A Material Flow Evaluation at Scania Production Slupsk S.P.S

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2007-09-27
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A Material Flow Evaluation at Scania Production Slupsk S.P.S

Master’s thesis written at Department of Management and Engineering (IEI), Linköping University
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Supervisors Marie Reinholdsson (S.P.S), Krister Alm (Omni Södertälje) and Janerik Lundquist (IEI)
Södertälje September 2007
Summary
This master’s thesis is performed at Department of Management and Engineering Linköping University, for Scania Omni at Scania Production Slupsk (S.P.S). Omni is responsible for development, manufacturing and marketing of city, suburban and intercity buses. After acquisition of the production unit in Slupsk in 2002 lower production cost per bus is possible. But without control over the organisation costs are rising due to late delivery fees and high stock levels. At the outset, the thesis included three clearly defined objectives:

- Map the present situation at Scania Production Slupsk regarding material flow from supplier to assembly line including a part and storage analysis.
- Benchmark the current routines at Scania Production Slupsk with other successful companies. Furthermore, conduct literature research in order to find theories and philosophies that support problem analysis and thesis solution.
- Develop standard routines for material control methods (MCM) and material supply methods (MSM).

A complimentary objective is to work as a catalyst during the time of the thesis.

The mapping of the present situation showed that MCM and MSM are very tight connected to each other. It was questioned whether this structure was the best way to manage the material flow. After a parts and storage analysis, material was divided into different segments depending of price, consumption and movement.

The benchmarking studies showed different ways to manage the material flow. Implementation of unit load, kanban and clear defined interface between departments showed potential to improve the material handling and increase effectiveness.

New routines and part segment definitions described in a logistics manual (Appendix I) were made align with a comparison between previous and recommended definitions. The result showed that some parts needs to be controlled differently.

Primary recommendations are that logistics manual shall be used when new parts are introduced into the Scala system. Responsible personnel are suppose to give suggestion concerning decision making of MCM and MSM and with help of the logistics manual the work can be more efficient, resulting in a material flow that is flexible and have potential for improvements.

Secondary, to avoid material handling to some extent implementation of two-bin system is recommended. Additional recommendations regarding two-bin system is to handle material according to unit load, which enable FIFO, traceability and higher turn over rate.
Preface

After a spring with hard work we have finally finished our master thesis, the last piece in our master’s examination in Communication and Transport Engineering. We have learnt a lot and it is hard to imagine how fast time goes by. There are many people who have made this master thesis a reality which we would like to thank.

First, we would like to thank Marie Reinholdsson and Tina Arnstedt at Scania Omni for initiating this master thesis. It has been really an interesting and challenging time both in Slupsk and Södertälje and we are very grateful for getting this opportunity. We would also like to thank our supervisor Krister Alm, for support and inspiration during the entire thesis period. Thanks also to all personnel at Scania Omni Södertälje and Scania Production Slupsk for assistance and giving up time answering questions.

During our master thesis we have also visited Scania Chassi, Scania Industrial & Marine and Toyota Material Handling Sweden in order to take part in there production. In all cases have they been very accommodating and we thank them for that. Further we would like to thank S.P.S suppliers Laminer, Emmarol, Kamir and Kendrion for our visits. It has been interesting and useful information has been retrieved.

Finally we would like to thank Janerik Lundquist, our supervisor at Department of Management and Engineering at Linköping University.

With expectation that this master’s thesis will enhance work at Scania Production Slupsk with continuous improvements.

Södertälje September 2007

Daniel Gustafsson  Mikael Johansson
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**List of Abbreviations**

AWC = Aluminium Working Centre  
CMR = Transport Document  
ECO = Engineering Change Order  
EDI = Electronic Data Interchange  
EFR = Exception from Requirement  
EOQ = Economic Order Quantity  
FIFO = First In, First Out  
GR = Goods Reception  
JIT = Just-In-Time  
KD-Package = Knock Down Package  
KOS = Katrineholm Order System  
KS = Construction Breakdown  
LIFO = Last In, First Out  
LTL = Less-Then-Truckload  
MP = Material Planner  
MC = Material Controller  
MCM = Material Control Method  
MH = Material Handling  
MPS = Material Planning System  
MRP = Material Requirements Planning  
MSM = Material Supply Method  
NC-Card = Non Conformity Card  
ROP = Reorder Point  
S.P.S = Scania Production Slupsk  
SS = Safety Stock  
TMHS = Toyota Material Handling Sweden  
TPS = Toyota Production System  
VMI = Vendor Managed Inventory  
Vv = Volume Value  
WIP = Work In Progress  
X-Specification List = Sales Order List of Features  
ZZC-List = A List of Customer Order Items
1 Introduction

1.1 Background

Scania Omni is a division within the Scania CV AB Group responsible for development, manufacturing and marketing of city, suburban and intercity buses. Main office includes development department and strategic purchase situated in Södertälje. The main bus production unit is located in Slupsk Poland. Further, buses are also produced in St Petersburg Russia and Tartu Estonia.

Scania Production Slupsk (S.P.S) has 688 employees and produce complete buses and chassis. S.P.S also Knock Down-Pack (KD-pack) parts for bus bodies assembled in St Petersburg. On a daily basis, the production rate is three production units, different weight depending on bus variant, one N-chassis and twenty KD-packages. As of today S.P.S has about 500 suppliers. To make call offs from its suppliers S.P.S use reorder point (ROP), batch and sequence, depending on price, size and consumption.

Scania Omni is operating according to Scania Production System. But, due to the recent acquisition of the production site in Slupsk, the organisation has been changed: new suppliers, different culture and old systems making the structure complex, all leading to a number of logistic related consequences. Lower production cost per bus is now possible, but without control over the organisation costs are rising due to late delivery fees and high stock levels. Furthermore, material control methods (MCM) are tightly bond with material supply methods (MSM) leading to lower effectiveness in storage. Another problem is lack of measurements and key figures concerning working routines, production and material handling. Nevertheless, Scania Omni is currently in an expansive situation with introduction of new product program and higher production tact, aiming at a larger market presents.

The main questions of the thesis are:

- How should MCM and MSM be tied together in an efficient way?
- Is it possible to decrease logistics related deviations? Through:
  - Clearly defined parts segments with appropriate call off method or
  - Standardised working routine concerning introduction of new parts or
  - A combination of the proposals above.
- Is present material flow suitable for future demands?
1.2 Objectives
The purpose is to perform an evaluation concerning material flow from supplier to production line, in other words secure right material at right time without holding a high stock level.

The study is further divided in three separate and clear objectives:
- Map the present situation at S.P.S regarding material flow from supplier to assembly line including a part and storage analysis.
- Benchmark the current routines at S.P.S with other successful companies. Furthermore, conduct literature research in order to find theories and philosophies that support problem analysis and thesis solution.
- Develop standard routines for MCM and MSM.

A complimentary objective is to work as a catalyst during the time of the thesis.

1.3 Delimitations
Due to the scope, the following delimitations have been made in order to fulfil the purpose within the time frame of this project:
- The analysis will only involve the production site in Slupsk.
- The study presupposes that suppliers are known and that parts are clearly defined.
- There will not be any time study included.
- The analysis will only include the material flow for bus production, from supplier to assembly. This leads to:
  - The flow between Aluminium Working Centre (AWC) and pre assembly will be excluded.
  - The flow between pre assembly and assembly will be excluded.
2 Methodology

In this chapter the methodology of the thesis is described. To start with, the research procedure is outlined and each step is explained and analysed. Finally a discussion concerning sources of errors is given.

2.1 Research Procedure

According to the objectives, listed in chapter 1.2, the thesis includes three steps illustrated in figure 2.1:

- Map the present situation at Scania Production Slupsk regarding material flow from supplier to assembly line including a part and storage analysis.
- Benchmark the current routines at Scania Production Slupsk with other successful companies. Furthermore, conduct literature research to find theories and philosophies that support problem analysis and thesis solution.
- Develop standard routines for MCM and MSM.

A complimentary objective is to work as a catalyst during the time of the thesis.

Figure 2.1 Thesis process.

2.1.1 Step 1

The first step is to get an overview of Scania Omni by information from supervisor Krister Alm and Tina Arnstedt. After a brief understanding of the organisation and structure, interviews with different departments are scheduled. The thesis is mainly written at Scania Omni, both in Södertälje and Slupsk due to nearness of supervisors, key persons and production line.

Interviews are held at different departments in both Södertälje and Slupsk. Information is gathered about present situation concerning material control method, material supply method and information flow. Several visits to the production plant are made to get a deeper understanding about working processes, culture and organization.

To be able to create improved working routines and find solutions concerning MCM and MSM, the first step is very important in terms of data gathering. The information is gathered via interviews and observations. Old studies are also used to accelerate the learning about the present situation. Logistics manuals from Chassi are also used as reference of how to set standards and routines. Regarding the study *Material Handling at S.P.S* (2006) by Frida Sandström interviews with the author where also held to
clarify some issues. Both local and international suppliers are interviewed to get a broader picture of the relationship between Omni and its suppliers. Issues discussed are information flow, lead-time and order handling.

