Kanban Boards

The kanban boards are a variation of the kanban cardholder racks, but the signal cards are replaced by magnets, plastic chips or other suitable objects. Likewise to the cards, these symbolize a unit of components in inventory. (Gross et al. 2003: 98.) In my opinion, the kanban board is basically utilized in the considerably similar manner than playing a board game with a couple of friends and following the rules. However, instead of throwing a random number with a dice and moving one's (game) piece accordingly, the inventory levels are constantly being supervised and the signal objects are moved around the kanban board based on the container's physical movement inside the factory.

In Figure 4 on the next page, possible movements between awaiting production and completed work in process on its specific part number and style rows are shown. The production or movement decisions are made according to the visual management based on the magnet board and the rules that are followed in operating the kanban board. (Gross et al. 2003: 98.)

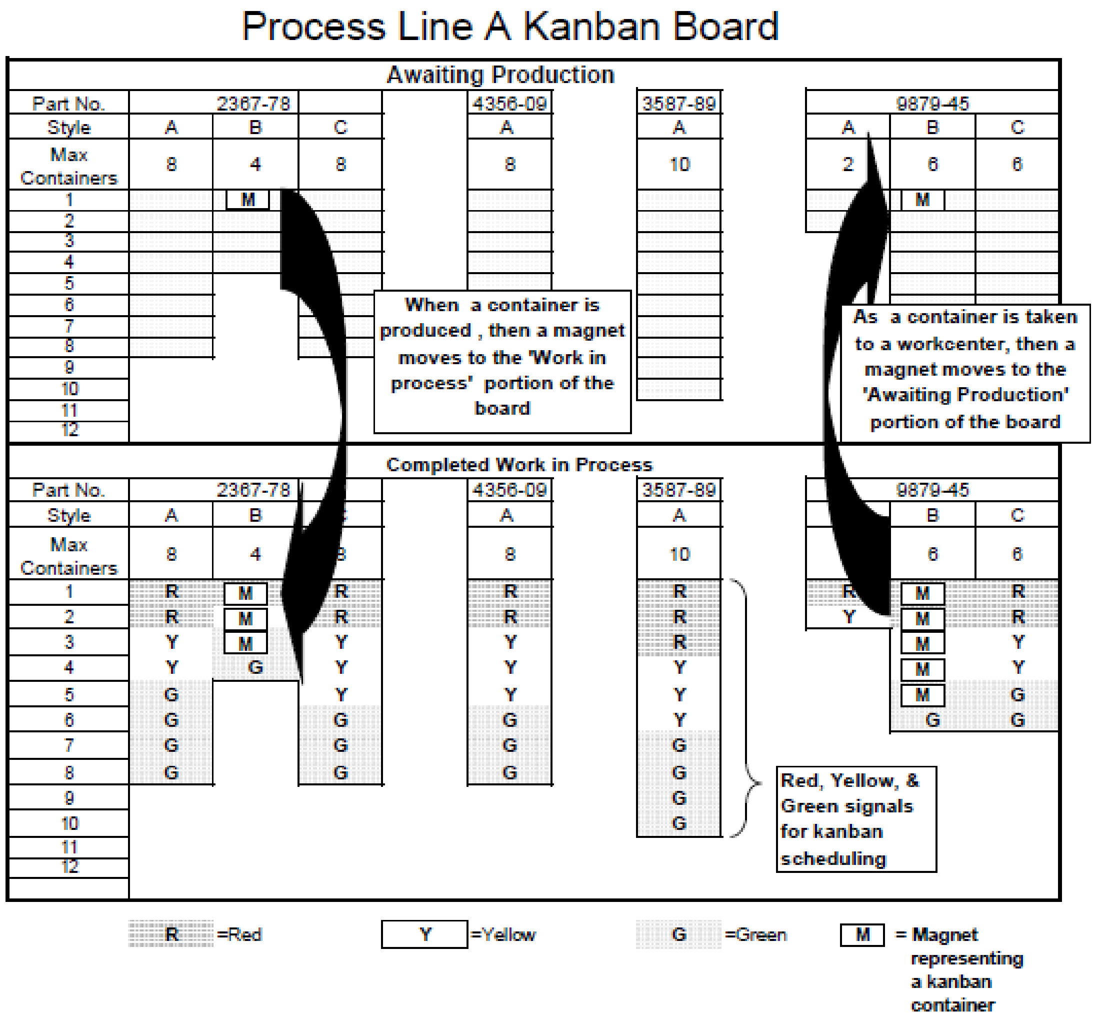

Figure 4 *Set-up and Operation of a Kanban Board with Magnets (Gross & McInnis 2003: 99.)*

Figure 5 on the next page demonstrates a type of kanban board operated with plastic chips. The layout is different, but the operating principle is similar to the magnet board. (Gross et al. 2003: 98.) In the examples, production (or make) kanban materials' process flows are illustrated. The materials' movement is similar, when withdrawal (or move) kanban materials' are managed on the board.

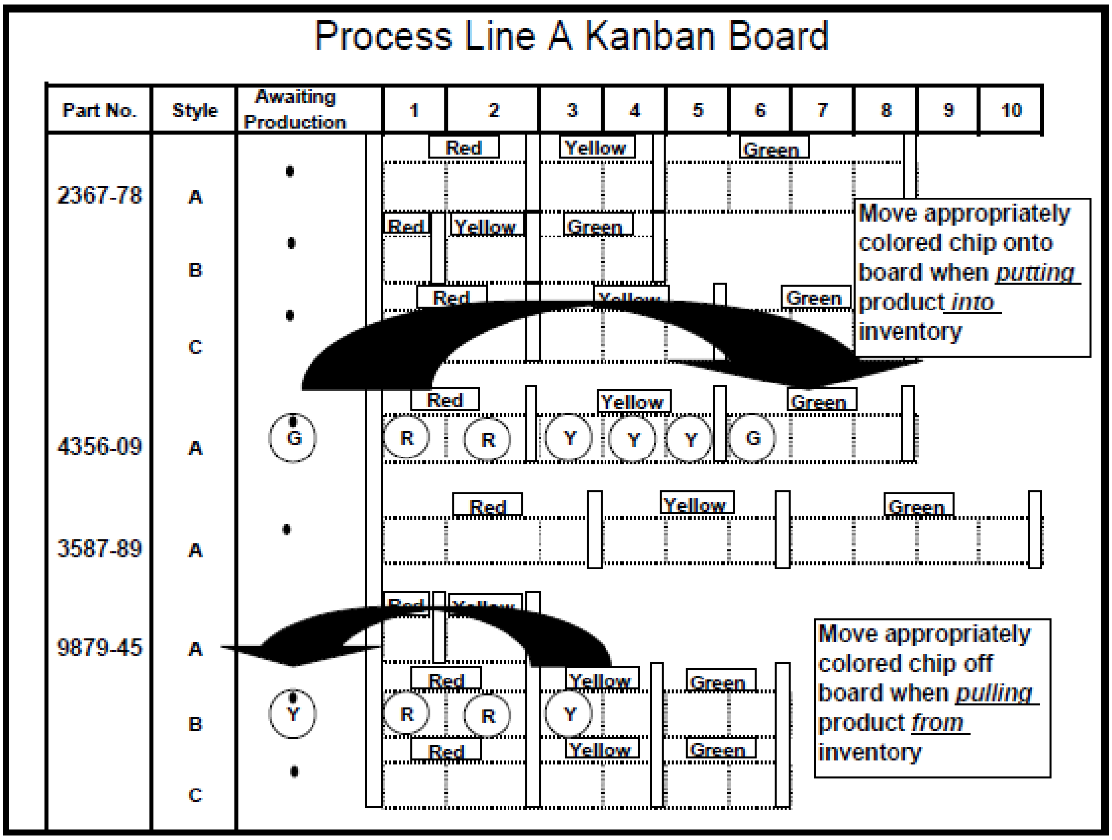

Figure 5 *Set-up and Operation of a Kanban Board with Plastic Chips (Gross & McInnis 2003: 101.)*

2.1.4 Two-Card System

A two-card Kanban system is a hybrid of the Kanban board and the Kanban cardholder racks. As the name entitles there are two cards assigned for each kanban box, container or pallet. These inform the material handlers of the storage location inside the factory and the time the container's content was produced or received. This form of Kanban is intended to use in a manufacturing environment that in addition to managing the materials movement and production scheduling, requires assistance for supervising product rotation. The two-card system operates simultaneously with a Kanban card rack and a FIFO (first-in, first-out) box. It is recommended to be utilized for floor stacked items and even pallet sized items. However, it is especially vital to maintain the system according to detailed rules and the operators need to be trained thoroughly before implementation. Figure 6 below demonstrates an example of the possible Kanban cards that can be operated in a two-card system. (Gross et al. 2003: 99–101.)

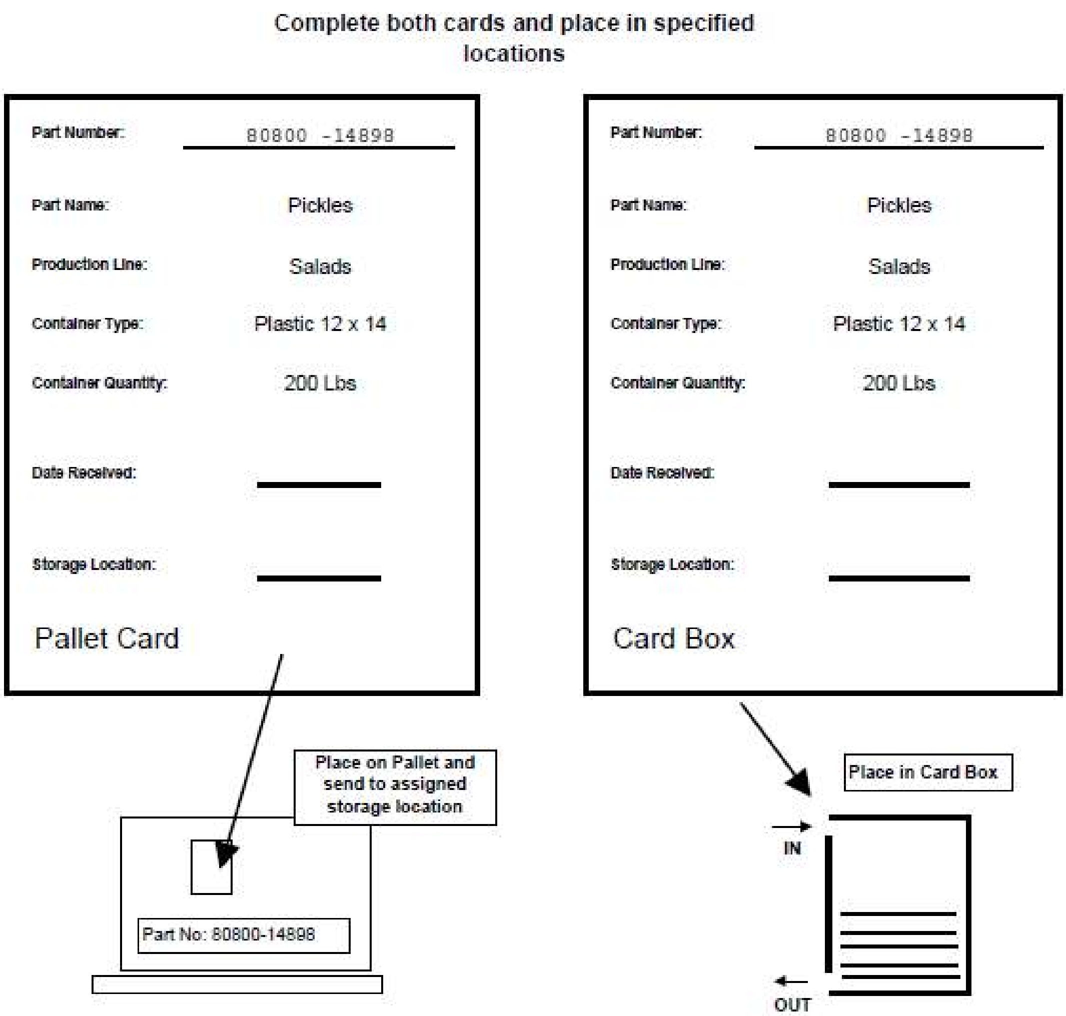

Figure 6 *Kanban Cards used for a Two-Card System (Gross & McInnis 2003: 103.)*

2.1.5 Faxbans and Kanban E-mails

Faxbans and Kanban E-mails are based on the Kanban card model, but allow wider and faster communication within larger plants and between the factory and off-site warehouses or vendors. In this type of Kanban solution, the operators need not to physically be alongside the cards or containers, but they are sent via fax or emailed to the destination. The main guideline is to operate according to a preset replenishment notification time and by utilizing a sheet form or template, which has been determined in cooperation between business partners. These procedures allow the process proceed smoothly and without misinterpretations. Since the system is fast responsive, Faxbans or E-mails are most optimized for deliveries that are to occur frequently, therefore, the ordering cycle is less than a week and often even under a day. By conducting preplanning and coordination thoroughly shorter lead times are obtained via cutting through purchasing organizations bureaucracies. One of the main drawbacks is that the system relies heavily on key personnel and might be unreliable during their absences. In Figure 7 on the next page an example of an ordinary Faxban sheet consisting of all the necessary information, is shown. (Gross et al. 2003: 101–104.)

Smith Brothers Manufacturing
10101 ABC Street
St. Louis, MO 76890

Date: ____________________

24 Hour Delivery Faxban Order Sheet—
Please deliver quantity ordered for tomorrow to the dock door listed at the specified time. If you have any questions, then call Jack Jones, Purchasing Manager, at (555) 555-5555.

Vendor: Acme Supply
Fax # 555-444-4444

Please ship the following items:

1. 6—100 Foot coils of #12 Wire, red insulation
2. 4—Cartons of P/N 234567 switches.
3.
4.
5.

Deliver to: Dock door 7
Delivery Time: 8:30 AM

Figure 7 *Typical Sheet for Faxban (Gross & McInnis 2003: 104.)*

2.1.6 Electronic Kanban

Electronic Kanban is an upgraded version of the Faxban and the restrictions to key personnel are removed by automating the replenishment process, thus the system is able to transmit requirements automatically. Electronic Kanban could also enable suppliers to monitor the customer’s inventory level and deliver replacements accordingly. These systems are usually customized for large companies conforming to their existing applications. The implementation process can be demanding, despite the fact that the electronic Kanban itself is not a complex system. The suppliers involved need to be assisted properly and they must be able to receive an access to the system. (Gross et al. 2003: 105.)

2.1.7 Warehouse Racks

Warehouse racks can be used as Kanban signaling method, if the system is combined with another more operational and reliable materials management tool. Since warehouse racks used as Kanban is basically a look-see system, any of the other form of Kanbans can be utilized for system enhancement from the visual management viewpoint. The goal is to maintain the inventory levels of the items in the storage racks. In addition, it is possible to manage optimized rotation of products, but the Kanban system's layout must be planned carefully. While considering large storage spaces, warehouse racks are recommended to be paired with an electronic Kanban, since the performance of this application is most synchronized. However, electronic Kanbans might become expensive because of their uniqueness and potentially high implementation expenditures. (Gross et. al 2003: 105–106.)

2.1.8 Move/ Production Kanban

Move/ production Kanban is, as its name entitles, a combination of these two. It is best utilized in a production facility that manufactures components for its own production. Move/ production Kanban is used for the communication between these different types of workcenters. Several workcenters order components by utilizing a Kanban signal from the storage for their end product manufacturing and fewer workcenters produce components for storage according to received Kanban signals. The signals used are move or production Kanban cards that are delivered between the specified parties. Figure 8 on the next page illustrates the steps during a replenishment process with the move/ production Kanban. Workcenter B requires components and Workcenter B produces them. In between is storing area that can be a warehouse or so called supermarket linked to the Kanban system. (Gross et al. 2003: 106–107.)

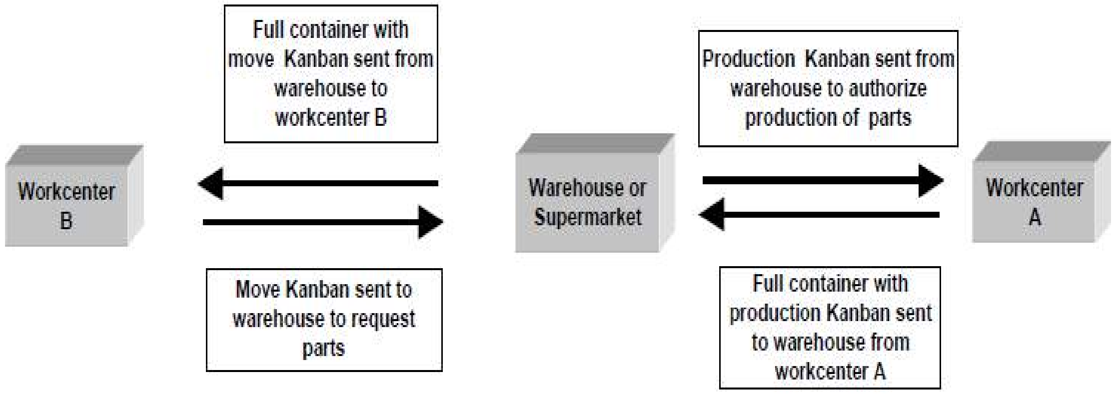

Figure 8 *Move/ Production Kanban Process Steps (Gross & McInnis 2003: 106.)*

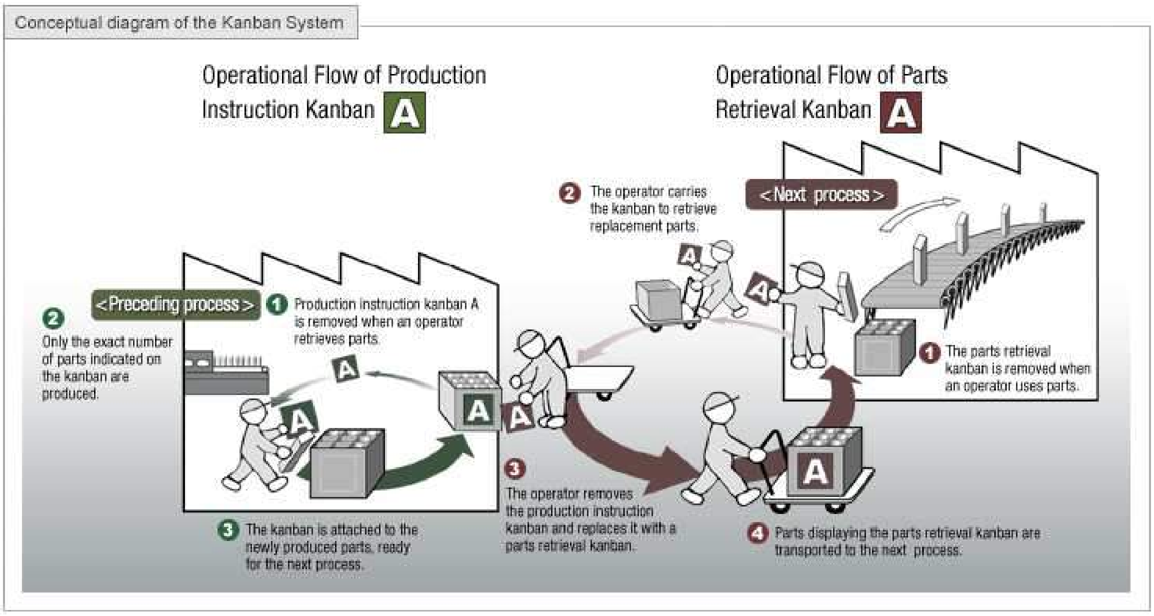

Figure 9 *Production Instruction Kanban and Parts Retrieval Kanban (Toyota Motor Corporation 2013).*

Figure 9 on the previous page is another detailed image of these Kanban systems. However, in Toyota Motor Corporation these are called Production instruction Kanban and Parts retrieval Kanban systems (2013). Juntunen (2012: 7–8) introduces yet another name for the system combination and it is called Dual card Kanban system. He highlights that one of the system's benefit is its ability to provide a possibility for lot splitting, thus the transfer batch size could be in smaller quantity than the production batch size is (Juntunen 2012: 7–8).

2.2 MRP vs. Kanban

According to Hyoung-Gon, Hong-Bum, Kitae, Han-Il and Park (2007: 309), material requirement planning (MRP) utilizes the master schedule, bill of materials (BOM) and inventory records in order to generate synchronized data of production and purchase orders. MRP is a time-phased production planning tool, but has its limitations for real time planning (Hyoung-Gon et al. 2007: 309). Mula, Poler and Garcia enlighten that MRP systems are commonly used in challenging manufacturing environments, which operate with complex BOMs having numerous components and rather demanding production processes consisting of multiple work stages (2005: 74). They are used for planning and decision making regarding production and material supply (Mula et al. 2005: 74).

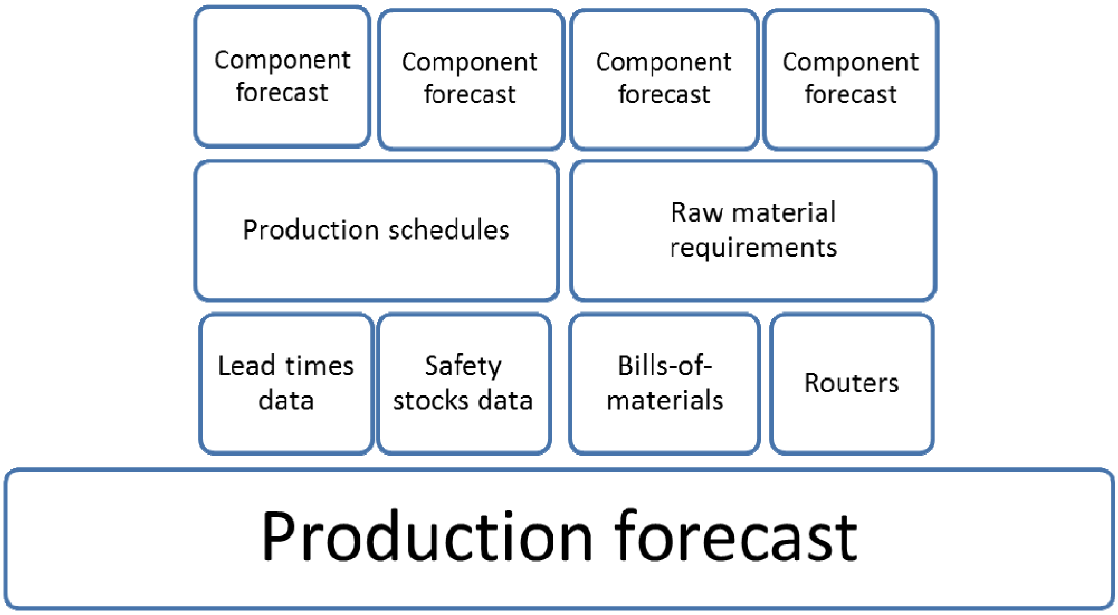

Figure 10 *MRP System Functionality (Modified from Gross & McInnis 2003: 181.)*

Figure 10 above illustrates the functionality and diversity within a MRP system. The complete production forecast is created based on information derived from component forecasts via production schedules, raw material requirements, BOM's, routers, lead time data and safety stock data. Juntunen (2012: 2) suggests an improvement to the system for dependent products by using the master production schedule, inventory status records and product structure records as three key inputs (2012: 2). Nonetheless, the MRP system is not as reliable in practice as in theory. There is a possibility to have complications and uncertainty with market demand, capacity data, costs and resources that have limited capacity. In addition, administration of production processes and inventory control only based on MRP does not provide optimized decisions. (Mula et. al. 2005: 74.) However, Gross et al. (2003: 184) suggests that a combination of MRP and Kanban as production management tools could provide several gains and complement the shortcomings of each. On one hand, they recommend utilizing MRP as a planning tool and to prevent overproduction and on the other hand to use Kanban for production scheduling execution on a daily basis. (2003: 184).

2.3 Lean Synchronization

The main idea behind lean synchronization is to enable meeting demand precisely and only at the time of occurrence. Thus there will not be stock outs or excess inventory. Normally, achieving the goal of lean synchronization means that pull control principles are being followed. Kanbans are related to lean philosophy because using them is the most common method of implementing or improving lean within an organization. (Slack et al. 2009: 349.) If Kanban system is coupled with Just in Time (JIT) practice in production processes, it is possible to achieve enhanced efficiency, reduced operations costs, improved competitiveness and even reach the target level of 'zero inventory'. JIT, Kanban and waste elimination are principles of Lean manufacturing system, which thrive towards manufacturing lead time reduction, inventory minimization and throughput improvement. In addition to being categorized as inventory stock control mechanism, Kanban system is also a tool for managing and controlling material logistics of manufacturing. (Naufal et. al 2012: 1721–1722.)

Slack et al. (2009: 348) are supporting the above definition and further state that lean synchronization is almost synonymous to the concepts of 'JIT' and 'lean operations principles'. The main goal of lean synchronization is to achieve highly optimized flow of products and services specifically according to the customer needs. This enables reduction of throughput time and elimination of interrupting delays in production because of in-process inventories. In a manufacturing facility, it is likely that all the problems within processes are not realized, since excess inventories are concealing them. In that sense, inventories are working against the business, since process improvement is hindered. (Slack et al. 2009: 348.)

In nowadays business environment, it is rather effortless to comprehend that the psychological barrier of completely eliminating excess inventories, which are operating as 'safety bumpers' is relatively high. At times their existence might transform challenging (or seemingly nearly impossible) production orders that are missing parts into on-time shipments that might otherwise end up jeopardizing business relations with important customers. However, if the inventory level is optimized, more warehousing space is freed up for correct inventory and it is the author's belief that after a while the problems would be reduced or even become nonexistent.

2.4 ABC Analysis

ABC analysis is performed based on the annual demand and unit values of materials. It is a popular tool for categorizing inventory to achieve improved control over the most critical materials and to transfer attention from less important ones. ABC analysis was created on the base of the Pareto principle also known as 80/20 rule during the 1950s. The key figures needed are value per unit in dollars and annual usage rate of the materials. The variables are multiplied material specifically resulting in annual dollar usage. These figures are utilized for forming a listing of the A, B and C materials.

Figure 11 on the next page reveals that 20 percent of the total annual items demand is actually equivalent for almost 80 percent of the total dollar usage. This 20 percent of materials is class A. It is vital to make certain that there is not going to be any stock outs with in this category. Class B and C are numerous, but their value is only about 20 percent of the whole materials. (Min-Chun 2011: 3416.) Naturally, ABC analysis can be performed by using also another currency than dollar. This currency is used in the ABC analysis theory and explanation, since the ABC model was originally created in the USA.

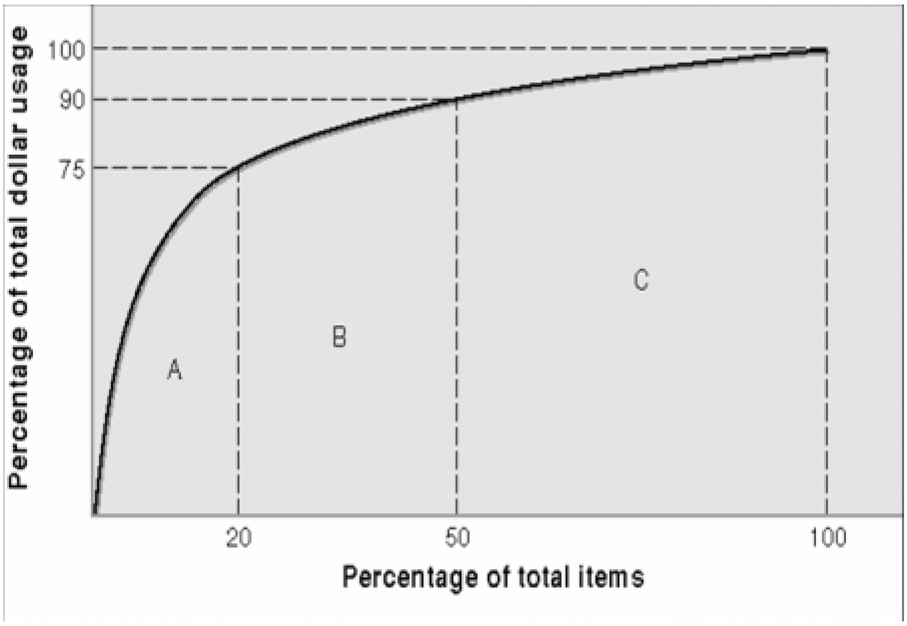

Figure 11 *ABC Analysis Classification (Lean Sigma Supply Chain 2013).*

The basic idea behind ABC analysis is simple, but it has been criticized. Even though, money is an important criterion in nowadays business world, ABC model is considered to be much too greatly focused on the dollar value of materials. It is argued that for gaining more reliable results for inventory control also other variables should be considered. These include, but are not limited to, lead time, obsolescence, inventory cost and order size requirements. However, the analysis turns out to be highly complex after three or more criteria are chosen to be in the classification process. (Min-Chun 2011: 3416.)

2.5 SAP ERP System

ERP (Enterprise Resource Planning) systems are computer, or other similar type of device, based programs used by companies varying from SMEs (small and medium-sized enterprises) to huge global conglomerates. The main idea is to synchronize business processes within the company, in order to improve and manage its operations virtually and concretely. In the employment company of this thesis, SAP system is used to administrate product selection, warehouse levels and order-delivery chain (ABB Inc. Press Release, RFID Lab Finland ry 2005: 5.) or more specifically supply chain (SC).