2.1.2 Step 2
This phase intends to increase the knowledge of how to be more efficient in order to secure right material at the right time for production, without high stock levels. For an effective benchmarking it is important to map the present situation and identify areas of improvement. The benchmark is focusing on MCM and MSM, how the storage is managed and the production system.

The benchmark is made by visits, guided tours and interviews with key persons at other companies. The first company to visit is Scania Chassi, another division within the Scania CV AB Group, which produce trucks and chassis. Standard routines and measurements are therefore easier obtained. Further, Scania Industrial & Marine is visited aiming at finding similarities in production with respect of Scania Production System. There are also benchmarking with Toyota Material Handling Sweden, former BT Industries, regarding positive effects after implementing Toyota Production System (TPS).

To get a deeper knowledge on related theories and science regarding areas evaluated a literature study is made parallel with the benchmarking. Information is gathered and written in a frame of references, used to underline the following recommendations and solution, but also to show the unversed theory behind reasoning and conclusions.

2.1.3 Step 3
Many aspects contribute to the final development of the material flow evaluation. Price, size and consumption are important factors, but consideration of which MCM and MSM to be used will have a large impact on the final recommendation. Useful data in this phase derives from discussions with persons involved in the different areas and from literature along with empirical findings. Finally, personnel aspects gathered from interviews on material facing have been used.

Due to the scope of this thesis no mathematical, simulation or optimization modelling will be used. Instead, the problem formulation will be approached in another pragmatic way of working. Different material segments will be analysed and a material flow evaluation will be made, in order to find deviations relating to MCM and/or MSM. By conducting this kind of survey new routines is recommended for introduction of new parts. The development of new routines can also be used in the daily work to improve present situation.

After development of a new part process a comparison with the present situation will give validation of the recommended MCM and MSM and how they are supposed to be tied together. Furthermore, validation will be done by interviews with key persons in different areas. Through discussion and collaboration with parameters the work will be
in constant motion and reevaluated to finally present trustworthy recommendations for continues work, shown in figure 2.2.

![Validation process diagram](image)

**Figure 2.2 Validation process.**

A complimentary objective is to work as a catalyst during the time of the thesis. Regarding this objective the outcome is hard to present. But, as the thesis progress continues discussions with Marie Reinholdsson and other key persons will be held. At those follow-ups the intention is to give away useful information about matters that do not adjoining the main objectives but are essential for continuous improvements at S.P.S.

### 2.2 Sources of Errors

In order to evaluate the reliability and validly of the thesis, sources of errors need to be identified and analysed. According to Garson (2007), one principle for collecting data is triangulation. Triangulation is an attempt to increase reliability by reducing method error, through a strategy in which the data is gathered from multiple sources. The data gathered in this thesis comes from interviews, internal material observations and literature.

A study is valid if its measures actually measure what they claim to, and if there are no logical errors in drawing conclusions from the data. To establish validity in this thesis interviews with different key persons, from all parts of the supply chain investigated, have been made. This is called investigator triangulation (Guion, 2002).

Most information is gathered from interviews with key persons. The weaknesses with interviews are possible misinterpretations of both questions and answers due to language problems or poorly constructed questions. Another aspect is that answers can differ depending on which department the questions are asked since there are conflicting objectives in different departments when it comes to logistics. One example is that the finance department want to have full control over costs regarding each bus body, leading to a lot of material handling, while logistics wants to minimize material handling to reduce waste.

Inaccuracies can appear when recalling the answers. Therefore, notes where taken during interviews. Taken notes during a conversation can lead to reduced attention; however more contact has been made to avoid misunderstanding when uncertainty has occurred regarding information gained during interviews.
3 About Scania

First, a short description about Scania CV AB, Scania Omni and the product range Omni can offer. The next section will give an introduction regarding organisation and history of Scania Production Slupsk.

3.1 Scania CV AB

The information about Scania CV AB is based on information from the Scania website (www.scania.com) and oral references (c.f. list of references). Today, Scania is a leading manufacturer of heavy trucks and heavy buses as well as industrial and marine engines. Scania is a global company with operations in Europe, Latin America, Asia, Africa and Australia. At the end of last year (2006) Scania had over 32,000 employees worldwide, mostly located in Europe and South America. Scania’s history goes back to 1900 when the company was founded, through a fusion in 1911 with Vabis, the company Scania-Vabis emerge. In 1969 a new fusion took place with Saab AB and Saab Scania was formed. In 1995 the companies were separated and Scania was again an own company.

Scania’s production of buses had until year 2002 comprised both chassis and bus body manufacturing but thru a restructure the operations was separated in a more industrial production of chassis and more craft production of bus bodies. At the same time, Scania completely owned subsidiary Omni Katrineholm AB was created with the liability of the bus body production. Later same year chassis production moved from Katrineholm to Södertälje and was synchronised with the truck production. The chassis built by Scania CV are divided in two types, N- and K-chassis, see chapter 3.2, which is sold to Omni and other external bus builders. In year 2004 Omni Katrineholm production moved to Slupsk Poland and the company name change to Scania Omni AB.

3.2 Scania Omni

The information about Scania Omni is based on oral references and information material from the company. Omni is responsible for the development, manufacturing and marketing of city, suburban and intercity buses. The total number of employees in year 2006 was 990 divided between Södertälje Sweden, Slupsk Poland and St Petersburg Russia. The main office includes development department and the strategic procurement department is located in Södertälje. Further, production plants are situated in Slupsk and St Petersburg where city and suburban buses are built. Baltcoach, an external bus body builder, located in Tartu Estonia, performs the production of intercity buses. The different production sites produce different buses depending on type and/or market. The production in Slupsk produce the city bus OmniCity and OmniDoubleDecker, the suburban bus OmniLink and also send KD-package to St Petersburg. Production in St Petersburg assembles buses based on KD-package from Slupsk with help from local suppliers. The production in St Petersburg is mainly for the Russian market. The production in Tartu produces the intercity bus OmniLine. The buses produced at the different production units are shown in figure 3.1.
About Scania

Figure 3.1 Product range from Scania Omni.

**N-chassis**
The N-chassis is built to serve city buses with a low floor in the entire bus. Therefore, the engine is placed in the rear, opposite the moving direction of the bus, to enable usage of a low floor. The production of N-chassis is located in Slupsk, under the management of Scania Chassi, and used for OmniCity and sold to other body builders. A special variant of the N-chassis, used for OmniDoubleDecker, is built in Södertälje.

**K-chassis**
The K-chassis, produced by Scania Chassi in Södertälje, is used for suburban and intercity buses. The engine is placed over the rear axis, in moving direction of the bus, which makes it necessary to use a higher floor in the back of the bus. Both OmniLink and OmniLine use the K-chassis. The K-chassis is transported from Södertälje to Slupsk for production of OmniLink. The K-chassis is also sold to other bus producers, among them Baltcoach.

**OmniCity**
OmniCity uses the N-chassis and is developed for city traffic. The bus has an all-through low floor, enable easy and quick possibilities to get on and off, it is available in both normal twelve-metre model and as a three-axle articulated bus measuring eighteen metres. The bus can be design in vary configurations depending on door configuration, interior and control systems. The production is located in Slupsk. Last year 210 OmniCity buses where deliver to customers around Europe.

**OmniLink**
OmniLink is a suburban bus based on the K-chassis. In differ to OmniCity the floor is low to the middle of the bus and thereafter higher. This results in a combination
between easy possibilities to get on and off in the front and middle of the bus and higher comfort and better view in the back. The configuration is made due to the fact that passenger is supposed to travel longer with fewer stops. The bus is made in twelve and fifteen metre versions as well as in an eighteen metre articulated version. Similar with OmniCity the bus can be designed in large variant of ways. Production of OmniLink is located in Slupsk and 2006 where 251 buses delivered.

**OmniLine**

OmniLine is a bus for intercity use. Similar to OmniLink it is based on the K-chassis but with a high floor in the whole bus and with an all through luggage compartment. The bus features high driver and passenger comfort, i.e. separate air vents and lighting for each passenger seat, to make long travel more pleasant. The production is located in Tartu and monitored by Baltcoach that delivered 64 buses during 2006.

**OmniDoubleDecker**

OmniDoubleDecker is a two level city bus, mainly for the UK market, based on a special designed N-chassis built in Södertälje. Like all other buses the design and configuration is very specific for each customer. The production for OmniDoubleDecker is located in Slupsk.

**KD-package**

KD-package is bus parts, for OmniLink, packed ready to be assembled. The KD-package is packed at the production site in Slupsk and sent to St Petersburg where it is assembled on K-chassis. The production in St Petersburg is mainly for the Russian market. Future plans to expand the production in St Petersburg, include OmniCity, are under discussion.

The wide range of possibilities and customers orders, results in a production based on make-to-order, where almost every bus or order is unique.

### 3.3 Scania Production Slupsk

As mentioned earlier the production unit in Slupsk produces buses, KD-package and N-chassis. The site was founded in 1992 as Scania Kapena S.A from a shared ownership between Scania CV (65 % of ownership) and Kapena S.A (35 % of ownership). In 2002 Scania CV acquire the ownership and the following year the name change to Scania Production Slupsk S.A. The production in Slupsk has produced trucks, bus chassis and city/suburban buses. Before Omni moved their production to Slupsk the site operated as an external body builder, assembling buses for Scania.

The production unit in Slupsk is the largest site within the Omni organisation with 688 employees. The production site includes: Three meeting points and one line for the assembly of OmniCity and OmniLink; S-line for production of OmniDoubleDecker and prototypes; chassis line for N-chassis production; KD-pack area for part packaging sent to St Petersburg; Pre assembly area; AWC for production of different aluminium parts; Different storage locations. The objective for S.P.S is to produce three production units per day at main assembly line, twenty production units per month at
S-line, three N-chassis per day and twenty KD-packs a month. The ambition for 2007 is to increase the production and improve the deliver reliability.

### 3.4 Organisation

Organisation and ownership structure, according to Tina Ar nstedt, for Scania CV AB, Scania Omni and the production units are shown in figure 3.2 and 3.3. As mentioned earlier Omni is a subsidiary of Scania CV AB responsible for the bus production with own departments regarding sales, planning, procurement and purchase. The production units in Slupsk and St Petersbourg are monitored by Omni but owned by Scania CV the production in Tartu also produces buses for Omni but is owned by Baltcoach.

![Figure 3.2 Organisational chart of Omni sales and production.](image)

![Figure 3.3 Ownership structure Scania CV AB.](image)
4 Present Situation

This chapter describes production in general, departments’ involved and material flow for S.P.S. A more detailed description regarding MCM and MSM is also included. Furthermore to give a broader picture of the present situation statistics concerning parts and storage are presented and described.

4.1 Time Table

The production of buses at Omni is scheduled according to a timetable shown in figure 4.1. Depending on the promised Delivery Date (DD) required activities are planned to make delivery possible. At least 80 days in advance of the DD customer demands must be complete and defined as a bus configuration to be handed over to the design department. The department then have 20 days to complete the design, Start Design (SD) to Design Complete (DC). For repetitive orders design department can reduce the time to 5 days and therefore decrease the timetable to 65 days. When design is ready procurement department start their work by contact existing suppliers and find new to purchase the parts and material needed. Depending on supplier lead-time orders are made, usually at the point of Material Control (MC). If orders are made according to plan and lead-time is achieved parts and material should be at line when it is needed, earliest time parts are required is Start Assembly (SA). At SA assembly of the bus body is initiated and at Meeting Point (MP) it is assembled on a chassis, N- or K-chassis depending on bus type. Thereafter, final parts and interior are assembled to complete the bus and tested at Test Delivery (TD). Remaining changes and improvements are then made during the finale days until the DD.

![Figure 4.1 Timetable for bus production.](image)

- **SD** = Start Design
- **DC** = Design Complete
- **MC** = Material Control
- **SA** = Start Assembly
- **MP** = Meeting Point
- **TD** = Test Delivery
- **DD** = Delivery Date

4.2 Departments

Departments’ involvements and responsibilities during the timeline are presented below. The description is simplified due to the fact that department’s works often overlap and integrate with each other.

4.2.1 Sales and Marketing

The sales offices are the first part of Omni to have contact with the customer. Local sale personnel meet the customer and specify their demands and requirements. After
an initial choice from Omni bus program, OmniCity, OmniLink or OmniLine, bus configuration is defined according to an X-specifications list. This list contains pre-defined choices concerning length, engine and door configuration etcetera. A requirement not covered by the X-specification list is defined as a customer order item, described separately. These (i.e. information systems, ticket systems, cameras and other special interior designs) can be specific for the customer or the market it operates at. After the configuration is completed and described the information is sent to planning department.

4.2.2 Planning and Procurement
When configuration is received from sales department information is implemented in the systems and a structure breakdown is performed to part level. The breakdown creates a material demand that purchase is based on. The department is responsible to plan the production so customer requirements are met. This means to find the right suppliers, with good quality and reliability, and plan the sequence in which the buses should be produced. Problem with supplier or production results in new plans in order to obtain the objectives. Personnel located in Södertälje do this part of the departments work. As delivery date is set other departments are informed in order to start their work and when the design department is ready with the design, local purchase personnel in Slupsk contact suppliers to initiate final orders. Based on non-confirmed bus orders or historic parameters suppliers receive forecasts. In differ to the rest of the Scania organisation Omni uses fax, to send orders and forecasts, instead of Electronic Data Interchange (EDI). EDI is a real time data system that for communication concerning orders and deliveries. The reason it was not implemented was the low production volume and the requirement have it implemented at suppliers.

4.2.3 Design
Due to milestones in the timeline, figure 4.1, design department should receive the complete configuration at SD. Inputs to the design department are the X-specification list and information concerning custom order items. Thereafter, design department construct custom order requirements; later describe in a ZZC-list. The department also handles issues concerning changes or configurations in the X-specification list. Due to the timeline design department have four weeks to complete their tasks and hand over the final specification to order parts and produce the bus according to the promised delivery date.

Another task for the design department is to take care of Engineer Change Order (ECO). This can be a requests form customer according new needs or changes after the design is complete. Another case of ECO is when the construction needs to be improved or changed in order to fulfil custom demands. As a temporary solution design department can allow an Exceptions From Requirement (EFR) to be used during the design of the new solution or improvements. This can be solutions from the production (e.g. extra spacers or use of other parts) to make the construction functional.
4.2.4 Production

As mentioned in chapter 3.2 Omni’s production is located in Slupsk, St Petersburg and Tartu. This thesis will only focus on the production in Slupsk. According to the timeline, figure 4.1, production should start assembly 17 days in advance of promised delivery date. This presupposes that design and purchase departments have completed their tasks. Parts missing at assembly are reported to material handlers by the assembly personnel and registered in a Shortage Database. If the parts is in store delivery is arrange as soon as possible. If the shortage depends of late delivery, GR is informed to set higher priority to that specific delivery. If the part is critical (i.e. can conduce line stop) and have not left the supplier a speed transport is arranged. When delivery arrives parts are sent directly to the line. Prioritised incoming parts should be at line in maximum one hour. If parts are missing in work order, not existing in the structure, or simply have not been ordered the material controller find the quickest solution to solve the problem either by contacting the supplier, Scania spare parts or a local supplier for a custom made solution. Another situation that can appear at assembly line is when a part is damaged, either from the supplier or during assembly. When this occurs personnel reports this by using non-conformity cards (NC-card). Depending on the cause different actions are taken. If the problem depends on quality issues from the supplier, information is modified. If the reason is weakness in the construction an ECO is created to change the part. If the problem is related to improper working routines new one should be developed. The development of routines is very limited. Depending on the cause of the NC-card time to get a new part varies. According to Marie Reinholdsson this matter sometimes results in shortages reports instead of NC-cards, in order to get the part quicker. A procedure leading to a situation where the real problem is hidden and right actions cannot be applied. Statistics from year 2006 shows an average of 25 NC-card reports per day. All information that NC-cards holds has been administrated in a data file. However, there exists no standard procedure in order to handle such problem, which leads to repetitive incorrect actions.

4.2.5 Finance

The finance department responsibility is cash flow, which involve everything from salary to bus production finance. In a logistic point of view the departments’ roll can be described as followed. In order to get a better view and control of the actual cost of every bus the finance department wants every purchased part to be bund up with a specific bus. This result in a situation where the department want more parts to be purchased based on sequence or batch instead of ROP. The reason is that the actual consumption per bus can be hard to estimate because of big variance. The need to bund up the parts with buses has also causes a strict relationship between MCM and MSM. If parts are purchased as a batch it also has to be distributed as batch to the line, which is not always the best solution in a material handling perspective. In discussions with the department have the relationships been told to be less important as long as there is a method to bind the costs.
4.3 Suppliers
Today Omni have about 500 suppliers, both local and international. According to Lechek Chudy 50-60 % of material goes through a hub in Ystad Sweden. The hub collects goods from all over Western and Northern Europe and arranged it in trailers. Suppliers from Poland and Eastern Europe deliver directly to S.P.S.

4.3.1 Kendrion JV AB
Kendrion is a medium company situated in Habo Sweden and supply S.P.S via Ystad. Their production philosophy is make-to-order but for parts that require long lead-time Kendrion hold a small stock of semi-manufactured articles. In that way high service level is reached without binding to much capital. Once every week Kendrion receives orders from S.P.S. According to Lars Nordgren the delivery schedule require improvement and better structure. For the moment new and old orders are mixed, making the structure confusing and hard to follow. Furthermore, Nordgren would like to visualise the number of parts in each unit in the purchase order. Some of these problems would, according to Nordgren, be solved by an implementation of EDI which Kendrion uses against other customers, among them Scania Chassi.

4.3.2 Emmarol S.A
Emmarol S.A is a local supplier and supplies Omni with approximately 200 different parts, both ROP and batch. According to Marek Krasicki the company is expanding very fast and the production is overloaded, leading to a situation where new orders cannot be accepted. In their planning system production time is allocated and call offs are made as soon as orders are initiated. For standard parts lead-time of raw material is one week, at maximum. Even though Emmarol receives forecasts for 20 weeks they do not use this information. The reason is lack of trust towards its accuracy. Experience from production based on forecasts shows examples when Omni has not ordered according to the forecast and Emmarol have overproduced. The content is that Emmarol do not order raw material from its supplier or allocate time in production until there is a definite order. In cases when Emmarol cannot deliver according to delivery schedule information is given at latest two days after receiving the order.