The SAP ERP system consists of several modules that are linked to the actual departments or process functions of most businesses, such as materials management, production planning, warehouse management and procurement. The system is meant to make processes more transparent and decrease the amount of paper consumed during business transactions. (Adams 2012.) Master data plays a vital role in the SAP ERP system operation and it has to be kept up-to-date and created correctly from the beginning. ERP Wisdom (2012) is following the same line of thought and suggests that the challenging, costly and time-consuming implementation and maintenance of the system is an SAP ERP system drawback. In addition, a complex system might take years to implement properly. (ERP Wisdom 2012.)

However, from the viewpoint of Kanban implementation it is important to reveal that it is possible to calculate vital parameters for production control in SAP automatically. The kanban (card) amounts and component quantities per kanban are significant for implementation project. These automatic calculations are done by defining all the necessary information into the system and using reporting transactions for approval. The main parameters are used for material circulation and stock definition. The aim is to minimize inventory levels by optimizing these parameters. In this case, optimization means achieving material management level that allows a minimum inventory, but is on a correct level for preventing material shortages. However, fulfilling these goals can be done only by monitoring the parameters regularly because market and component demands are changing constantly. (SAP AG 2013.) Basically, the Kanban process of SAP is close to following JIT principles and could be modified accordingly.

To achieve automatic kanban calculation in SAP, it is critical to maintain control cycles with standard values and assign supply areas to BOM components (via production version or linking supply area to material master). If the SAP's Kanban version is customized, further prerequisites are needed. SAP performs parameter calculations based on the results that are received from planning run or long-term planning. Main decisions include selection between long-term planning and MRP, the method of maintaining master data, and defining necessary data into control cycles. The report 'Change proposal settings for Kanban control cycles' defines propositions for parameters (kanbans and kanban quantity). Approval is made with 'Checking the results of the kanban calculation' function. The action can be repeated countless times for optimizing the Kanban loop. (SAP AG. 2013.)

2.6 RFID Technology

RFID technology forms a complex network and it is introduced in this chapter. There are three different main categories of tags: active, passive, and semi-passive. These transponders operate in different radio frequencies, depending on the country of origin and their structure. The physics of RFID are simplest in a passive RFID system. The system's operating procedure may be described according to the following explanation. Firstly, an antenna and transceiver generate a radio frequency field. The tag is activated as it reaches the RF field. Secondly, as a result it processes the signal received and transmits an RF wave, which is programmed in its computer chip (or memory area) and uniquely identifies the tag. Thirdly, the antenna detects the response. Fourthly, the reader sends this data to the middleware system in a host computer. Lastly, after processing, middleware forwards the data to other systems that are meant to have the information. (Sweeney II, 2005: 77–81.)

RFID technology can be used to assist and improve processes involved in numerous industries, such as automotive, cattle ranching, health care, manufacturing, marine terminal operation, the military, warehousing and distribution systems, retailing, and transportation (Banks 2007: ix–x). Below is a listing of benefits that could be gained with RFID technology in manufacturing industry:

- Work-in-process tracking
- Quality assurance
- Parts identification
- Inventory control
- Production planning
- Replenishment
- Reverse logistics tracking (Banks 2007: 321).

It could be concluded that “... RFID technology is gradually becoming a strategic tool in warehousing to defeat competitors by improving the customer service level while keeping the cost of operation to a minimum” (Banks et al. 2007: 363). However, an RFID system is not perfect. Srinivasan & Chandrasekar (2011: 7545) argue that there are also numerous drawbacks related to RFID. Because of the communication via radio waves, an interference of signals may occur and it is also possible to experience a reader or tag collisions. They represent another technology called MIFARE that has an evolving potential for replacing RFID in the future. MIFARE has the ability to overcome the problems RFID currently faces by having more highly developed memory capacity and improved security aspects. (2011: 7545.) However, it cannot be denied that RFID technology is able to provide benefits for several companies and organizations also in the future (Srinivasan et al. 2011: 7550).

3. KANBAN CASE STUDIES

The Kanban case studies are selected and included in the thesis because of their empirical added value. They also contain theory and provide guidelines for the current Kanban project and the future application. The goal is to research and learn from previous Kanban implementations by actual companies. Case studies often provide valuable information and experiences that can be exploited. It is also cleaver to research possible problems or mistakes from other companies' history.

3.1 Case 1, Motor Plant

The first case study is chosen because the company involved has a similar field of business than the company for which the Master's thesis is currently being conducted. Both manufacture a wide variation of electric motors. In the first case study Kanban is being implemented mainly for stamped metal castings that are one of the main components in motor production. These parts require special attention because the supplier's plant is situated in Mexico and the motor manufacturing plant is in the central United States. Therefore, the shipping time is long and the deliveries are weekly truckload quantities. The main problems are related to inventory management because forecasting the correct customer demand beforehand is extremely difficult. It has resulted in high inventory levels of castings, since the company tries to avoid frequent stock-outs that lead to missed delivery dates and line downtime in production. (Gross et al. 2003: 223–224.)

The situation before Kanban implementation was alarming. The total number of castings for motor production was fifty-two of which thirty-eight were entitled to a volume that required a stock. Castings were ordered on a three-week lead-time and the demand was forecast based on an MRP system. Since the demand had high variation and the lead time was long, the company ended up having an average inventory level of over eighteen days of production and significant variations in quantities ordered. Because of large inventory levels the company had to rent warehouse space adding an unnecessary cost in order to assist its production. (Gross et al. 2003: 224.)

The solution in the first case study was to implement a pull system and streamline the supply chain. Kanban was the main tool during this process. Since the products were customized, it was impossible to reduce the variation of customer demand. In addition, creating a buffer with finished products would not have helped to decrease the inventory levels. The supply chain was modified to meet the actual demand and react faster to the variation. (Gross et al. 2003: 224.)

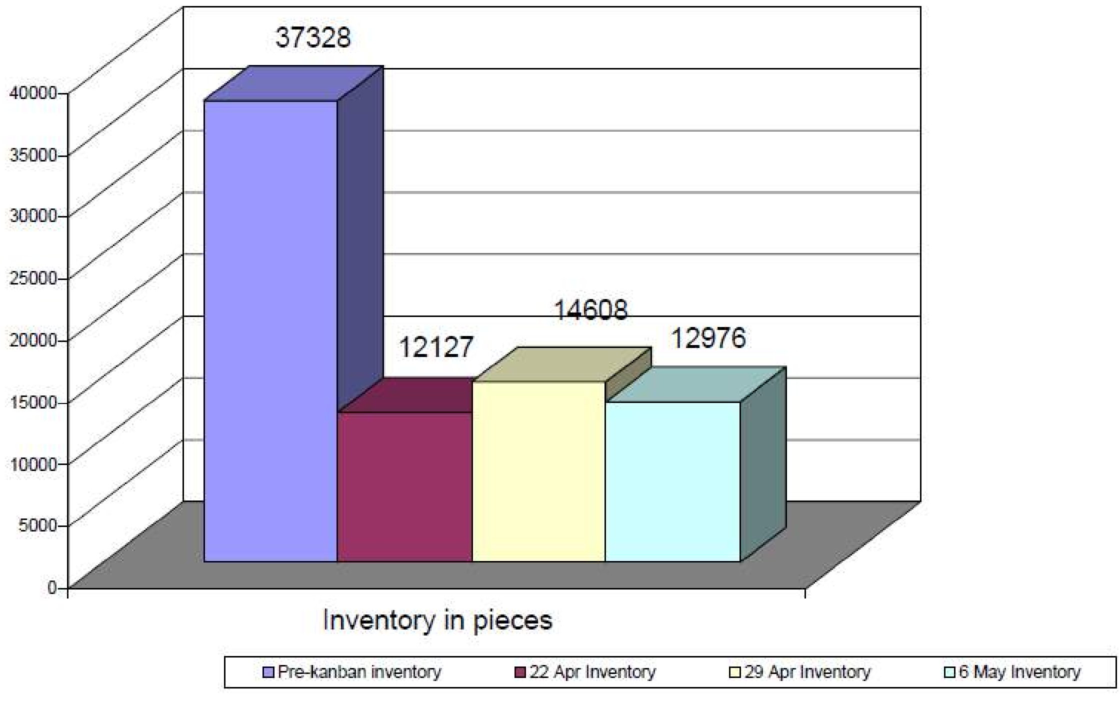

Figure 12 *Before and After Inventory Levels (Gross & McInnis 2003: 232.)*

The final results of the Kanban implementation at the motor plant were extremely promising. Figure 13 on the previous page illustrates the progress gained. The total quantity of castings was reduced from 37,328 to 12,976 pieces and the inventory level decreased from over eighteen days to less than seven days. In addition, the stock-outs were much less probable with the new system. (Gross et al. 2003: 231.)

3.2 Case 2, Rubber Extrusion Plant

The second case study involves a tier-1 automotive supplier and the expansion of one of its rubber extrusion manufacturing plants. The aim was to increase the number of extrusion lines from three to seven. In order to achieve this, the plant needed to drastically decrease its work-in-process (WIP) inventory because of floor space limitations and working capital constraints. The time used for the production at the beginning was also crucial, since the manufacturing processes later were creating higher rates of scrap, if the extrudate was able to age too long. Therefore, an updated scheduling system was also required, since managing larger departments and improving flow between operations was one of the goals. The solution was to implement a Kanban system that would schedule production and control WIP inventory levels. (Gross et al. 2003: 233–234)

Three months after the Kanban implementation, the inventory levels were compared to the starting point. The company used buggies as its SKUs during the production. Before Kanban the inventory level was $82,604. This was 106 buggies of product and 1,060 square feet of storage space. The company was able to decrease these numbers into $47,518, 56 buggies and 560 square feet. As a conclusion, WIP inventory level was reduced by 42 percent, $35,086 in working capital was saved and 560 square feet of shop floor space was now freed up to other uses. (Gross et al. 2003: 244)

3.3 Case 3, Valtra Inc., Suolahti

The third case study is describing a cooperation project with two Finnish companies, Valtra Inc. and Vilant Systems Inc. Valtra is a market leader in tractor industry in the Nordic countries and has also gained a strong brand in Latin America by becoming the second most popular. Valtra tractors are currently sold worldwide in over 75 countries. (Manufacturing & Logistics IT Magazine 2009.) Valtra is highly customer-focused and each tractor is customized and made-to-order (Valtra, Inc. 2012). Vilant Systems supplies complete RFID applications and is one of the market leaders in Europe. Vilant is also strongly customer-oriented and RFID software and hardware offered is being integrated with customers' own systems during the implementation project. (Manufacturing & Logistics IT Magazine 2009.)

An RFID system was implemented to Valtra's tractor factory in Suolahti, Finland by Vilant for inbound material flow automation. In addition to Suolahti, Valtra has another factory in Mogi das Cruzes, Brazil and both of the factories are defined to be the most advanced manufacturing plants of the industry. (Manufacturing & Logistics IT Magazine 2009.) Nowadays, Valtra prides itself with award-winning logistics of which automating both the material supply process and material buffer management at Suolahti factory is a good example. The goods receiving process at the dock doors is automated by utilizing RFID gates and RFID equipped inbound conveyors. This enables monitoring inbound logistics' material stock levels in real time. The pallets utilized for transporting the goods inside the factory have reusable RFID tags attached. The RFID enabled forklifts are forming the foundation of Valtra's RFID system. These vehicles play an important role, since they are able to read the available data from the tags, while moving correct material pallets from the material buffer area to the consumption area for production. This action initiates new orders directly to the suppliers based on the information that is converted into Valtra's ERP system. Thus the RFID system triggers the replenishment process and replacement order is delivered to the suppliers, when material consumption is becoming sufficient and a target buffer quantity is reached at the material buffer area. The RFID software reveals and maintains data of real time material buffer inventory levels, pending replenishment orders and inbound shipments. (Vilant Systems 2012.)

By improving material flow with the RFID system, Valtra is practicing one of the key elements of Lean production philosophy. The positive results of the implementation, which vast groundwork initiated already years before the actual launching of the system in 2003, are showing in several areas. These include, but are not limited to, improved material handling efficiency, reduced manual errors, enchanted accuracy in virtual and physical stock levels, prevented material shortages, improved transparency of the supply chain regarding suppliers and In-house logistics, added frequency inventory cycle time, reduced labor costs, and improved inventory control. Supply Chain Manager of Valtra, Mr. Timo Husso, clarifies that these improvements were enabled by testing the designed RFID system as a pilot prior to the actual implementation for production processes and gaining satisfactory results and experience from it. He also informs that Tieto and Liaison were involved with the IT systems' implementation and that the RFID pilot was conducted with one of the Valtra's suppliers, Metalpower. Mr. Husso is planning on further expanding RFID applications and is part of developing them at Valtra's Suolahti factory. Improved production traceability and internal material movement automation are already part of the Valtra's RFID system. (Manufacturing & Logistics IT Magazine 2009.)

The implementation project at Suolahti factory referred to in the preceding paragraphs is not described in detail publicly, but based on the available data and the previous knowledge of the thesis author; it is possible to conclude that the implemented RFID system has a Kanban system within that is managing the replenishment process. In the Valtra's Kanban system a triggering signal is the action of transporting the goods from a specified area (storage) to another specific area (production) with an RFID enabled forklift that operates as an RFID reader. It is not mentioned in the source articles, but typically the RFID readers are installed into the “fork” or close to the lifting mechanism. Moreover, the author believes that the buffer and consumption areas’ entrance and/or departure “driveways” are quite certainly created into RFID gates or other type of reader points that are able to collect the information of a passing pallet. Hence, the pallet’s tag is read only, if the object is lifted and transferred. The position of adjustment depends of the application, and the type or model of reader and vehicle. Vilant Systems’ RFID readers used by Valtra are shown in Figure 13 below. The readers operate at immediate closeness to forklift’s “fork” and on both sides of a conveyor to provide a reliable communication between the tags and readers.

Figure 13 *Forklift and Conveyor with RFID Readers at Valtra (Manufacturing & Logistics IT Magazine 2009.)*

3.4 Case 4, ABB Inc., Drives Unit, Helsinki

Similarly to the previous case, the fourth case study is also describing an implementation project of an RFID system conducted in cooperation by two companies;

ABB Inc. Drives business unit in Helsinki, Finland and its collaboration partner Vilant Systems Inc. ABB Drives employs approximately 700 people at its Pitäjänmäki factory that operates for developing, manufacturing and marketing frequency converters. Vilant is a Finnish RFID application provider, which core competence is operating as an RFID system integrator, including supplying software and hardware systems, related to applications for improving logistics processes. Two other project cooperation partners of ABB Drives were Tekes and VTT. (ABB Inc. Press Release, RFID Lab Finland ry 2005: 4.) The RFID system is rather similar then the one implemented at Valta, but ABB Drives case has an empirical value for the thesis as well, since it has a more detailed description of the RFID system with its integrated Kanban process.

On April 4, 2005 ABB Inc. published a press release that informed of the ongoing implementation project of an RFID system at ABB Drives' Pitäjänmäki factory. Because of this project, ABB became a pioneer of the RFID technology application for material logistics and order-delivery chain management in Finland. Since ABB Drives was a RFID technology forerunner in a manufacturing and logistics solution at the time of the implementation, the system was especially carefully planned, tested and piloted with selected suppliers. (ABB Inc. Press Release, RFID Lab Finland ry 2005: 1.)