4.3.3 Kamir S.A
Kamir is a supplier of sheet metal batch parts. Small details are produced according to make-to-stock and bigger more bulky parts are make-to-order. Kamir divide orders into three categories: standard, prototype and urgent. In that way manufacturing priority are set for production. Regarding package material Scania pallets are used, but packed by experience because lack of instructions. To motivate personnel and keep the knowledge within the company workers have piece wages. According to Arkadiusz Kusmerczyk forecasts are used to some extent, mainly as information for purchase department to prepare orders. Kusmerczyk also mentioned that the initial work could be simplified with drawings in 3-D.
4.3.4 Laminer S.A
Laminer is a small plastic manufacturing company, situated outside Slupsk, supplying Omni with panels and covers. All production is make-to-order and standard lead-time is six weeks. For the moment a computer based planning system is not used, but due to increased order stock and savings implementation is planned in the near future. Another benefit with this system is that EDI can be managed. Drawings, documents regarding production processes, material consumption etcetera are kept in logbooks for each part number. In that way information is easy to find when new orders are made. Regarding package material Scania pallets and boxes are used according to Scania standards. If there are no packing instructions available, Omni is informed. According to Janusz Swiderski forecasts are rarely used, because of the uncertainty where they have experienced the same situation as Emmarol. Swiderski also explained that it is difficult for a company in their size to hold stock regarding raw material or finished products.

4.4 Material Control Methods
Material flow from suppliers to Scania Production Slupsk is managed by MCM. Material control methods used at S.P.S are ROP, batch and sequence, which are separately described below.

4.4.1 Call Off
Omni divides parts and materiel into three different categories depending on price, size and consumption. According to Jakub Garbacz and information from parts data file, described in chapter 4.6, share in storage between ROP, batch and sequence are:

- **ROP** 19% of storage
- **Batch** 77% of storage
- **Sequence** 2% of storage
- **Other** 2% of storage

In total S.P.S has about 9,000 parts with balance in storage, of which 6,500 have been used during the last six months. The average consumption for a bus is between 1,500 and 1,800 parts.

**Sequence**
Respective supplier dedicates parts controlled by sequence for a unique chassis or bus body. According to production plan, material controller place orders according to assembly date. S.P.S uses MCM sequence for parts that are expensive, bulky and variant dependent. Typical sequence parts are seats, fabrics and carpets. Sequence parts are visually buffered in order to easy detect deviations.

**Reorder Point**
Parts managed by MCM ROP usually have low value and high frequent usage (i.e. screws, nuts and rivets). The method is also used for parts where consumption is hard to estimate and therefore should be available in the storage over time. Parts are automatically ordered when balance in storage reach a pre defined reorder point level. The quantity ordered is a defined economic order quantity (EOQ) based on expected consumption.
Expressions used by S.P.S:

\[ ROP = \text{Max Consumption} \times (\text{Lead time for supplier} + \text{Transport time (Poland 1 week, Foreign Countries 2 weeks and Scania Parts 0.5 week)} + \text{Safety Buffer (1 week of consumption, worst case)}) \]

\[ EOQ = \text{Calculated quantity of consumption for 4 weeks (frequency: 1 delivery/4 weeks)} \]

As mentioned earlier calculation of EOQ for ROP parts is based on predicted consumption. However, ordering cost and holding cost are not taken into consideration.

**Batch**

MCM batch is used for parts with irregular consumption and/or high value and are ordered based on actual demand. The total requirement is calculated from a long-term prognosis and the net requirement is determined by subtracting physical inventory level.

Once a week responsible material controller (MC) faxes purchase order and delivery schedule, together with forecasts for twenty weeks to respective supplier. 96 % of parts using MCM batch have a lead-time of six weeks. In conclusion, material controllers at Scania Production Slupsk do not work with firm planned orders. Regarding package instructions work has been initiated to establish standards and manuals for both existing and presumptive suppliers.

**4.4.2 Goods Reception**

Goods are delivered to goods reception (GR) from Omni’s suppliers via transports, mainly trailers. As first authority GR are responsible for unloading, register, sorting and handling deviations of incoming goods. The average number of incoming deliveries is presented in table 4.1. These deliveries are not allotted a specific slot time; instead it is “first come, first serve”. The majority of full trailers come from Ystad via boat, which results in a concentration of arrivals during the morning. Due to higher workload during the mornings the lead time for GR is set to 24 hours.

Inputs for GR are transporter, number of consignments and date/week of arrival. This information is provided from responsible MC. Some deliveries, mainly from local suppliers, are not advised and therefore cannot be compared to the delivery schedule.

<table>
<thead>
<tr>
<th>Period</th>
<th>Small</th>
<th>Medium</th>
<th>Trailer</th>
<th>Total</th>
<th>Ystad</th>
<th>Ystad %</th>
</tr>
</thead>
<tbody>
<tr>
<td>11.2006</td>
<td>233</td>
<td>296</td>
<td>128</td>
<td>657</td>
<td>34</td>
<td>27%</td>
</tr>
<tr>
<td>Per day</td>
<td>11</td>
<td>14</td>
<td>6</td>
<td>31</td>
<td>2</td>
<td></td>
</tr>
<tr>
<td>12.2006</td>
<td>192</td>
<td>280</td>
<td>105</td>
<td>577</td>
<td>29</td>
<td>28%</td>
</tr>
<tr>
<td>Per day</td>
<td>11</td>
<td>17</td>
<td>6</td>
<td>34</td>
<td>2</td>
<td></td>
</tr>
<tr>
<td>01.2007</td>
<td>277</td>
<td>311</td>
<td>114</td>
<td>702</td>
<td>39</td>
<td>34%</td>
</tr>
<tr>
<td>Per day</td>
<td>13</td>
<td>14</td>
<td>5</td>
<td>32</td>
<td>2</td>
<td></td>
</tr>
<tr>
<td>02.2007</td>
<td>236</td>
<td>258</td>
<td>95</td>
<td>589</td>
<td>26</td>
<td>27%</td>
</tr>
<tr>
<td>Per day</td>
<td>12</td>
<td>13</td>
<td>5</td>
<td>29</td>
<td>1</td>
<td></td>
</tr>
</tbody>
</table>

Table 4.1 Statistic over incoming deliveries.
After unloading, GR personnel execute a first inspection to verify the number of consignments is correct according to the CMR (transport document from driver). Furthermore a visual inspection is made to discover obvious damages. After the first survey personnel take parts in Euro pallets and smaller packages through the goods reception building and manually register it in an Excel file. Larger consignments are handled outside in the same way. It is the storage personnel responsibility to assign each pallet an address in store. Furthermore is every pallet/box labelled with arrival date and pallet address. Some parts, not arriving in Scania package, are repacked before stored.

Scala is S.P.S’s material resource planning system and is comparable with a MRP I system. The arriving parts are registered and storage balance is updated in real time.

Storing
From the buffer area in between GR and storage, forklift drivers pick up the pallets and store them according to address labels. Almost all parts have a permanent location in storage where new parts are stored on top of old parts. If current location is occupied storage personnel is responsible to relocate a new location. When parts are placed on top or in front of old parts FIFO is not obtained.

4.4.3 Storage
Overall five storage areas that are used and material are located according to call off method and size described below:

- A-store with a capacity for 5700 pallets
- B-store consists of 500 pallet places of larger pallets.
- M-store contain 1600 ROP parts (Euro pallets, small and mini boxes etcetera).
- 02-store for storing of seats outside the factory area.
- Other storage areas: Outside on yard and other smaller storage buildings.

There is no clear visual tagging in storage showing min and max levels or the time parts have been stored. Batch and sequence parts are stored together and location in storage is set according to station at line and usage frequency. Further, the occupancy level in storage is high due to introduction of new parts, sleeping parts and high balance, leading to lower efficiency in storage. According to Robert Pacocha a future objective is to increase turnover rate in all storage areas, primary by lower lead-time and improvement of order quantities.

Packing Material
Regarding packing material Scania has a policy that all suppliers have to pack the material according to Scania standards. Scania standards are a wide range of Scania pallets and boxes that include: Euro-pallet, small box, mini box etcetera. Despite these standards Omni has not put pressure on all suppliers to fulfil these demands. Parts from suppliers that do not use Scania package is in some cases repacked by GR, which is time consuming, and increase damage risk. Another effect is that the number of pieces in one package can vary from time to time.
4.5 Material Supply Methods
MSM include material flow from store to assembly line.

4.5.1 Material Handling
Material handling (MH) is responsible for fulfillment of material requirement from assembly line, pre assembly and AWC. When the signal is set, MH needs to transform each requirement into an order against internal suppliers, GR and storages. Ordered material ought to be at MH according to arrangements so each assignment can be executed. Material in storage is then distributed to respective station address. Empty pallets and boxes are taken care of and returned to storage for recycling.

At present situation there is no usage of min and max levels at pre assembly regarding production rates. Resulting in a situation where the production is not adjusted in case delays at assembly line. MH only uses buffer areas to some extent.

4.5.2 Ordering goods
S.P.S use three different methods for internal material handling, described below.

Kanban
All ROP parts are ordered in pre-defined batches using internal kanban cards. Assembly personnel are responsible for ordering by placing a kanban card in an order box for that specific area. There is no minimum level for the parts in the boxes, which means that assembly personnel need to estimate when to order a certain part. Once every shift MH personnel collect the cards and deliver parts the following shift. Kanban parts addressed to a specific area are packed together in a pallet and left outside the M-store ready for distribution.

Picked Parts
Based on work order specification parts are order picked for each bus body or N-chassis. Almost all batch parts are supplied to assembly line by this method. Four days in advance responsible person order parts to each assembly station, by filling in an order list. Depending on station and bus sequence material is usually ordered for three to nine buses at a time. Based on the demand pick lists are created by store administrator, who distributes the pick lists to the different stores. One day in advance store personnel pick parts in pallets, which are labelled with a sticker. Ready pallets are place in different distributions areas depending on assembly station. Finally, forklift driver transport pallets to a buffer area or final station.

Sequence
MH manages the internal flow of sequence parts according to production sequence. Due to size and package material sequence parts are found in vary storages. To order sequence parts MH fill in a sequence order list depending on min and max level for each line buffer area. For bulky parts that do not have a buffer area close to assembly line com-radio is used to signal MH.
The interface between MH and assembly personnel can sometimes be diffuse. There is no clear definition concerning responsibility of material. In example both MH and assembly personnel have unloaded the pallets with new parts arriving at line.

4.5.3 Feedback Systems

In excess of the NC-cards and registration in shortage database, described in chapter 4.2.4, MC and assembly responsible have daily routines for follow-ups. MC meets and discusses shortages, suppliers and speed transports etcetera to keep control of department’s responsibilities. In the same way responsible personnel from assembly, GR, MH, MC and planning gather to discuss present situation. These follow-ups lead to a situation where problems are visualised, to avoid similar situations in the future.

4.6 Parts and Storage Analysis

In order to get a better view of the present situation concerning parts and work related to them, a parts and storage analysis where preformed. Four parts from each material control method; ROP, batch and sequence, was chosen and followed through the supply chain. The selection of parts where made according to; non-working parts; parts working according to plan and supplier location. Some of the suppliers where visited, see chapter 4.3. Responsible MC supported with information and Jakub Garbacz was interviewed for a more detailed description.

Information where gathered from interviews aligned with two data files. The first file consists of balance and location in storage, value, latest transaction date, supply method and parameters etcetera. The second file where based on consumption over the last six months, 2007-01-01—2007-07-01. All information those files where gathered from Scala. Based on the study and the information gathered inferences and calculations where made, in order to describe the present situation. According to chapter 4.4 parts are controlled by ROP, batch or sequence. Some parts have the state 00, which means not in breakdown structure, or state 99, parts in a phase out state. The share between parts controlled by different methods is shown in table 4.2. One problem found during the study where that some of the parts handled by ROP was not included in the structure and therefore do not show the correct consumption, shown in table 4.2. According movements from storage 1 240 parts have been consumed compared to 815, if the information is based on the structure breakdown.

<table>
<thead>
<tr>
<th>Share 2007-07-20</th>
<th>Consumption since 2007-01-01</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Movement from storage to line, part with balance 2007-07-20</td>
</tr>
<tr>
<td>00</td>
<td>196  2,3 %</td>
</tr>
<tr>
<td>ROP</td>
<td>1 521 17,6 %</td>
</tr>
<tr>
<td>Batch</td>
<td>6 618 76,7 %</td>
</tr>
<tr>
<td>Sequence</td>
<td>230  2,7 %</td>
</tr>
<tr>
<td>99</td>
<td>67   0,8 %</td>
</tr>
<tr>
<td>Blank</td>
<td>1    0,0 %</td>
</tr>
<tr>
<td>Total</td>
<td>8 634 100 %</td>
</tr>
</tbody>
</table>

Table 4.2 Share based on supply method with different approaches.
S.P.S has different storage locations, both indoor and outdoor, where parts are stored depending on usage, size and supply method. Table 4.3 shows value of parts stored at S.P.S.

![Table 4.3 Number and value of parts in storage at Scania Production Slupsk 2007-07-20.](image)

As mentioned in a previous discussion (Chapter 4.4) MCM ROP usually is used for parts with low unit price and high consumption or if consumption is hard to estimate. Due to this fact and information found during the study where batch parts with balance in storage studied. The reason is to find potential parts more suitable to be controlled by other methods. The result is displayed in table 4.4.

![Table 4.4 Number of low unit price batch parts with balance at S.P.S.](image)

A similar study was preformed based on information gathered from the file concerning consumption, shown in table 4.5. In excess of the number of parts consumption where also analysed, in order to display all parts with low value.

![Table 4.5 Number of consumed low unit price Batch parts since 2007-01-01.](image)

Parts controlled by MCM ROP is ordered in quantises of EOQ as ROP is reached (Chapter 6.2). The maximum balance in storage should occur if nothing is consumed during the lead time, Maximum balance = EOQ + ROP. A situation where balance exceeds the maximum level occurs if parameters are changed, i.e. if parts are ordered by more then one production unit where largest consumer sets package quantity. Otherwise, parts are not ordered according to standard routines. Table 4.6 shows balances for ROP parts in terms of ROP and EOQ.

![Table 4.6 Balance for ROP parts in regard to ROP and EOQ.](image)
Parts controlled by ROP at S.P.S usually have low unit price or roughly estimated consumption. Due to those presumptions unit price have been studied, displayed in table 4.7. In excess of this information parts with high consumption are included do display parts controlled by improper methods.

<table>
<thead>
<tr>
<th>ROP</th>
<th>Total</th>
<th>Unit price ≤ 5</th>
<th>5 &lt; Unit price &lt; 20</th>
<th>Unit price ≥ 20</th>
</tr>
</thead>
<tbody>
<tr>
<td>With balance</td>
<td>1 521</td>
<td>1 143</td>
<td>265</td>
<td>113</td>
</tr>
<tr>
<td>With balance, moved after 2007-01-01</td>
<td>1 240</td>
<td>945</td>
<td>205</td>
<td>90</td>
</tr>
<tr>
<td>Consumed according to structure</td>
<td>815</td>
<td>598</td>
<td>144</td>
<td>73</td>
</tr>
<tr>
<td>Consumed according to structure, consumption &gt; 70 %</td>
<td>265</td>
<td>194</td>
<td>51</td>
<td>20</td>
</tr>
</tbody>
</table>

Table 4.7 Share of parts controlled by ROP based of unit price.

Almost all batch parts have six weeks lead-time. This is used as default value when new parts are introduced resulting in a situation where parts have to be ordered in an early stage to guarantee availability. Long lead-time also makes late changes and deviations in delivery critical. Another issue concerning lead-time is the impact on turn over rate, where long lead time requires more planning. Lead-time depending on MCM is shown in table 4.8. Worth noticing is that lead time for sequence parts is excluded due to incorrect information in the data file.

<table>
<thead>
<tr>
<th>MCM, Nr./LT</th>
<th>0</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>6</th>
<th>7</th>
<th>8</th>
<th>9</th>
<th>10</th>
<th>11</th>
<th>12</th>
<th>13</th>
<th>14</th>
<th>15</th>
</tr>
</thead>
<tbody>
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Table 4.8 Lead time according to MCM.

As new designs and solutions are developed, parts are no longer used and are therefore phased out. If this work is neglected a situation with sleeping parts occurs, material with no movement. Another situation is when purchase is based on incorrect information or changes of custom made parts. Parts only stored and not used simply add costs and allocate space in storage. If parts cannot be phased, a consideration between keeping them in storage or sell/scrap them is made. If the parts are sold or scraped it unbind area in the storage, which can be used for other needs. Table 4.9 displays the number and value of sleeping parts both half and one year basis (the parts that have not been used in one year is included in the once for half year), based on parts with balance in storage. The table also includes parts labelled as 00 and 99.
4.7 Scania Production System

Scania started fifteen years ago to reform working routines, aiming at rationalize production processes. The objective was to work with improvements in a simple and structured way. Today the reform is known as Scania Production System and work as a common basis for all activities within Scania CV. Scania Production System summarize guidelines and philosophies together with prioritisations and principles that Scania work with. Further, working routine is built on four corner stones, shown in figure 4.2:

- Normal situation – Standardised Working Method
  Normal situation is built on standardisation, a fixed tact time, levelled and balanced flow through the supply chain. Work should be visualised so deviations are easily detected with feedback information to right receiver.

- Right from me
  Right from me, imply to do things right from the start. Through purposive tools, instructions and methods that exclude the possibility to do wrong.

- Consumption Controlled Production
  Production is initiated only when actual demand exists.

- Continuous Improvement
  Challenge and improve all processes through elimination of waste. In that way, new improved normal situation is achieved.
After the acquisition of the production site in Slupsk Scania Production System has been implemented to some extent. During the time of the thesis continuous improvements has been made regarding standard working routines, aiming at finding a normal situation. According to Anna Nibelska working groups has been put together for each working station where personnel are educated in Scania Production System. Furthermore, every week time is assigned for reflection and discussion about present situation and how working routines can be improved. Whiteboards and documents are used to visualise normal situation but also deviations as they occur. A lot of work has been done but Scania Production System is a never-ending process with continuous improvements.
5 Problem Definition

The problem definition is mainly based on information gained during the first step of the thesis, explained in chapter 2.1.1.