The first stage of the RFID application of ABB Drives is illustrated in the Figure 14 on the next page. This new type of raw material logistics management in Finland is consisting of a combination of Kanban process cycle and RFID technology and is being applied between the manufacturing plant (ABB Drives) and component suppliers. ABB Drives has about 150 component producing suppliers of which one tenth is utilizing standardized (Kanban) raw material boxes. When transported to the loading dock, empty raw material boxes trigger a replenishment order. The order automatically becomes visible to the suppliers' extranet. After fulfilling the order, the supplier reprograms an electronic reference to the RFID tag attached to the replenished boxes and they will be delivered back to ABB Drives. The goods receiving process is virtually automated and the data of the delivered raw materials is transferred into the SAP system after transportation through an RFID forklift drive-through gate. Thus there is no need for delivery slips or packing lists. (ABB Inc. Press Release, RFID Lab Finland ry 2005: 1.)

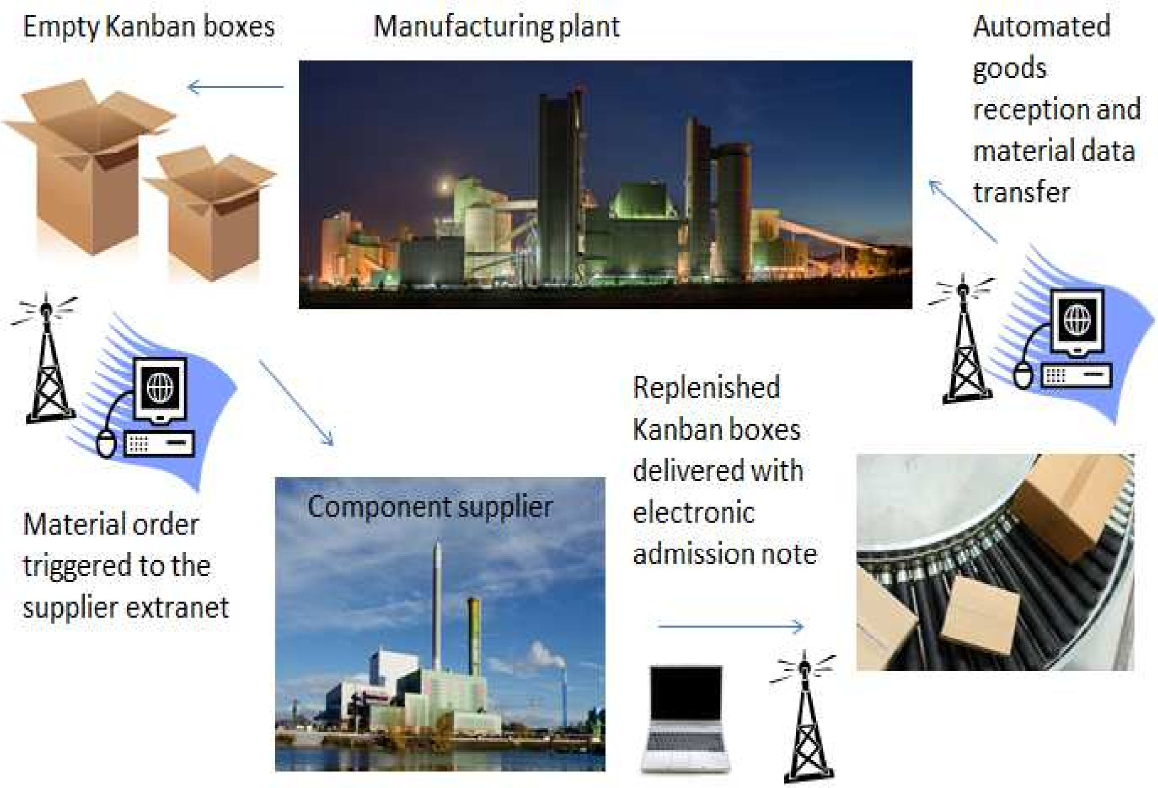

Figure 14 *RFID enabled Kanban System of ABB Drives (Created based on ABB Inc. Press Release, RFID Lab Finland ry 2005: 1)*

The ability to identify several transport units' contents simultaneously by utilizing RFID forklift drive-through gates and transforming RFID tags into electrical delivery notes are definite advantages of an RFID system at Pitäjänmäki. In addition to Kanban boxes, the installed system is able to receive pallets and bulk material without additional configurations. (ABB Inc. Press Release, RFID Lab Finland ry 2005: 3.) Following the Kanban process cycle picture is a photo (Figure 15) of an RFID forklift gate with Vilant's RFID readers at Pitäjänmäki factory of ABB Drives.

Figure 15 *RFID Forklift Drive-Through Gate and a Pallet with RFID Tag at ABB Drives (ABB Inc. Press Release, RFID Lab Finland ry 2005: 2)*

In addition to being a pioneer, ABB Drives implemented a system based on UHF (ultra-high frequency) RFID technology that is the most up-to-date and efficient version of RFID. The hardware enabling its usage became available in Europe during 2004, which is the same year that ABB started its implementation. The project was scheduled to last about a year. The implementation and testing were conducted during the fall and the system was being launched for the production in December 2004. By the end of June in 2005, the fifteen chosen suppliers for piloting phase were hooked into the system. However, the operation is considerably simpler for the suppliers than to ABB Drives and the actual implementation at the vendors' premises could last as little as half an hour. Vilant provided a complete system for ABB and the package included process consultancy, RFID measurement services, device installations and software system integration services. The latter consisted of RFID software system and extranet system implementation and integrating the systems with ABB Drives' ERP system, SAP R/3. The IT system managing RFID tags' data makes the supply chain more transparent by enabling location and status monitoring of the shipments. This information can be shared via extranet user accounts for suppliers' utilization. (ABB Inc. Press Release, RFID Lab Finland ry 2005: 3–4.)

During this first stage of the RFID system implementation, ABB Drives was focused to automate its Kanban orders. The goal is to gradually expand the system to cover approximately 60 percent of the yearly 160,000 goods receipts at the factory. The challenges linked to the system expansion are not internal, but they are related to the vendors. To avoid these potentially forming into drawbacks, it is vital to get the suppliers on board with the project and train them properly to use RFID tags instead of regular delivery slips. (ABB Inc. Press Release, RFID Lab Finland ry 2005: 3.)

After the successful pioneering implementation by ABB Drives, CEO of Vilant, Mr. Antti Virkkunen is encouraging other Finnish industrial companies to consider RFID technology for improving their own processes. He emphasizes that in the case of ABB, the challenges surfacing out of a new technology have been solved once in an authentic environment, varying from the selection of an RFID tag to SAP R/3 integration (ABB Inc. Press Release, RFID Lab Finland ry 2005: 3.). Mr. Antti Permala of VTT was involved with the project as an RFID and Logistics Specialist. He is also pleased with ABB's project and clarifies that the company has calculated the profits and savings of the complete chain, invested into the system and now offers its suppliers the possibility of connecting into real time information flow (ABB Inc. Press Release, RFID Lab Finland ry 2005: 3.). This is groundbreaking in Finland and a textbook example of maximizing the benefits of RFID technology in a supply chain. Technology Specialist of Tekes, Mr. Jouko Hautamäki was glad that Tekes was part of the project and states that the implementation enabled the project team to lead the way and reveal gains achieved to a larger audience. (ABB Inc. Press Release, RFID Lab Finland ry 2005: 3.)

Logistics Director of ABB Drives in Pitäjänmäki and the owner of aforedescribed project, Mr. Harri Heimonen enlightens that they have previously been able to get hundred percent of our suppliers to utilize our own goods receipt barcode standard. We believe that after discovering the system benefits, our suppliers will also want to take the next step and shift into the world of RFID. Our project has awakened also a lot of internal interest globally within ABB (ABB Inc. Press Release, RFID Lab Finland ry 2005: 3.)

ABB is now aiming at constant development regarding RFID technology and is researching other potential application possibilities for improving monitoring and managing the material flows with the assistance of new automatic identification and software technologies. (ABB Inc. Press Release, RFID Lab Finland ry 2005: 3.) Vilant Systems (2012) describes the project objectives for ABB Drives to be optimization of the inbound material flow and acceleration of the replenishment order triggering process for Kanban boxes. The results were notable. Material receiving efficiency increased, but manual labor and human errors decreased. The Kanban reorder process quickened, stock turnaround times became faster and inventory levels were reduced. Thus the goals were achieved and even exceeded. (Vilant Systems 2009.)

It is problematic to analyze the ABB Drives’ project completely objectively, since everything written in the press release and an article is also partly advertisement of the RFID technology and the companies involved. On one hand, the benefits gained are strongly highlighted, on the other hand, problems, drawbacks and errors possibly evolved during the implementation are absent from the sources. However, a pioneering project being perfectly successful during all of its stages could be considered a physical impossibility. Nevertheless, the press release was a valuable source and included important and detailed information about combining the Kanban system with RFID technology. This is considered in chapter 5 of the thesis that presents a suggestion of RFID Kanban application design.

4. KANBAN IMPLEMENTATION IN ABB'S MOTORS AND GENERATORS BUSINESS UNIT IN VAASA

The ABB Group is a global power and automation technologies organization that has gained a leading role in the market. The company has operations approximately in hundred countries and its shares are traded in the stock market of Zurich, Stockholm and New York. ABB is divided into five main divisions, which are organized into specific business units having different core competencies based on various industries and product categories. The main divisions are Power Products, Power Systems, Discrete Automation and Motion, Low Voltage Products and Process Automation. The thesis is focused on Motors and Generators business unit (BU) in Vaasa, Finland. One of the key facts relating to the unit is that ABB is currently the world's largest supplier of industrial electric motors and drives. (ABB 2013.)

ABB's Motors and Generators business unit in Vaasa (from now on called 'ABB MoGe' in the thesis) produces electrical motors that generally have approximately 150 different components. The material handling, procurement and production challenges increase because ABB MoGe factories manufacture customized motors based on customers' individual requirements and wishes. Since a large amount of customer orders are linked to manufacturing ocean vessels or large marine ships, the customers have a strict schedule that should not be compromised because of the in-house logistics, purchasing or logistics troubles. If the motors manufactured by ABB MoGe are late, these marine customers will face considerable additional expenditures, since their projects have to be delayed as well. It is nearly impossible to install the motors into a vessel or ship after it is build, and therefore the whole project often needs to be put on hold until the motors' arrival. If the project is finished late, it could even have an effect on the customer satisfaction of the company that is ABB MoGe's client. Naturally, this in turn results in causing dissatisfaction also in the customer of ABB MoGe. At its worse, the company can start losing orders and end up having an untrustworthy reputation among its potential customers.

Because of the fact that the motors manufactured in ABB MoGe are customized, it is increasingly complex to forecast the demand of the materials and a high variance in demand is part of the nature of business. While producing customized products the BOM is varying greatly and it is difficult to manage only with MRP. All the assembly lines of the two factories (MM and KK) in Vaasa are producing motors of their own specific size range. The main components are arranged and stored close to the assembly line they are needed, but some parts are used on several assembly lines of the factories and have to be considered accordingly. However, it is challenging to order or move all of these materials in a way that is optimized, since the demand varies based on the production orders. Often the confusion results in an additional labor for In-house Logistics or Production operators and is time-consuming. For example, MM factory has had five (5) assembly lines spread in two floors. The assembly lines upstairs are not straight or side-by-side and therefore need more storing space for common materials.

4.1 Background of Kanban Implementation Project, ABB MoGe

ABB's MoGe business unit in Vaasa is currently utilizing inventory management that includes bulk materials, made-to-order (MTO) components in varying quantities, vendor managed inventory (VMI) and re-order point (ROP) materials. The latter two material groups are basically based on two- or three-bin look-see Kanban system. However there are major drawbacks involved and stock outs or misplaced components are a daily problem that greatly affects production negatively. VMI and ROP materials are at the focal point of this thesis, whereas, MTO and bulk materials are not considered becoming part of the Kanban system.

Figure 16 on the following page illustrates ABB MoGe's vision of the material groups that are used in production and the purchasing methods used within the company. Materials are divided into customer specific and standard components. These main categories are then specified according to the length of lead time, the frequency of usage and the unit price amount. Purchasing methods for customer specific materials are Purchase Requisition (PR)-list and JIT because MRP production method is used for controlling the availabilities or inventories. Standard materials are operated based on ROP and VMI. Their purchasing methods are divided into Pull, Kanban and JIT. (Global Value Chain Team 2012: 6). The other categorization is made from the procurement department's viewpoint and materials are divided into Buy to Project (customer specific materials) and Buy to Stock (standard materials). Fundamentally, MRP is used for the first material group and in addition to MRP, call-off (JIT or Pull), 3^{rd} party logistics (VMI), 2-bin (a basic form of Kanban) and ROP are utilized for the second group. (Global Value Chain Team 2012: 2).

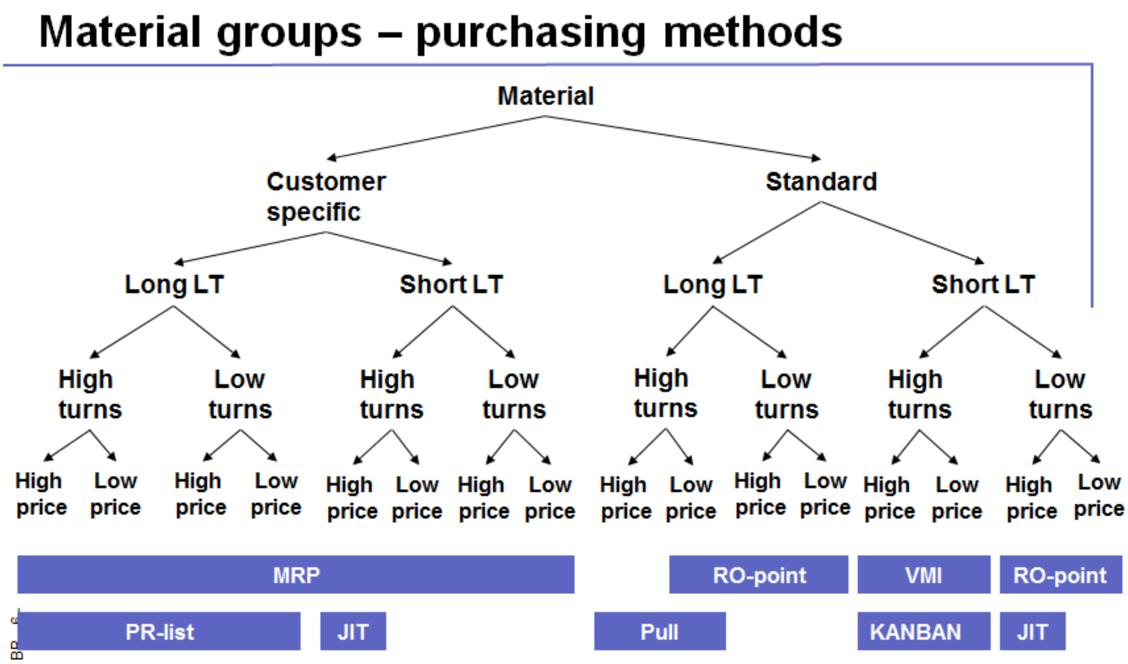

Figure 16 *Material Groups and Purchasing Methods. (Global Value Chain Team 2012: 6.)*

The replenishment procedure of re-order point (ROP) materials is defined in the Figure 17 on the next page. Curves are illustrating the amount of existing inventory in pieces (Q) at the time (t). The amount above ROP line is enough for the production, but below the line is the amount (D) that is required for production during the time that order placed after reaching ROP amount will be filled. The lead time (L) of supplier should also include ABB MoGe's average time that is spent to review the materials or stocks. The final measure of ROP procedure for preventing stock outs is safety stock (SS) level that is enough to cover the amount needed in production for a while, if something goes wrong or the delivery is delayed and DL amount is not sufficient. SS's function is to compensate variations in lead time and demand. Basically fixed order point is reached, whenever the ROP line is met by inventory level. Materials also have fixed order quantities. Thus the order is placed at the right time to prevent stock outs of vital components and not to receive excess inventory. The correct amounts for forming a ROP model are carefully defined and/or calculated based on formulas defining variables and average demand of materials. One of the ROP models benefits is that it enables the use of an ERP system. (Juntunen 2012: 3–4). Enterprise resource planning system is a companywide software system that integrates different departments and aims more synchronized operations within organization (Wolf 2011). Thus SAP can be operated in ABB MoGe to support the ROP replenishment procedure.