The intention with defining the problem is to determine clear objectives and delimitations for further work. All consecutive chapters either support the problem definition direct or indirect. Furthermore, the main questions have emerged during mapping of present situation together with the given background and therefore lead the way to a reliable analysis and solution. The main questions are:

- How should MCM and MSM be tied together in an efficient way?
- Is it possible to decrease logistics related deviations? Through:
  - Clearly defined parts segments with appropriate call off method or
  - Standardised working routine concerning introduction of new parts or
  - A combination of the proposals above.
- Is present material flow suitable for future demands?

Delimitation is stated in their context in order to difference issues analysed from subjects that are not of interest to finalise the thesis. In that way the border between suggestions, recommendations and implementation are clearer.
6 Frame of References

The frame reference will explain the theory chosen, to enable an evaluation of what influence decision-making regarding MCM and MSM. First, brief explanations of different supply chain concepts will be given as well as some supply chains philosophies. The next section describes storage management and the last section emphasise lead-time, waste and tact time. How the different sections in this chapter are linked is shown in figure 6.1.

![Diagram of theoretical coherence](image)

**Figure 6.1 Theoretical coherence.**

6.1 Supply Chain Management and Logistics

A definition of Supply Chain Management from Council of Supply Chain Management Professionals (CSCMP, 2007) is:

“Supply chain management encompasses the planning and management of all activities involved in sourcing and procurement, conversion, and all logistics management activities. Importantly, it also includes coordination and collaboration with channel partners, which can be suppliers, intermediaries, third party service providers, and customers. In essence, supply chain management integrates supply and demand management within and across companies.”

Hence, supply chain management include all companies in the supply chain. Business processes and functions needs to be linked between companies and may include cooperation in sales, product design, finance and logistics. According to Chopra and Meindl (2004) supply chain management involves the management of flows between and among stages in a supply chain to maximize total supply chain profitability, without sub optimisation of smaller parts of the supply chain. The definition of Logistics Management from Council of Supply Chain Management (CSCMP, 2007) follows:

“Logistics management is that part of supply chain management that plans, implements, and controls the efficient, effective forward and reverse flow and storage of goods, services and related information between the point of origin and the point of consumption in order to meet customers' requirements.”

24
Here, logistics management is seen as a part of the supply chain. It involves transportation, warehousing, storage management and material planning. However, many definitions of both supply chain management and logistics management exist. The difference between them depends on who is addressing the issue and there is not always such a clear distinction between them as the definitions above. There will be no distinction made between the two in this thesis.

6.1.1 Implementation of Logistic Changes
According to Storhagen (2003) logistics have a broad span regarding both width and depth. Breadthways logistics enclose the entire supply chain from supplier to customer and traversal traditional departments and organisation boundaries. Further, logistics always implicate levelling amongst different resources. If an action is conducted within one function it practical always has an impact on other functions. The versatile of logistics makes logistics problem more complex.

Performance of logistics improvements is also hard to measure. The reason is that logistics span horizontal whereas traditional accounting systems span vertical, which make decision making of key figures difficult. A consequence of previous discussion is that logistics reforms are seldom approved when there is no possibility to measure the effects (Storhagen, 2003).

6.2 Supply Chain Concepts
Some important supply chain concepts are stated in this section, in order to understand how the present material handling is managed and how different material control methods and material supply methods can be tided together. There exist other interesting methods that allow another way of working. These concepts will be explained, but only used as recommendations.

6.2.1 Push/Pull Based Supply Chain
The way of controlling the material flow through manufacturing, distribution or a combination of them both can have different take of points. The core in a system is usually based on material requirements planning (MRP), which is a centralised way of mange material flow.

In a push-based supply chain, production and distribution decisions are based on long-term forecasts (Simchi-Levi et al, 2004). With push systems, execution is initiated in anticipation of customer orders. Central personnel using an MRP system control often push systems. Manufacturing is made in large lots making a high level of work in process (WIP) and long cycle time for the lot. As a benefit there is a high level of inbound material to each process, which leads to high load for each and every process. However, when using a push strategy there is always a risk of over production.

In a pull-based supply chain on the other hand, focus is on matching customer demand with production. To be more specific execution is initiated in response to a customer order (Chopra and Meindel, 2004), leading to customer demand is known with
certainty. Furthermore products are made-to-order and there is no inventory in a pure pull system.

A more modern way of thinking is to focus on ascertain demand for the following action. In that way material is pulled through the supply chain and material is ordered, against the previous actor, when there is actual need instead of based on forecast as for push systems. A comparison between push and pull based supply chains are shown in figure 6.2.

| Push system: Order |
| --- | --- |
| Material Flow |

| Pull system: Order |
| --- | --- |
| Material Flow |

Figure 6.2 Comparison between a push-system and a pull-system (Storhagen, 2003).

According to Nicholas (1998) a number of conditions need to be fulfilled to make implementation of a pull-based system successful. The requirements are:

- **Decentralised responsible for planning and controlling**
  Pull-based production is dependent of supervisors and production personnel to have some responsible regarding planning and controlling production.

- **Focus on consumer based production**
  A fundamental requirement is that production can only be initiated when actual demand exists. Never initiate manufacturing because available time exists at line.

- **High quality and preventive maintenance**
  Production with low inventory levels requires a high level of availability and that material are sent to the next step, which has to hold desirable quality.

- **Short setup times**
  Small batch sizes are necessary for production with low inventory levels, which also requires short setup time.

- **Flow shop layout**
  In order to synchronise production processes some sort of connection needs to be established between disjoint working stations and production cells with remaining production steps. Furthermore, capacity and possibility to produce according to tact time needs to be levelled across all stations to be able to even out the material flow.
Level production plan and constrained production mix
In general a pull-based system can handle variations no greater than ± 10 %, higher variations needs to be levelled on forehand.

6.2.2 Just-In-Time
During the last few decades the Japanese industry has shown improved efficiency and development. Behind the success lies a high level of productivity enhancement, due to reduction of production costs and higher total asset turnover. Through simple information system Japanese companies have decreased stock levels, shortened total lead time, reduced waste and lowered administration costs. Common for all Japanese production system is quest aspiration towards produce right amount at right time. An umbrella term for these methods is Just-In-Time (JIT) (Liker, 2004).

JIT open possibilities for a lower amount of WIP. By constant reducing stock levels problems will arouse and be solved, instead of being covered. A high level of WIP can give high expectations, but hold capital and require comprehensive material handling. JIT is achieved by pulling the material from a station to another, as an alternative to deliver according to a delivery schedule (Olhager, 2000).

According to Olhager (2000) implementing JIT require short set up time, small lot sizes, short lead time, flexible personnel and decentralised quality management. Thereby, an amendatory prerequisite is made towards an efficient and straightforward production. Figure 6.3 illustrate an implementation plan for JIT, among other thing it shows necessary actions to be taken before a Kanban system can be implemented.

![Figure 6.3 Implementation plan for JIT (Olhager, 2000).](image)

6.2.3 Lead Time
The logistics structure is driving cost, but also lead-time and delivery service (Abrahamsson & Aronsson, 1999). An important aspect when evaluating the material flow is the current lead time to customers and how essential lead time is to them (Olhager, 2000).

The high competition on the market increases the importance of short lead time to attract customers. Also, the rapid introduction of new products or features needs to be considered in terms of lead-time.
Accurate lead-time is also essential when calculating safety stock and reorder point level. According to Piasecki (2003) lead time should include supplier manufacturing lead time, time to initiate the purchase order or work order including approval steps, time to notify supplier, time to process through receiving and any inspection operations.

According to Euler (2002) short lead time gives following benefits:
- Less tied up capital
- Shorter forecast horizon
- Better prerequisites for customer-driven manufacturing

However, to be able to decrease lead-time standard-working routines needs to be established. Furthermore, cost rationalisation requires to be made in order to find areas of improvement (Euler, 2002).

6.2.4 Optimal Order Quantity
Determine optimal order quantity has long been a logistic problem with multiplies answers depending on who is addressing the issue. A frequently used formula is economic order quantity (EOQ) and is dated to early twentieth century. Even though it is over hundred years old it is used widely. According to Lumsden (1998) high volumes gives low ordering cost but high holding cost and vice verse. In it simplest model EOQ determine optimal order quantity with respect of demand, ordering cost and holding cost, shown in figure 6.4. Ordering cost and holding cost are weighted against each other with respect of total cost and optimal order quantity is given.

![Figure 6.4 Graphical descriptions between ordering cost and holding cost to achieve optimal order quantity (Olhager, 2000).](image)

Nevertheless, according to Olhager (2000) EOQ prerequisites following:
- Demand divided in time is constant and known
- Ordering cost is known and independent of order quantity
- Holding cost per unit and time is constant and known
- Delivery to storage is made by full order quantities each time
EOQ do not consider transport inventory, planning horizon and shortage cost when calculating order quantity. Furthermore, discounts for larger batches or lower transport cost due to joint loading are also excluded (Storhagen, 2003).