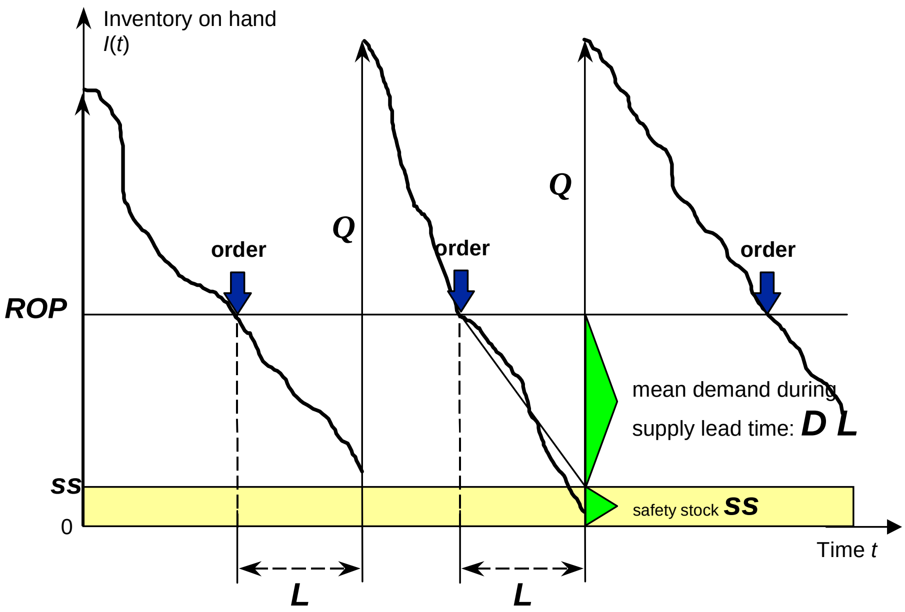

Figure 17 *Re-Order Point Definition (Juntunen 2012: 3)*

VMI procedure shifts the reliability of stock replenishment and inventory control from a customer to the vendors. The customer does not need to submit orders because the vendors take responsibility of the inventory control. VMI is at times also called as supplier managed inventory (SMI) or co-managed inventory. In theory, VMI has considerable advantages for the customer company. These include increased retail and supplier sales, and decreased inventory carrying, transaction and manufacturing costs.

Pros are normally gained by reduced stock outs, strong trading relationships, degreased cycle times, amount of inventory, ordering costs and more up-to-date sales information, improved priorities and reduced coordination expenditure. (Juntunen 2012: 2). However, in ABB MoGe some of the problems are caused by not being able to completely synchronize the warehouse management systems with the different parties and thus the process is not operating in real time and sometimes there is a significant delay in information flow. This in turn can lead into stock outs in production of critical materials.

VMI also has theoretical disadvantages, which need to be considered. Outsourcing operations increases vendor's administrative costs and the risk of losing control and flexibility over processes. In addition VMI is hard to utilize with volume discounts and other special pricing, and in the short run the replenishment system becomes more complicated for the customer. As a conclusion VMI provides improved results with articles that have a short lead time and a capable supplier that is willing to negotiate a long-term purchase contract. (Juntunen 2012: 2). The replenishment process must also be operating as real time as possible, or the gains are harder to achieve and the drawbacks are more difficult to avoid.

In ABB MoGe VMI procedure is adopted by outsourcing demand based inventory control of certain standard materials or material groups to the vendor or 3rd party logistics partner, Piccolo Logistics Inc., DHL Logistics Inc. and Bufab Finland Inc. By the end of 2012 the cooperation with DHL regarding VMI materials is discontinued and it needs to be at least partly replaced by an actual Kanban system. From the beginning of 2013, ABB MoGe's In-house Logistics department will handle the transition. Bufab is mainly delivering bulk materials, such as bolts and screws, therefore, it is seen as Logistics partner that has important part of the in-process inventory and the cooperation is continuing. Piccolo will also remain as a Logistics partner and currently its warehousing and logistics operations are vital to ABB MoGe's production. However, the procedure with VMI replenishment is eventually going to be replaced with the Kanban system.

Since ABB MoGe has outsourced its warehousing operations partly to Piccolo, the company has become a major raw materials and components warehouse that is storing components and materials varying from stator frames, rotors and end shields to valve discs, outer covers and terminal box frames. Piccolo is situated at the same industrial yard area than ABB MoGe and several other ABB's units, but the most concerning disadvantage is that raw materials and components get lost or misplaced also in Piccolo's warehouse. The inventory control is not transparent enough between the partners and it is not highly synchronized or operating in real-time. The systems of both companies have a possibility for human error, therefore, they sometimes happen. Some of the inventory records held in SAP are years old and it is frequently unclear, does the material quantity only exist virtually or is it also stored somewhere in the warehouse area. Usually these mix-ups in inventory records require a lot of additional labor, since they cannot be solved only based on the warehouse system(s) or SAP.

Made-to-order components are probably the most critical in inventory management. If these materials are not in their right place at the right time, the assembly line needs to be stopped until the part is found and/or the WIP-motor has to be lifted aside, and at least one employee starts searching the missing part. Since all the motor orders manufactured in ABB MoGe are based on customers' needs, there are several types of made-to-order parts, such as stators, rotors, special colored paints, tachometers, brakes and squirrel cage motors. These parts often do not have huge containers or are delivered in large batches; therefore, it is extremely difficult to locate them, if they are for some reason misplaced or stored incorrectly. However, these parts cannot be included in the Kanban system because their yearly demand does not meet the criteria explained in the next subchapter.

The thesis will concentrate on managing materials, which each affects over 200 motors per year, thus the gains made are making a larger improvement in production. As an additional bonus, the author believes that it will become more organized to store and locate the made-to-order components, after the Kanban system is implemented and the In-house Logistics operations of ABB MoGe are thus more synchronized.

In addition to misplaced materials, a major problem is also the regularity and existence of component stock-outs. These are quite often related to the materials that have a large yearly demand and are needed in producing most of the motors. Since the warehouse system or SAP is not operating in real-time and there are errors in the inventory records, these appear as a unwanted surprise, when the component is already required in the production. Often the materials are not found and the current inventory records of the material have to be deleted. A new order is placed for Piccolo, DHL, Bufab or for another supplier, depending of the material and its availability.

4.2 Kanban Application Pilot, ABB MoGe

Before the Kanban system implementation of ABB MoGe, it is vital to consider that it will affect three different sections from two factories. This creates challenges and requires a throughout planning. There are three main areas of production in ABB's Motors and generators unit in Vaasa that each need to have components and raw materials at hand. In addition, these areas have their own demand and a certain material might not fill Kanban specifications in all areas. Factory MM has upstairs and downstairs areas and factory KK has only one floor area on which the motor production is concentrated. Even though, the electrical motors manufactured vary greatly in frame size between these two plants, there are components and raw materials that are used in both factories. ABB MoGe's motors produced in KK vary from 80 to 250 millimeters and in MM from 280 to 450 millimeters (Penttinen 2011: 12). One of the criterions for becoming a Kanban material was thus ruled based on the whole component demand of the ABB MoGe.

Kanban materials were selected mainly according to an average yearly demand. If the average yearly demand of a material was over 200 pcs, then it was considered to become a Kanban material. Most of these were previously ROP materials. Another criterion was to have an even consumption and this was estimated based on an average weekly demand. It was also considered important to have a value range (€) of material's weekly demand on a sensible level. In addition, the chosen suppliers were to be close range businesses, hence to allow starting the Kanban implementation with parts that are fast to deliver, in case a mix up is formed during the Pilot phase, while ordering via new system. Additional aims were to review the ROP materials based on their current demand, and to look into potential Kanban components also outside the group of all ROP parts, for example within current bulk or other high demand materials. The goal was to have less ROP materials and a justified amount of Kanban materials.

4.2.1 Falco Project

The new upcoming layout plan of ABB MoGe, relating to a project called Falco, had an effect on choosing the Kanban materials as well. In the near future, there will be only two assembly lines (upstairs and downstairs) at the MM factory with greater production volume via process optimization. The first improved assembly line will be launched in the beginning of week 13, so the starting date is set to be March 25 in 2013. Therefore, the potential Kanban materials were also evaluated based on their future assembly lines, in order to being able to define the correct Kanban shelf.

Hiipakka further describes ABB MoGe's Falco project and reveals that the mission is to create conditions for being able to produce electric motors with a lead time of four weeks. The goal is to manufacture them from the order receiving all the way to loading the end products into a transportation truck during the set mission timeframe. The process and potential of creating a centralized warehouse(s) for better achieving the goals of Falco project and improving the planned kitting of motor specific parts at ABB MoGe was researched in her thesis (2012: 12.) The new production model and layout is targeting to double the production capacity in ABB MoGe. All the warehouse tasks that fail to add value to the end product have to be eliminated. In-house Logistics department has a key responsibility in maximizing production processes by providing right components, to the right place, at the right time. (Hiipakka 2012: 59).

4.2.2 Kanban Implementation Plan

The first official Kanban meeting was held on September 28, 2012. There were white-collar employees from In-house Logistics, Outbound Logistics, Purchasing, Production and Information Technology (IT) divisions present. A presentation was also held by a supply managerial person from ABB's Low Voltage Systems business unit because they are already using a Kanban system for supporting the production processes. The planning of ABB MoGe's Kanban system had begun few weeks earlier within In-bound Logistics division by chosen employees and a smaller meeting had already taken place a week earlier.

A general outline was decided and responsibilities were divided among the key personnel of the divisions. In-house Logistics prepared criteria for selecting Kanban materials and Procurement deparment's key personnel chose potential candidates. In-house Logistics made also own selections, combined the Excel-lists and made final decisions. After the task was concluded, the following information about the Kanban materials was available:

- ✓ Material code
- ✓ Material description
- ✓ Supplier
- ✓ Assembly line
- ✓ Production area
- ✓ Order or batch size
- ✓ Average yearly demand

In-house Logistics' key personnel modified the list even further by computing a suitable fixed order size and defining a proper storing unit type for each material. ABB MoGe had done an ABC Analysis for ROP materials earlier and Safety Stock limits were also defined previously. Therefore, these were not done during the Kanban project. Instead, Procurement department relied on the professionalism of purchasers and previously computed definitions of chosen materials. Based on the purchase contract negotiations, it has been confirmed that the suppliers are prepared to modify the batch and/or delivery sizes according the upcoming needs of ABB MoGe.

One of the goals was to reduce the current ROP materials by 50 percent. Since the starting point was 560 materials, the aim became 280 components. The Kanban materials for Assembly line 2 were defined first, since the Pilot 1 is starting there. The result was 108 materials. Next, other materials for Assembly line 1 and the future assembly lines in the KK factory were considered and the total was 147 materials. Based on these figures the total amount of planned Kanban materials will be 255 for the Pilot phases. Since ROP materials are being reduced also in other means than converting them into Kanban materials, the end result is quite close to the original goal.

ROP materials will be revised based on their up-to-date average yearly demand and this procedure itself will decrease the amount greatly and other purchasing methods are to be utilized in the near future. These require modifications in SAP, negotiations with suppliers and alterations in purchasing process, but in the end will reduce inventory costs and free storing space. From the beginning of 2013, In-house Logistics department assigns resources for replacing personnel handling the previously outsourced procurement goods deliveries and assists during the transit time of implementation.

4.2.3 Kanban Implementation Schedule and Suppliers

The first stage of the Kanban Implementation project of ABB MoGe is planned to last until June 30, 2013, which is the end of week 26. The assembly line AL2 will be launched in two phases. After Easter vacations on April 2, 2013 former AL55 will be transformed and on April 29, the AL35 is combined with AL55 to form the new AL2. AL35 will be thus completely in the downstairs of the MM factory. There are to be seven pilot phases, Pilot 1, Pilot 2, Pilot 3 and so on. Pilot 1 is to involve only the (upcoming) assembly line 2 (AL2) and Pilot 2 will engage also the (future) assembly line 1 (AL1) and the assembly lines at the KK factory. After this ABB MoGe has a Kanban system in both factories and all assembly lines.

Figure 18 on the following page defines the main actions performed till week five (5). Pilot 3 gets started in the beginning of week seven (7). In addition to the meetings held and Kanban research performed prior the actual project, the planning stage lasts ten (10) weeks. By the end of week 50, the overall planning and obtaining functionality into SAP should be completed. During the week 51, Master Data regarding the first pilot materials should be updated in SAP. The standard Kanban application has naturally been tested before launching it into the actual business side of SAP. Trainings for the employees involved are held frequently until the procedure is clear in SAP and in practice. The assembly of Kanban shelves is scheduled to last two weeks and planned to begin during week 50, however, there is a minor confusion currently with the future layout and it causes a bit of a delay. This in turn might postpone the launching of Pilot 1.