EOQ formula:

\[ EOQ = \sqrt{\frac{2 \times O \times D}{P \times H}} \]

*EOQ* = Economic order quantity  
*O* = Ordering cost  
*D* = Annual demand of the product  
*P* = Purchase cost per unit  
*H* = Holding cost per year as a fraction of product cost

Ordering cost is a fixed cost incurred per order and is independent of order size. Costs that are involved are mainly dependent of administrative time and document handling. In other terms ordering cost is the total cost to make call offs that guarantees material availability for production. According to Piasecki (2006) ordering cost also include costs for controlling, register, receive and handling payment for merchandise. Usually, ordering cost is calculated on a yearly basis and then split onto every order that has been made over the last twelve months.

Holding cost is primarily made up of the costs associated with inventory investment and storage cost. But, also divided costs for material handling, inventory rent, insurance, scrap and obsolescence. In the EOQ formula, holding cost is represented as the annual cost per average on hand inventory unit and is usually assumed to be linear and dependent on inventory level in storage. Further, holding cost can be differentiated amongst parts with respect to size and need of special treatment (Olhager, 2000).

According to Piasecki (2006) mistakes in calculating storage costs are common in EOQ implementations. Generally companies take all costs associated with storage and divide it by the average inventory to determine a storage cost percentage for the EOQ calculation. This tends to include costs that are not directly affected by the inventory levels and does not compensate for storage characteristics. Carrying costs for the purpose of the EOQ calculation should only include costs that are variable based upon inventory levels.

Holding cost is fairly easy to determine even though some of the cost are template divided (i.e. computers) and include:

- Buildings including rent, facilities
- Inventory including shelves, racks
- Physical inventory
- Forklifts
- Maintains
- Computers and administration
As awareness it is relevant to mention that a company’s possibility to change call off of material is often dependent of various restrictions. Therefore, the discussion regarding EOQ can seem a bit theoretical and less useable in reality. Despite the last statement and the limitations of EOQ it is essential to investigate if EOQ can contribute to a more efficient purchase operation (Storhagen, 2003).

While EOQ may not apply to every inventory situation, most organizations will find benefits in some aspect of their operation. Every time repetitive purchase or planning of new parts is made, EOQ should be considered. Obvious applications for EOQ are purchase-to-stock distributors and make-to-stock manufacturers. However, make-to-order manufacturers should also consider EOQ for multiple orders and when planning material and pre-assemblies. Though EOQ is generally recommended in operations where demand is relatively steady, parts with demand variability such as seasonality can still use the model by usage of shorter time periods for the EOQ calculation. However, safeguard of usage and holding costs are based on the same time period is of importance (Chopra & Meindl, 2004).

Even though accuracy is crucial, small variances in the data inputs generally have very little effect on the output when calculation EOQ, shown in figure 6.5.

![Graph showing increase in cost dependent on parameter error](image)

**Figure 6.5 Description how the cost increases dependent on parameter error (Euler, 2002).**

In content, EOQ is easy to use and relative insensitive. Despite that forecast is uncertain and ordering cost align with holding cost is challenging to determine, EOQ is rugged for a variety of “carelessness” regarding calculation these parameters.

### 6.2.5 Safety Stock

The most important issue for inventory storage is to handle fluctuations between inbound and outbound material over time. Hence, if the problem on optimal order quantity as mentioned in previous discussion is solved, the inventory storage will never cause any logistic related problems. On the other hand, this is only valid when demand/consumption is stable.
According to Storhagen (2003) it is impossible to calculate safety stock in order to hedge for all kind of shortages, the relationship is illustrated in figure 6.6. Fill rate indicate the probability to deliver from storage. Duplication of safety stock only enhances deliver reliability from 95 % to 98.5 %. In conclusion, to achieve 100 % fill rate an infinite safety stock is required.

![Figure 6.6 Relationship between safety stock and fill rate (Storhagen, 2003).](Image)

Practical it is an issue of how many shortages the company can accept over a given period of time. The theoretical objective is to minimize the total cost of shortages and safety stock. In real life, due to difficulties of unequivocal determine shortage cost, fill rate is defined via company policy for each and every article. With holding cost in mind it is vital that company policy correspond so safety stock levels are hold to a minimum. Concurrent an economic judgement between ordering cost and safeguard sale if shortage occurs need to be considered.

### 6.3 Material Control Method

#### 6.3.1 Material Requirements Planning

Material requirements planning (MRP) are support in connection with tactic-operative controlling and planning in first hand. The objective is to control purchase and secure availability of material for production in term of right material to right quality, at right time to lowest possible cost. According to Storhagen (2003) the main principles for MRP can be sum up in following items:

- Information about market and presumptive sales are gathered in a master schedule. From the master schedule a provisional production plan is carried out with respect of resource requirements and asset of capacity, in a way that reasonable level of load is reached.
- Product structure is specified for every finished product. It illustrates how the product built detail for detail, usually in a shape of a product tree.
- With respect of the product tree MRP calculate gross requirement. Further, ordered quantities and inventory level in store are also involved, which give net requirement. Finally is lot size concerning optimal order quantity and lead-time from supplier taken into a count and additional purchase plans are presented.
The output is a time based material requirements plan that indicates what material needs to be ordered at a specific moment.

MRP is systematic built up and have capacity to manage a great number of components, even if some have low frequency and represent low volumes. The take-off point with MRP is expected demand, but MRP work according to a push based system in practically (Storhagen, 2003).

For MRP to work satisfying following demands needs to be met:

- Accurate and stable sales forecasts.
- Substantial and extensive communication between involved departments and functions within the organisation.
- High reliability regarding lead-time from suppliers.

The tact-based foundation is also a disadvantage. Large market changes or disturbance in planning shows limitations with MRP systems. Another disadvantage is replanning, which is time consuming and resources requirements that appear when not expected usually leads to uncertainty and uneven load. MRP also have problem with finding correlation between cause and effect (Storhagen, 2003).

### 6.3.2 Reorder Point System

When parts with independent demand exits the most common method for material control is ROP system. When inventory level reaches a predefined reorder level the purchaser order material or production order is initiated (Olhager, 2000). An important factor is to bring open orders into calculation, especially if order quantity is less then consumption over lead-time. Therefore, inventory level and open orders are summarized to get an accurate purchase signal. Regardless of previous, reorder point is always classified as safety stock and anticipated demand over lead-time explained in following expression:

\[
ROP = SS + D \times L
\]

- \(ROP\) = Reorder point
- \(SS\) = Safety stock
- \(D\) = Demand per period
- \(L\) = Lead time

Ordering of material is conducted in fixed quantities, for example according to EOQ formula. Lead time include the time from order point to delivery of material and make no difference between purchases of material to storage or if production is set for finished goods inventory. Figure 6.6 illustrates a ROP system.
The figure shows that safety stock (SS) is used when consumption over lead time is higher than expected, but also when lead time is longer than in a normal situation. Another situation when SS come into hand is when a differential between balance in the planning system and actual inventory level occurs. In that case, the reorder point level has already been passed when the signal is set by the planning system. Furthermore, ROP systems require that inventory levels continuously are scanned and that orders are initiated when the reorder point is reached (Olhager, 2000).

The reorder point is often expressed in quantities, in other words number of units, but can also be expressed in time. Y-axis (Figure 6.6) is then given as cover time instead of inventory level. Cover time relates to the time a specific inventory level is expected to cover, either external demand or internal consumption:

\[
\text{Cover Time} = \frac{\text{Inventory Balance}}{\text{Expected Demand per Period}}
\]

The cover time is determined against lead-time and requirements on SS. Sometimes it is easier to use time perspective rather than given inventory level. Reorder point, in term of time is simple because cover time at order point is equal with lead-time plus safety time.

According to Olhager (2000) ROP system is easy to use with a broad practice base, but is only suitable for parts with independent and even consumption. Nevertheless, ROP systems only observe each and every part without respect of product structure or derived consumption relating between parts.

### 6.3.3 Kanban

Kanban is an information system for production and material handling, aiming at controlling and reducing WIP-levels. The system can be used both as production release and/or transport ordering of material, which is controlled by circulating cards, also called Kanban, which is Japanese for card. The card contains information such as part number, ordering quantity and station address.

The main philosophy with kanban as part of a JIT system is that material should be supplied when demand in production occurs. The method has been implemented in varied enterprises and the main benefits are:
• Improvements in productivity and greater control between various production stages
• Lowered levels of raw material, WIP and finished goods inventory
• Reduced production cycle time
• Improved turn over rates

However, there exists several problems associated with implementation of a JIT system and it is not appropriate for every enterprise. Since JIT reduces inventory levels to the point where there is no safety stock, it may not be optimal for an enterprise for which a stop or a slowdown in production raises great costs. The JIT system requires small frequent deliveries, which increases cost for transports since the deliveries will increasingly be done by less-than-truckload (LTL). Furthermore, it can result in a higher cost per unit from the supplier, since production of smaller lot quantities may raise setup and production costs. The distance to the supplier incurs a longer time for delivery and makes the transport time less predictable. The variability in transport time can cause stock outs, which causes disturbance in the production scheduling and may even cause stops in the production. These factors must all be combined and the enterprise must assure that the total cost of these factors does not exceed the savings in inventory carrying costs (Lambert et al, 1998).