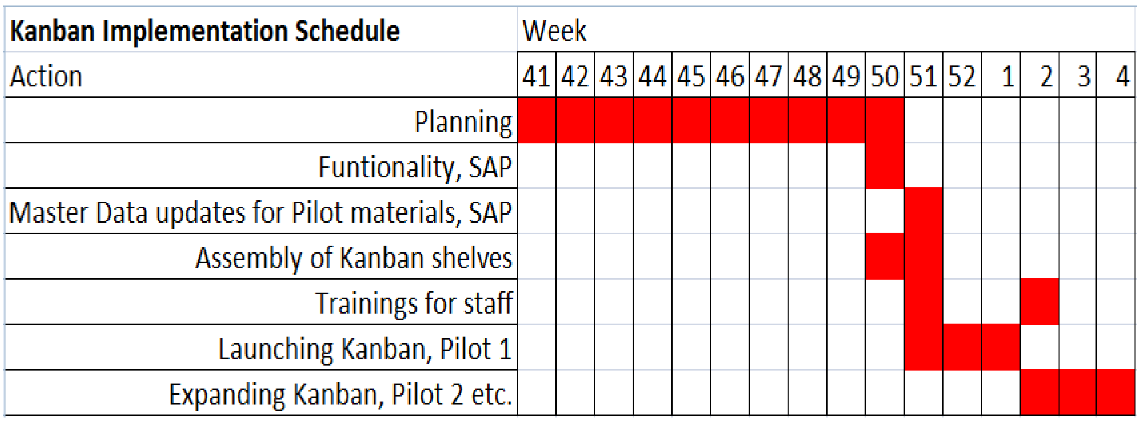

Figure 18 *Kanban Implementation, Launching Schedule*

One of the most significant decisions during the planning phase was to rule involving suppliers one-by-one to the project. This allows the implementation to become more manageable and helps to focus on each supplier in turn. Thus the project is proceeding gradually, with a clear step-by-step approach. In the Figure 19 on the next page, the gradual progress of the Kanban implementation is illustrated with 232 materials chosen by Procurement. The current Framework order (FO) materials are also listed and they are SAP's equivalent of ABB MoGe's ROP materials. There are 372 of those, but a selection of them will be converted into Kanban materials. These are not the final quantities, since In-house Logistics is not yet modified the list of materials, but the graph gives an overall picture of the implementation process schedule with a focus on the suppliers.

Kanban Implementation Schedule, Suppliers

			Week																											
Supplier	FO Qty	K Qty	51	52	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26
Metallityö K. Kukkanen Inc.	42	50																								■	■	■	■	■
Scansolo Inc.	90	58																			■	■	■	■	■	■	■	■	■	■
Laine-Tuotanto Inc.	40	34															■	■	■	■	■	■	■	■	■	■	■	■	■	■
Wel-Mach Inc.	48	14												■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■
Österberg Inc.	13	14									■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■
Ouneva Group	135	60				■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■
InCap Plc.	4	2	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■

Figure 19 *Kanban Implementation, Suppliers*

Pilot 1 of Kanban implementation starts in week 51, is planned to last three weeks, and includes only two materials from a single supplier. These Kanban materials are fan covers produced by InCap Inc. The supplier was chosen to be the first pilot, since the volume of the deliveries is efficient to manage and the company is located at the same industrial area than ABB MoGe. It was also a vital factor that both of the chosen materials are used only at the downstairs area of MM factory, therefore, AL2 will be the first to adapt the Kanban system. There are only two other fan covers that the company supplies to ABB MoGe, so all of the deliveries can be carefully monitored from the Kanban functionality point of view. It is also easier to locate potential faults or surprising situation during the Pilot 1 and the employees involved are able to familiarize the new materials management system.

Pilot 2 begins in week 2 with Ouneva Group. Since this phase will have an effect on both factories and there will be over 60 materials converted into the Kanban system during it, Pilot 2 is scheduled to last five (5) weeks. This should allow enough adjustment for the new processes and to the infrastructure. After Pilot 2, the other suppliers' materials are gradually added into the Kanban system according to the same guidelines. The time span has been defined based on the amount of materials to be converted.

Following the first stage of the Kanban Implementation project of ABB MoGe, there will be a second one that starts in the week 27. The vision of this stage is not completely clear yet, but the main goal is to expand the supply Kanban system (currently being implemented) to include also a type of movement Kanban for more synchronized cooperation with logistics partner, Piccolo. Additionally, a type of production Kanban could be considered potential for components produced in the ABB MoGe's factories for the motor production. These components include a selection of rotors and stators. But these require further research before strict plans or schedules are being made.

As a side note, the new value-added tax (VAT) legislation changes and the raise of the standard rate in Finland affected the ABB MoGe's Kanban project and the implementation schedule was modified accordingly to be initiated also in the beginning of the year 2013 because it is more straightforward for financial figures and reporting of the ABB MoGe and its suppliers. However, in this subchapter the scheduling graphics and dates are based on the original schedule. Based on this information, the VMI co-operation between InCap, Piccolo and ABB MoGe was terminated on December 19, 2012 and the responsibility was shifted to In-house Logistics of ABB MoGe. The Pilot 1 of Kanban system is implemented on January 2, 2013.

4.2.4 Kanban Infrastructure

In its simplest form the Kanban infrastructure in ABB MoGe has three bins per material (code). Figure 20 below illustrates the process of 2 bin Kanban system with an operator. The 2 bin system is complimented with an additional bin at the Kanban shelf administrated by In-house Logistics. Otherwise, the concept is similar with 2 bin system. In the beginning both bins are full of components and the consumption for production is started. Next phase happens, when the box is emptied during the electric motor manufacturing. After assigned production operators have informed the demand for the replenishment, In-house Logistics will fetch the empty box with the Kanban card and replace it with a full bin from the shelf. A replenishment order to the supplier is then made via SAP by a logistics operator, before the readily stored bin is transferred to the correct assembly line. Thus, the production of new components for the empty bin is started in the supplier's factory, based on the information of a Kanban card. After the fulfilled bin has been delivered to the ABB MoGe, it will be received and transported to the Kanban shelf In-house Logistics to wait for another signal from the assembly line.

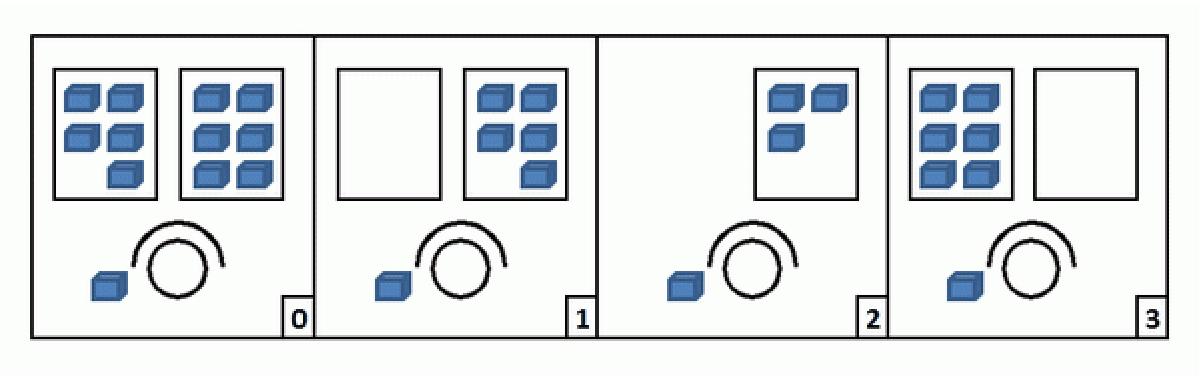

Figure 20 *Two Bin Kanban System. (Lib13 Net 2010)*

Kanban, bulk and kit (for the sets of AL2) containers alongside the assembly lines are color coded in order to make the recognition of a component type more efficient and straightforward. For example, to the MM factory’s downstairs area it is planned to have roughly 160 and upstairs 150 boxes in the beginning. Since Kanban boxes are yellow, it is decided that bulk boxes are blue and kit boxes are grey. At the end of the first phase of the Kanban implementation project, there will be seven suppliers involved and approximately 255 different Kanban materials. This means that there would be at least 765 Kanban bins constantly rotating within the whole Kanban loop. However, some of the bins are combined, if the materials are small. Moreover, the goal is to be able to remove the usage of additional Kanban shelf operated by In-house Logistics and reduce the amount of Kanban bins. This is planned to be done after the Kanban procedure is sufficiently familiarized by ABB MoGe and its suppliers. The integrated Kanban warehouse area is new and built for the Kanban implementation project. There are also additional separate Kanban shelves that are modified from previous ROP shelves.

However, the future assembly lines (AL1 and AL2) also have common materials that are used at the both or even all three main areas in two different factories. In this case, the yearly consumption is normally greater in one of the main areas and in another area could be less than required 200 pieces per year. These materials are so called Joker Kanbans and there are 22 of them. The term ‘Joker Kanban’ is not an official one, but it was created by the author of this thesis because it makes the description of ABB MoGe’s case clearer. At the proximity of the official Kanban shelves, there will be a special Joker-shelf with assigned bin slots for these Kanban materials. From the Kanban shelf the warehouse workers, who are collecting motor specific kits, will fetch small amounts of the Joker Kanbans to the other main area’s shelf and thus closer to the other assembly line with a smaller consumption. After these components are used, the operator will fetch more from the official Kanban bin. If this transfer needs to be performed between MM and KK factories, the Joker Kanban amount transferred is larger, since the distance is greater and extra transfers for only few materials need to be minimized in order to be more productive and achieving more optimized In-house

Logistics operations. Joker Kanban shelf concept was created for ABB MoGe with an intention of minimizing the time and labor resources wasted in transfer of materials because of occasional or low demand. In the beginning of the piloting phases, the Joker Kanbans are ROP materials system wise in SAP. They are modified and defined correctly as collect Kanbans after ABB MoGe's SAP has a proper way of configuring Joker Kanbans.

ABB MoGe provides yellow, plastic boxes (and other transportation and storing units) to the suppliers for the Kanban system rotation. Since part of the ABB MoGe's Falco project is to improve Lean procedures, there will be more JIT deliveries in the near future. Replenished Kanban boxes will be transported simultaneously with the other collected JIT deliveries from the suppliers' that are moderately close to ABB MoGe's factories and thus from a pickup loop for the trucks operating on a daily basis scheduled by ABB MoGe. At the time of writing the thesis, the Kanban system is running smoothly for the Pilot1 (InCap) and Pilot2 (Ouneva). More boxes have been ordered for the upcoming Pilots 6 and 7 (Scansolo and Kukkanen) and an order for cages has been made in preparation for the Pilots 3, 4 and 5 (Österberg, Wel-Mach and Laine) for components that include fan covers and fans. They are being delivered shortly.

Additionally, forklift truck operations in In-house Logistics will be improved with a more synchronized operation model. Combined with the Kanban implementation project, there will be a pilot for replacing handheld barcode readers, which are used by forklift operators, by a PC's installed on the forklifts. This will allow a better access to SAP, Manufacturing Execution System (MES) and a warehouse management system (WMS). MES is operating between SAP and manufacturing operations and is RFID enabled in ABB MoGe. The aim is to make WIP material flow more transparent. Via PC's on the forklifts, it is also possible to have a list of transfer orders required for smoother operations of production or goods receiving. Therefore, the labor efficiency and work flow would be highly improved. This would also enable to reduce the amount of required paperwork and printed transfer orders greatly. In addition, manual and/or human errors could be moderated. Consequently, the inventory control and warehouse records would be more up-to-date and have a quality for better administration and decisions.

4.2.5 Kanban SAP Solution

For being able to proceed with Kanban implementation according to ABB MoGe's vision and the schedule, system configurations for SAP were started early on. This phase required several meetings, background research and negotiations with another organization and their SAP consults. It could be said that this process was almost an additional project with the major Kanban implementation project. Since SAP is an old software system, if is not majorly flexible for changing requirements in nowadays business world. However, SAP supports Kanban procedures because that production philosophy was also created about six decades ago.

However, there were system wise problems and challenges related to the Kanban installation. The most critical one was how to make replenishment orders by In-house Logistics key personnel, when the same employee is not allowed to both order goods and receive them for production processes in SAP. This was an obstacle that was not easily circled. In one of the Kanban transactions of SAP these options are visible as 'To Empty' and 'To Full' buttons that are clicked by an operator to make the action of ordering and receiving also in real life. However, since a Kanban order is not an actual order, such as ROP or PR order made by purchasers, the problem was solved by configuring it as withdrawal Kanban. After this the same operator is able to place orders and receive goods in SAP because it is not possible for him/her to make changes to the batch or order amounts or prices of the goods. Therefore, the problem was solved by updating the SAP rights of the key personnel. The solution was good. After all, it was the main idea of ABB MoGe (and the author of the thesis) to create withdrawal Kanban system for the most frequently used components to achieve a more efficient procurement process and reduced bureaucracy of purchasing procedures. In this case, withdrawal Kanban is based on purchase impulses and kanban signals with specified batch sizes.

Another problem with SAP's manual Kanban process is that the command To Full confirms the oldest order of the material and changes its status into 'delivered', even though, it might in fact be one of the orders, which is made after it. Thus first-in, first-out (FIFO) inventory control rule is not followed correctly according to the company guidelines and inventory turnover is not optimized. Moreover, a reference number for goods receiving is an important part of each order, since it is used to direct an order with the actual delivery in SAP environment. This allows greatly improved goods receiving process and provides information of the assembly line and bin for transfer. Otherwise, there is an increment of labor and waste of time and resources during directing the goods to specific orders. This challenge will be outcome on June 12, 2013 during an upcoming SAP release that upgrades the system.

There are different options for choosing the mean to transmit a purchase order to the vendors. Normally with SAP Kanban configuration E-mail, hard copy print out, electronic document interface (EDI) or Association Core Components (ASCC) interface is utilized. Basically ASCC is SAP's EDI and it has a Kanban status report as standard. This report visualizes the status of all Kanban boxes that are assigned for the vendor. (Pylkkänen 2012: 3).InCap and Ouneva are already using this connection for achieving improved communication between business partners, such as supplier and manufacturer. With a Kanban system it is very useful interface, since the deliveries need to be done based on the continuous demand, but there might be fluctuations in the weekly demand, since it is based on averages figures. In Figure 21 on the following page, is shown an example of component's data that is used for creating a Kanban material into the SAP.

The example material's control cycle is 9999990, code is 3GZF294730-608, description cable gland, plant 0800, supply area 8021SA5E, storing position downstairs of MM factory at the Kanban shelf, number of Kanban bins four and order quantity 1,000 pieces. Additionally, there are basic information of procurement type, purchasing organization and vendor.

Figure 21 *Example of a Control Cycle (SAP, ABB MoGe 2012)*

At a visibly clear location at the end of the main Kanban shelves, a touch screen monitor is placed with a Kanban board that demonstrates the status of different Kanban bins. SAP enables the monitoring of the orders and demand of Kanban materials relatively close to the real time. In a Figure 22 below a Kanban board is shown from the testing side of ABB MoGe's SAP. Column 'Material' informs the material codes and 'Description' has material descriptions. 'Storing Pos.' column informs that the first two materials are stored in the Kanban shelf of MM factory's downstairs and the two latter materials are stored in the Kanban shelf of KK factory. The last column informs the Supply Area of each material. On the right hand side, the Kanban bins are numbered and visible with a coloring code that shows the status of each bin. Only bins 17452, 17449, 17457 and 17470 are red and require immediate action. The rest of the bins are green and thus the amount of these components is appropriate for the manufacturing needs.

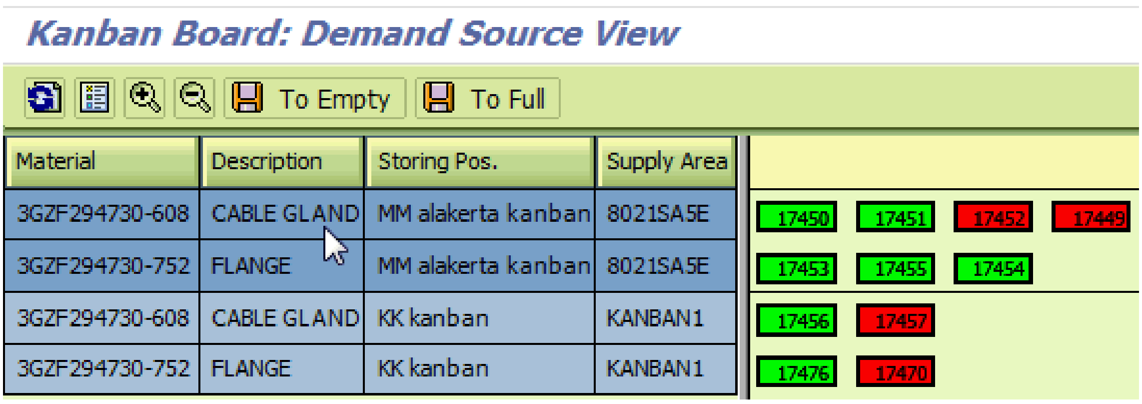

Figure 22 *Example of a Kanban Board (SAP, ABB MoGe 2012)*

4.2.6 Kanban Calculations

Following section introduces independently performed safety stock level and kanban calculations without SAP system with chosen materials of upcoming AL2 at ABB

MoGe that are turned into Kanban materials. The aim is to utilize key data and define optimized kanban and/or container amounts for the materials based on the available data. Exact weekly demand figures were not available in the background data, but they were estimated for the calculation based on the actual total yearly demand. Thus standard deviation is not completely exact either, but it allows demonstrating the procedure of an example months deliveries. Ideally this calculation is performed with actual weekly demands of one year. However, at the moment figures are based on the total yearly demand and safety stock levels are calculated for the chosen example materials. First calculations are made by utilizing below formula (2) introduced in Kanban theory section.

$$N = (dL + S)/C \quad (2)$$

For the reason that Kanban materials are critical for the production, it should be guaranteed that stock outs are not occurring. Kanban system was created to prevent material shortages, but on the other hand to avoid excess inventories. Therefore, a service level between 90.0 and 99.0 percent should be enough and 99.9 percent can be considered exaggerating and operating against the ideology behind Kanban. Achieving a 99.9 percent service level requires a seamless and highly efficient operation with suppliers and normally this also means increased service and/or transportation costs. For this calculation a service level of 95.0 percent is primarily chosen, thus the equivalent coefficient is 1.64 with a data distributed according to the standard deviation. This should be the case with Kanban materials, since the demand is hypothetically even. However, coefficients of 99.0 and 99.9 percent are also utilized in calculations to provide wider scope for the analysis.

Similarly with Kanban calculations, there are several formulas available for defining safety stock level (Lean Sigma Supply Chain 2013). Safety stock amount can be calculated for each material based on the material specific coefficient (or confidence interval) and standard deviation of demand by multiplying them (Gross et al. 2003: 227.) More complex formulas require mean and standard deviations of the lead times (Baudin 2012). A simpler method is chosen for the thesis because the lead times used in these calculations are relatively realistic, but not completely accurate. This is because updated information of Kanban process length is not available for all the parts. However, the lead times are considered from the suppliers' viewpoint and consist of the time frame from triggering a replenishment impulse until the refilled kanban container is delivered to the ABB MoGe. Lead times depend of the components, suppliers and the transportation distance. Actual data of material descriptions and suppliers is left out because of confidiality reasons and only material codes are used. Means of component demand, standard deviations and safety stock levels are calculated in addition to the available information. Excel formulas AVERAGE, STDEV and NORMSINV were utilized for the Appendix 1. Calculations are made with three different service levels with a formula (3) below introduced in the Kanban theory section.

$$K=((RT*AC)/Cont)*(SF+C) \quad (3)$$

All of the example materials do not give a correct idea of Kanban materials, since they would not necessarily require highly efficient transportation and consumption rotation. However, formula is modified by changing time unit from hours to days, since it responds better to the ABB MoGe's needs. In a chart (Figure 23) on the following page are illustrated the results of calculations by using two different formulas and three variations of the coefficient. Appendix 2 shows the final results of calculating the material specific quantities of kanbans. These figures offer an outline of computed amounts to be considered.

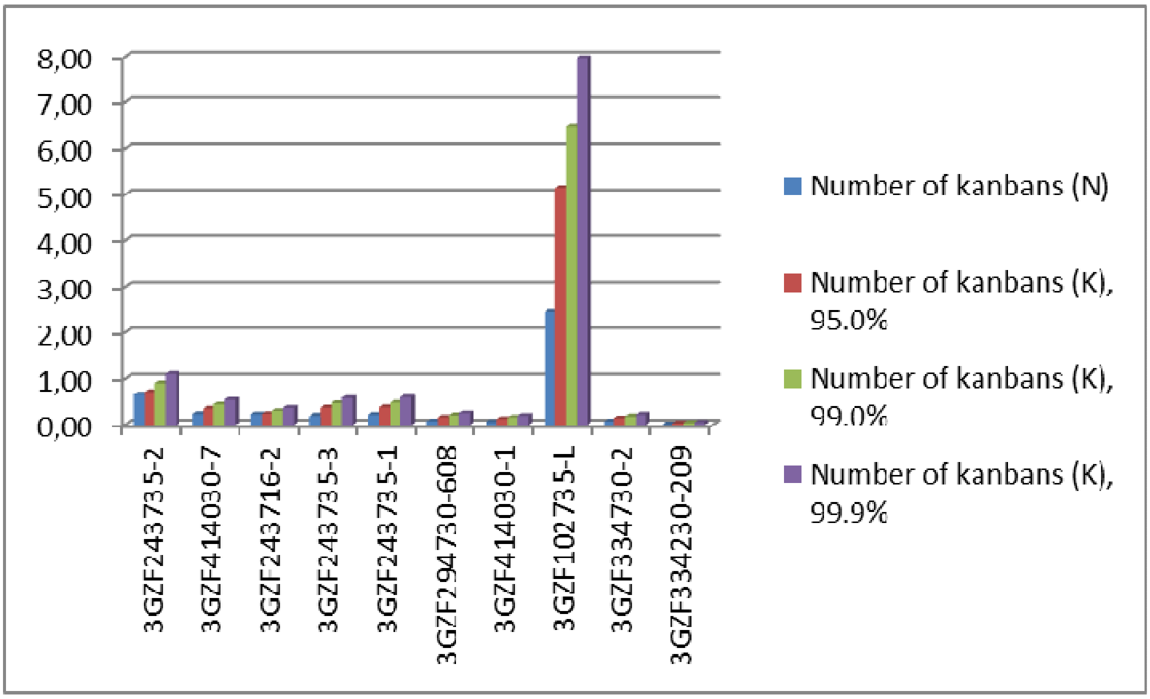

Figure 23 *Results of Kanban Calculations*

Based on the original order sizes and demands, only one (3GZF102735-L) out of ten example materials should be considered to become a Kanban material. Another material (3GZF243735-2) could be considered to be converted also, but based on the calculations, it would have only one kanban card. Therefore, if it was to become a kanban material, the batch size should be divided into smaller orders. However, during the Kanban implementation project of ABB MoGe, they were all chosen and this is mainly because of the upcoming factory layout that is going to nearly double the production. Thus the consumption of the key materials will also increase significantly. In addition to the growing production the example materials were chosen also because there the order batch sizes and lead times were adjusted with the suppliers to become more suitable for the Kanban system. For pilot stages, ABB MoGe defined the container amounts based on having three kanbans per material. Naturally material specific revision is required, when the Kanban system is running with some of the suppliers and the new assembly line(s) is launched. By defining optimized amounts of kanbas and containers, the full potential and gains of the Kanban system can be reached.

4.2.7 Analysis of Kanban Implementation

The author of this thesis has been part of the thorough planning work for the Kanban system implementation by attending weekly six (6) hour meetings, researching the subject independently based on theory, case studies and internal material of ABB MoGe, completed Kanban calculations based on actual materials and figures, offering insight and opinions for Kanban implementation at ABB MoGe and attending SAP, Kanban and other important meetings related to the project. The main input is practical knowledge of the production and logistics operations at ABB MoGe and theoretical knowledge of Industrial Management, Kanban, Lean and RFID technology. The Falco meetings are held twice a week and are normally lasting twelve hours per week. Part of the employment has also been completing tasks relating to the project, such as combining the material list of In-house Logistics and Procurement by utilizing a spreadsheet program to create a united listing of chosen Kanban materials for pilot stages, or defining the stage of assembly line in which the Kanban materials are consumed in order to assign the most suitable storage bin for them by the correct assembly line depending of the main area of usage (MM factory’s downstairs, upstairs or KK factory).

At the time of finalizing the thesis, the training of the key personnel and other staff members had gone well and the operators had adapted to the change of procedures. A Kanban training lasting an hour was held twice and it was enough to get the system started. There are 6–7 in-house logistics operators involved and monitoring Kanban shelves. In addition, the Kanban system is working well with the two first pilot stages. There are about 60 Kanban materials currently in the system and it is functioning well.

All the positive and negative outcomes of the Kanban implementation project are not yet clear at ABB MoGe. However, it is suggested that the potential of Kanban system in the manufacturing processes of customized products include improvement of lead time and delivery time, reduction of inventory cost, improvement of In-house Logistics functions, reduction of Lead waste and a better customer satisfaction.

SAP wise it is a bit unclear situation with the reference numbers for goods receiving, but each Kanban order has only one position and it enables to direct the ordered goods to specific orders. However, otherwise the system is operating according to the plan and ordering process is faster than in normal component procurement at the ABB MoGe. The designing and constructing process of a new assembly line is shifting the attention slightly from the Kanban project and the new pilot stage will be completed for the next three suppliers simultaneously in May or June. It is a different approach and schedule than originally planned, but it is not necessarily worse. This allows the staff to better adjust to the changes that the Kanban system and a new layout brings.

Even though, SAP has been only partly included in this thesis and the Kanban project, it should be mentioned that it is not the most optimized ERP system for ABB MoGe. During the project there had to be made changes to the original procedures and plans because SAP did not provide an efficient functionality to the company's needs. It has Kanban ability, but it is not operating seamlessly and the configuration was planned and implemented with a great effort from the key employers. However, currently the system appears to be functioning with it and because of the Kanban implementation, some of the drawbacks and errors of SAP's warehouse records and other figures might be able to end up being reduced or eliminated.

In a large global organization project management requires great efforts and seamless administration. However, it is not always possible towards all the ongoing projects within the organization, divisions or even business units. These require constant attention and resources that might not be available at all times, since most of the project team participants also have their daily tasks regarding to their regular job description. It was also a case with this project, since the Falco project was prioritized. It involves larger investments and cross functional knowledge from even more departments than the Kanban project. However, the personnel that were involved were dedicated and wanted to create a successful implementation. Nevertheless, a learning point would be related to the fact that there was a major hurry involved with getting the project started and done, but still it was constantly delayed because of the other project or technical difficulties related to SAP or the new infrastructure of the assembly line and erecting the Kanban shelves. It is better to finalize the groundwork first and launch the operations afterwards.

The Kanban project was created in order to achieve more optimized materials management, order replenishment and inventory control management processes and to enable lower inventory levels, improved material receiving efficiency and faster stock turnaround time. Kanban might be able to correct some drawback of current operations by addressing them during the production and logistics processes. Thus it can be expected that these goals will be achieved overtime by finalizing the project and adjusting the amount of Kanban bins into more optimized quantity.

5. FUTURE RFID KANBAN APPLICATION DESIGN FOR ABB MOGE

The future Kanban application designed for ABB MoGe is presented in this chapter. It is a suggestion for upgrading the system that is being currently implemented. The upgradation is planned to be done by installing RFID technology into the previous Kanban system and improving chosen Logistics operations. Another technology called MIFARE has a potential for replacing RFID in the future. However, ABB MoGe would gain more by implementing an RFID Kanban system, since it is more widely used in manufacturing and logistics industries and the suppliers are easier to get involved with a technology that is currently more common. The requests from ABB MoGe are taken into consideration during the application design process; however, there is still room left for potential changes even after the thesis is complete. Feedback from aforementioned system described in previous chapter is not yet available, since the first Kanban project will be finalized approximately three months after the thesis is submitted for grading. Therefore, a detailed evaluation of previous implementation has to be delimited outside the scope of this thesis and concrete advantages and disadvantages are not yet known and thus, cannot be exploited during the RFID enabled Kanban application design.

However, based on another case and previous theory, there are several benefits that a Kanban system is able to create, but upgrading it with RFID technology the advantages can be greater. Improvements are possible in material handling efficiency, material availability (at the production site and factory), inventory cycle time, warehouse records and inventory control. Moreover, manual errors, material shortages and labor costs in the inbound process are reduced because of goods receiving becomes automated. The real time visibility of material flow and replenishment based on the real time demand in production makes inventory information and inbound shipment data more accurate and thus useful for the administration and operators. (Manufacturing & Logistics IT Magazine, 2009). On the other hand, utilizing RFID technology cannot be recommended in all situations and companies, therefore, the decision should be made based on analyzing the possible profits and drawback of the planned system.

The requests made by ABB MoGe include envisioning an implemented production Kanban for in-house component manufacturing, a differentiation between internal and external Kanban process, an automated receiving process of Kanban (and more preferably receiving of all orders with handheld barcode reader or other similar device), and including Piccolo into the Kanban system as withdrawal warehouse. The suggestions made in this thesis are for upgrading the system that is currently being implemented, therefore, it is not recommended to make use of them before the first Kanban implementation project is finalized.

The reliable analysis of possibilities and threats regarding the idea of implementing a production Kanban system (with or without RFID technology) for component manufacturing requires a wide statistical and practical background research of rotors, stators and stator frames produced in ABB MoGe that it would require an extensive study. However, the process should be started similarly than the first Kanban implementation project by defining the yearly average demand of these components and eliminating customer or motor specific components. Utilizing a production Kanban system in component manufacturing, could create benefits for inventory control and enhance the process transparency of production. Nevertheless, the consumption frequency of components should be high and sufficiently even, in order to gain the benefits of a Kanban system. In addition, there have to be a differentiation between internal and external Kanban process, in system and process wise. Basically, after this type of implementation ABB MoGe would have a move/ production Kanban system that was utilizing both move and production kanbans.

Receiving process is automated and each shipment is rather quickly surveyed visually on the surface before acceptance and internal transit. However, more thorough quality inspections are made based on a randomly selected sample and critical components are carefully measured with special equipment according to the current instructions. Since the suppliers of Kanban materials are accepting the new procedures, it could be used as a chance to harmonize the receiving processes via implementing a common receipt slip template applicable for all goods received and preferably in electronic format, such as via EDI system or email. EDI enables electronic documents exchange between computers and just-in-time deliveries (WebFinance, Inc. 2013). More precise explanation is to clarify that the documents are in a standardized electronic format and EDI is used to exchange these between business partners (GXS Ltd 2013). The objective is to enable a completely automated receiving process of inbound goods. With RFID technology handheld barcode readers would be replaced by RFID readers and gates within the factory.

There are also other more evolved possibilities to further cooperate with the suppliers by beginning to utilize reusable RFID tags on the shipments or even implement ASN (advance shipping notifications) system for all the materials and thus making the process truly electrical and/or automated. The latter is described by SupplyOn AG (2013) as a merchandise management tool, which enables the receipt company to reach improvements in planning and correct deliveries and reduces overall costs by eliminating inadequate shipments and mistakes in packaging and labeling. In addition, SAP is compatible with the system (SAP AG 2013). Based on the SAP source material, ASN processing in SAP could be considered a rather straightforward process. Furthermore, ASN is one of the most common business document exchanged via EDI (GXS Ltd 2013) and its potential with Kanban implementation was requested by ABB MoGe. However, an automated goods receiving of all the inbound materials is not closely linked to the Kanban system, which is the main emphasis of the thesis; hence ASN is not researched deeper. If the suppliers cooperate by adopting RFID tags, the inbound shipments could be followed in real time and in addition to In-house Logistics also the production knew the status of replenishment orders. Thus the information flow would be greatly improved and material flow more transparent.

ABB MoGe is considering the possibility of deepening the partnership with Piccolo by adding Kanban withdrawal orders into its operations. In order to being able to operate as Kanban materials warehouse for ABB MoGe, it is recommended that Piccolo updates its In-house Logistics operations by implementing RFID technology at least in a basic form and further synchronizing vital software systems with ABB MoGe. The materials that could be considered are standard components with even demand and considerable consumption, such as end shields, stator frames, rotors, terminal box frames, valve discs, and outer covers. Additionally stators might be considered, but at the moment they are not normally stored in Piccolo's warehouse. If Piccolo will be part of the Kanban process, the system has to be modified within ABB MoGe.

5.1 RFID Kanban System Infrastructure

The RFID enabled Kanban system infrastructure and operation model is planned for this thesis to be implemented for supplementing the system being completely in operation by the end of June, 2013. In the model created, reusable UHF RFID tags will be attached to the boxes, pallets or other storing units. The type of tags is chosen because most of the ABB MoGe's components are metal and the radio waves and thus essential signals are easily reflected or disturbed with tags operating in lower frequencies. In the Europe the UHF bandwidth is 865–869 Megahertz's (ABB Inc. Press Release, RFID Lab Finland ry 2005: 5). UHF tags will replace Kanban cards by having the information programmed into them. After the key data is attached, the tags will also operate as signals (kanbans). The information will simultaneous with the stock transfers because in addition to attaching PC's on the forklifts, they are also formed to be RFID enabled and the bins data is read, when the container is lifted.

RFID forklift gates are also recommended to the strategic locations of the factory because the material movement can be followed by based on the forklift transfers and having the coordinates of important materials at all times. There will also be handheld RFID readers for the operators, if these are needed. Since forklifts are not the only means on transportation within the factories, conveyors and inbound gates will similarly be modified with RFID readers. These types of readers are already in use for production operations in ABB MoGe.

SAP has a compatibility with RFID technology. The combination is recommended for automated mapping of physical goods movements and offers possibilities for Kanban processes, container management and returnable packaging. It is also suggested that the SAP RFID system is able to provide other benefits as well, such as streamlined material flow systems, improved process security and increased data quality and integrity. (SAP AG. 1: 2005). Figure 24 on the next page reveals the architecture behind the SAP solutions and RFID technology. In the case of ABB MoGe, the forwarding agent and also partly (or completely) the storage would be Piccolo. However, the author of this thesis is slightly skeptical towards SAP's ability to process the immense amount of information that an RFID Kanban system would be collecting continuously with several RFID readers and from hundreds or thousands of tags. The challenges are increased, if other inbound and outbound materials are included into the SAP RFID system.

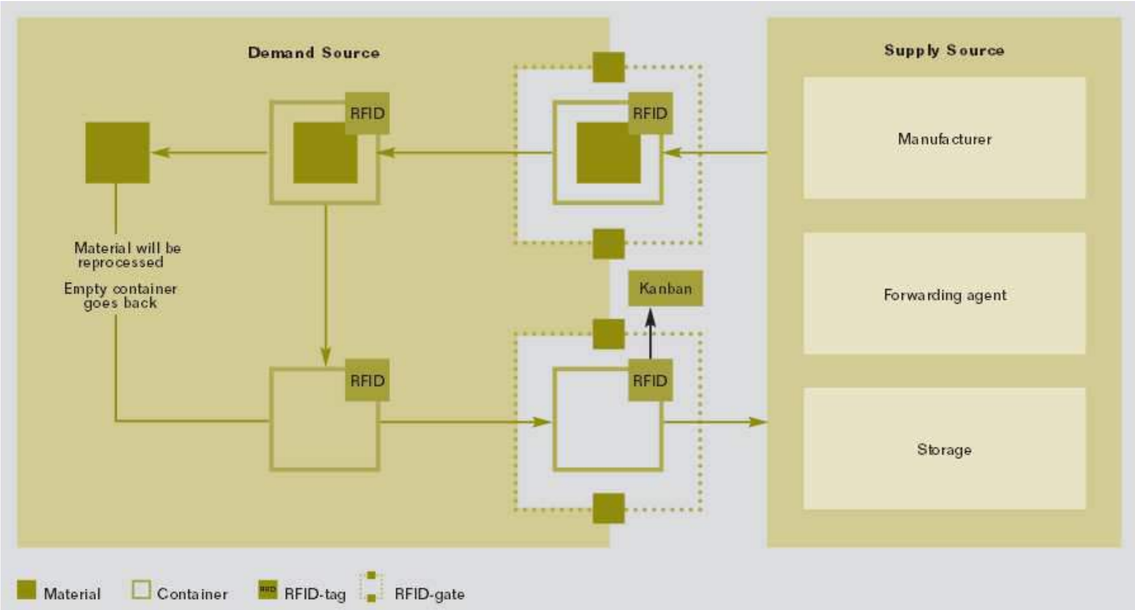

Figure 24 *RFID Integration Streamlines Kanban Processes (SAP AG. 2013)*

Inbound material flow monitoring can be optimized via RFID only, if the chosen key suppliers also implement this technology into their operations. Additionally, there need to be a pilot for an RFID closet or shelves, which automatically initiate the replenishment process straight to the supplier, when an emptied Kanban box or pallet is placed in or on them. In a Figure 25 on the following page is illustrated a typical RFID solution for manufacturing and logistics. Smart labels are tags, portals RFID gates, wireless access points are RFID readers and tagged locations or slots can be areas for Kanban bins that enable the automated replenishment signal straight to the suppliers. In the example figure also inbound and outbound materials have RFID gates and the suppliers are connected to the RFID Kanban system.

Figure 25 *An RFID Solution for Manufacturing and Logistics. (Smartag 2012).*

5.2 Analysis of RFID Kanban Application

RFID technology enables the enhancement of the currently implemented Kanban system. Since RFID is already partly in use in production processes at the ABB MoGe, the adaptation procedure is easier, but the implementation project would require larger resources and investments than the Kanban project. However, the return of investment (ROI) is normally achieved only after the process is properly functioning and has been for a longer time period than, for example, when implementing barcodes into logistics operations.

The new layout of the MM factory is not finalized and completed yet because the Falco project is still ongoing and the production facilities will be greatly change after the conclusion of this thesis. Therefore, it is not possible to design an optimized model of RFID Kanban system and its architecture for ABB MoGe. However, some of the possibilities have been revealed and new propositions have been made for the improvement of the Kanban system currently being implemented. More detailed plan and infrastructure are possible to design after all the details are clear regarding to the new layout, assembly lines and shelves. The RFID infrastructure is sensitive for readers close to each other or a huge amount of simultaneous traffic of tags. Therefore, it should be carefully researched, which are the best locations and the optimized quantity for the readers within the factory.

6. CONCLUSIONS

In this thesis, the potential advantages and disadvantages a Kanban system implementation might cause to the material management processes of a manufacturing facility are researched and the theoretical and/or practical reasons behind these results are defined. On an empirical level the research question is analyzed by participating to a Kanban implementation project at the ABB, Motors and Generator's business unit in Vaasa (ABB MoGe). An additional research problem is to study the possibilities of improving the Kanban system with RFID technology. Since ABB MoGe utilizes SAP as its ERP system, SAP's functionality was also taken into consideration.

Research strategy was to collect the data by utilizing academic articles, publications, eBooks, case studies and additional materials obtained during employment at the case company and weekly meetings held during the Kanban implementation project. Part of the project are also employees' training, changes related to the infrastructure, hardware, software and warehouse area organization, implementation in practice, piloting stage, application launching, final results and possible modifications. All of the activities were not described in detail, since the study was mainly structured around Kanban and only the key elements are defined and included. Research methods of this study were a combination between structural, qualitative, and quantitative approaches. There were several key findings discovered during the study that are described in the following paragraphs.

In addition to the Kanban implementation project at ABB MoGe, four other case studies were selected and summarized for the thesis. The empirical method is to analyze the results of case studies objectively and to define, whether the Kanban system generally improves the overall production processes and inventory management in manufacturing facilities based on the theory and experiences of selected companies. Half of the sample had a regular Kanban system and the other half had RFID Kanban systems. Based on the findings, implementation drawbacks remained insignificant and there were only few restrictions for Kanban implementation. Basically, all the resources were complimenting the Kanban system as a part of production operations and inventory reduction. The case studies showed remarkable improvement in reducing the inventory levels and increasing storage space. Even though the quantity of readily available components was reduced, the stock outs became less probable, which meant that the manufacturing process was also developing. Half of the case study companies was described to have had savings and were also able to provide better customer satisfaction because of improved production efficiency.

RFID technology enables upgrading of the currently implemented Kanban system, which is mainly utilizing barcodes. RFID system is not perfect, but its technology is an important strategic tool in several industries including manufacturing and logistics. Since RFID is already partly in use in production processes at the ABB MoGe, the adaptation procedure is easier, but the implementation project requires larger resources and investments than the Kanban project. However, ROI is normally achieved overtime and not until the process is properly functioning and improving operations. MIFARE technology has a potential for replacing RFID in the future. However, ABB MoGe would gain more by implementing an RFID Kanban system. The new layout of the MM factory is not finalized and completed yet because Falco project is still ongoing and the production facilities will be greatly changed after the conclusion of this thesis. However, some of the possibilities have been revealed and new propositions have been made for the improvement of the Kanban system.

Even though, SAP is not the most optimized ERP system for ABB MoGe and there had to be made changes to the original procedures and plans during the project because SAP did not provide an efficient functionality to the company’s needs. However, SAP is able to perform automatic Kanban calculations in order to define important parameters for production control. The actions of computing the optimized material specific kanban (card) amounts and component quantities per kanban container are vital for up-to-date improvement of the Kanban system. End result will be a topnotch material management level that allows a minimum inventory, but is still sufficient enough to prevent stock outs of critical components. These calculations can be performed also without SAP and necessary mathematical formulas are introduced and utilized with actual materials of ABB MoGe. Since the kanban amounts and order quantities were defined differently before the pilot stages of the Kanban implementation project, these methods offer an insight that should be considered during the rest of the pilot stages and after the project is completed. Only by defining optimized amounts of kanbas and containers used in the material circulation, the full potential and gains of the Kanban system can be reached.

At the time of finalizing the thesis, all the positive and negative outcomes of the Kanban implementation project are not yet clear at ABB MoGe. However, it is suggested that the potential of Kanban system in the manufacturing processes of customized products include improvement of lead time and delivery time, reduction of inventory cost, improvement of In-house Logistics functions, reduction of Lead waste and a better customer satisfaction. The Kanban project was created in order to achieve more optimized materials management, order replenishment and inventory control management processes and to enable lower inventory levels, improved material receiving efficiency and faster stock turnaround time. Kanban might be able to correct some drawback of current operations by addressing them during the production and logistics processes. Thus it can be expected that these goals will be achieved overtime by finalizing the project and adjusting the amount of kanban bins into more optimized quantity. The Kanban system is not a magical solution for all the problems related to manufacturing customized products, but together with a pull system and the Lean concept, it offers a significant improvement for the production operations and inventory management.

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APPENDICES

	3GZF243735-2	3GZF414030-7	3GZF243716-2	3GZF243735-3
YTD	2985	3216	3252	3410
Wk1	62	67	68	71
Wk2	51	56	87	82
Wk3	42	76	98	66
Wk4	75	49	40	75
YTD Weekly Average	57	62	63	66
YTD Daily Average	8	9	9	9
Standard Container	60	200	300	200
Average:	58	62	73	74
Std Dev:	14,2678	11,9162	25,4125	6,7522
Lead time in days	2	3	3	3
Safety Stock	23	20	42	11

APPENDIX 1. data of kanban calculations, part 1

3GZF243735-1	3GZF294730-608	3GZF414030-1	3GZF102735-L	3GZF334730-2	3GZF334230-209
3535	3768	4351	4757	5923	9159
74	79	91	99	123	191
77	70	89	89	143	189
87	80	87	90	121	178
65	78	79	101	112	200
68	72	84	91	114	176
10	10	12	13	16	25
200	500	1000	20	1200	10000
76	77	86	95	125	189
9,0940	4,4980	5,1594	6,1524	13,0572	9,0275
3	3	4	3	4	5
15	7	8	10	21	15

APPENDIX 1. data of kanban calculations, part 2

	3GZF243735-2	3GZF414030-7	3GZF243716-2	3GZF243735-3
Number of kanbans (N)	0,66	0,23	0,23	0,20
Number of kanbans (K), 95.0%	0,72	0,35	0,24	0,37
Number of kanbans (K), 99.0%	0,90	0,44	0,30	0,47
Number of kanbans (K), 99.9%	1,11	0,54	0,37	0,58

APPENDIX 2 results of kanban calculations, part 1

3GZF243735-1	3GZF294730-608	3GZF414030-1	3GZF102735-L	3GZF334730-2	3GZF334230-209
0,22	0,08	0,06	2,45	0,07	0,01
0,38	0,16	0,13	5,15	0,14	0,03
0,49	0,21	0,16	6,49	0,18	0,04
0,60	0,25	0,20	7,98	0,22	0,05

APPENDIX 2 results of kanban calculations, part 2