Number of kanban card for a specific part is determined according to following relation:

\[ y = \frac{DL(1 + \alpha)}{a} \]

- \( y \) = Amount of kanban cards
- \( D \) = Demand
- \( L \) = Lead time
- \( \alpha \) = Safety factor
- \( a \) = Number of part in a carrier

Kanban is only meaningful if production is repetitive with high consumption. Also, to fulfil the requirements for JIT philosophy the demand ought to be steady and high. Another aspect to achieve benefits with low inventory levels is that suppliers using kanban is situated close to production to establish short, secured and frequent deliveries. Finally, products that are included into a kanban flow needs to be more or less standardised. Hence, the level of complexity rises with number of variants (Olhager, 2000).
6.4 **Inventory Management**

Inventory management is all about determine when to initiate order and optimal order quantity.

Top management needs to determine objectives concerning tied up capital and service level. In that way the main objective can be broken down to operative objectives. A storage can contains of a wide variety of parts with many different presumptions, *i.e.* need of storage area, average storage volume and value. This results in a situation where the storage must be designed and managed by a combination of different methods and designs in order to make the work effective and reduce total cost (Lumsden, 1998).

The design of the storage both affects the handling and storage of parts. According to Lumsden (1998) there is often a conflict between those two, due to the fact that effective material handling requires easy access to material whereas effective storage requires high volume usage. One solution is to divide the parts by classification *i.e.* volume, weight or volume value. Finally, volume value is the most useful parameter regarding material flow.

### 6.4.1 ABC-Classification

In ABC-classification are parts classified based on the volume value $(V_v)$:

\[
V_v = n \times p
\]

\[
V_v = \text{volume value of parts in storage}
\]

\[
p = \text{price of part}
\]

Parts are divided into A-, B- or C-classes based on $V_v$. Classification often show the same result as the 80–20 rule, where 80 % of the $V_v$ is represented by 20 % of the parts. Parts in different classes are handled differently. High value parts are most important and require more work in order to reduce the lead-time and ordering costs and increase turnover rate. Low value parts can be monitored by less sophisticated routines to guarantee assets to a low cost. A problem with ABC-classification is that parts with low price and high consumption can be placed in the same class as parts with high price and low consumption. Due to this fact, it is not wise to monitor parts only based on this information. Another issue, ABC-classification does not consider profitability of parts and that related parts can be placed in different classes (*i.e.* doors and frames), which result in diverse availability (Lumsden, 1998).

### 6.4.2 Unit Load

Usage of unit load is a method to reduce the material handling. A benefit is that parts is handled and transported by the most common tools and recourses from supplier to assembly line (Lumsden, 1998).

The usage of unit load contributes to both advantages and disadvantages. The negative sides is that the fill rate can be low and that the inventory level can be high due to the
fact that new deliveries have to be delivered in full units. The benefits with unit loads are however dominating and are:

- Reduce the number of transhipment in the transport chain
- Quicker loading and unloading of parts
- Reduce the number of routes and vehicles required to move the parts
- Usage of standardised handling tools and storage devices
- Can reduce the possibility of damages and thieveries
- Simplify the inventory where unopened units can be counted and multiplied with the included
- Easier storage possibility’s where the whole chain can be designed according to the unit loads

An important point according to Lumsden (1998) is that the unit load shall be handled as one unit as long as possible and not be opened unless it is required. The reason is that the potential profit increases as long as the unit is unopened.

From the storages point of view it is good if the unit load contain smaller units due to the fact that issues from storage often require smaller quantities. Therefore, the unit load should be designed based on the whole chain in order to make the most benefits.

### 6.4.3 Two-Bin System

A simple but yet effective principle to replenishing parts is usage of two-bin system. The system consists of two containers each holding a predetermined quantity of the same parts. According to Chaneski (2002) two-bin systems is designed as followed:

- The first bin is stacked on top of, or in front of, the second bin.
- A reorder card is placed on the bottom of each bin.
- Material is drawn from the first (or most accessible) bin only.
- When the first bin is empty, it is exchanged with the second bin.
- The reorder card is used to replace items in the first bin.
- Material is then drawn from the second bin while waiting for receipt of the material on order.
- When the new material arrives, it is placed in the empty bin, and the reorder card is returned to its proper place in the bin.
- The procedure is continued, with material being selected from one bin until it is depleted. The material is then replenished through use of the reordering card.

For two-bin systems material is always received in the same quantities, which makes unit load (chapter 6.4.2) suitable.

According to Storhagen (2003) two-bin system can be compared to a simple form of kanban system consisting of two carriers. Lumsden (1998) describes two-bin as a ROP system where an empty bin signals order.

A principle to reduce the volume of parts in stock is to have a smaller quantity in the second bin. This quantity, called reorder point quantity, must be sufficient to cover the time required to receive the material (Chaneski, 2002).
6.5 Storage Principles

As the storages and routines shall be designed and settled, choices have to be made. Material flow of parts is mainly decided upon the issue principles, i.e. FIFO or LIFO. The average time in storage is the same for FIFO and LIFO. The main problem is that maximum time differs depending on method, where it is critical for LIFO and may cause:

- Obsolescence where the quality of the parts is reduced
- Changes of design where old parts is no longer useful
- Long storage time can result in less control

Storage design affects the access time of parts in storage and a computer based register of the storage locations is a powerful tool. The most determinate element how easy parts can be found is the placement principle, fixed or random storages locations (Lumsden, 1998).

Fixed position means that all parts have a fixed storages location. The size of the storage is the same as the safety stock and the batch size of the parts. Random location means that arriving parts can be placed anywhere in the storage. This results in a situation where storage locations are used in a more efficient way and therefore require fewer locations. The location is decided as new parts arrive and is often connected to some kind of computer based storage system to optimize storage, based on picking effectively. This system is also needed as the parts are picked.

Need of storage locations:

\[
\text{Fixed location} = \text{Safety stock} + \text{Maximum cycle stock} \\
\text{Random location} = \text{Safety stock} + \text{cycle stock} = \text{Safety stock} + \frac{\text{Batch size}}{2}
\]

Possibilities to reduce storages locations alter depending on order routines. However, storage with random locations must have a more advanced system regarding optimization and control.

The parts placement is also important as it affects the access time. If parts are placed according to consumption, it results in reduction of average time for picking. Due to reduction of time capacity increases as larger volumes can be handled. The load in the storage is also connected to the access time. High load makes the placement of new parts more difficult which require more time and reduce the efficiency of picking as parts can not be placed according to consumption.

According to Lumsden (1998) there is no general or optimal solution on how to locate parts in storage. A number of principles, described below, must be studied as design and locations shall be decided.
Rotation principle
If the parts have to be consumed during a certain time FIFO must be applied. The storage is then designed to always pick the oldest part first. FIFO also excludes some methods *i.e.* stacking where the handling and sorting would be too complicated. The same reasoning can be used if LIFO has to be applied.

Picking position principle
In order to make the picking more efficient, parts being picked at the same time are placed close to each other. This method can be applied on both fixed and random locations.

Family principle
Parts with similar features (*i.e.* size, special demands etcetera) shall be placed together due to storages and security design. Another reason is that they need the same handling tools, which make the handling more efficient.

Popularity principle
Parts can be placed according the ABC-classification based on volume or picking frequency. It is not unusual that 85% of the volume is connected to 15% of the parts, 10% is connected to 30% and the last 5% is connected to 55%. In conclusion, the storage contains of few parts with high consumption and a large number of parts with low consumption.

Similarity principle
Parts with arriving or delivery similarities are placed together in order to reduce the handling time. If parts are similar that picking mistakes is made if they are place next to each other is the method not appropriate.

Size principle
Large and heavy parts difficult to handle shall be stored separate close the usage area. The reason is that the handling costs are larger and reduced by shorter transports.

Height principle
The height of the placement affects how fast parts are picked. High and heavy lifts often cause problem, to avoid this situation parts shall be placed in the best height to simplify picking and improve work environment.

6.5.1 Picking Storage
Picking is used to handle variations in the production and work as allocation and sorting place. According to A picking storage can be described by four functions:

- Buffer zone
- Issue principles
- Picking methods
- Final work
Buffer Zone
In a picking storage is three buffer principles detected: outlying, close or picking buffer. In outlaying buffer are parts stored away from the picking area. As shortages occur in the picking area a delivery is required from the outlaying buffer. Close buffer is located nearby the picking area (i.e. high location in storage). In the same way as the outlaying buffer new parts is ordered as shortages occurs. When the buffer is located in the picking area shortages shall never occur during normal situations.

Issue principles
The issue principles are defined depending on the combination of how parts and orders are organized. Are parts picked from part or the whole assortment and if one or several orders are picked at the same time.

One order – Part of assortment
One order is divided in to several orders depending on different zones in the storage. Picking personnel only operates in a certain area of the storage and finalise their assignment before it is handed over to the next worker.

One order – Complete assortment
One worker is responsible for one order and picks all the parts required. Disadvantage is that the picking effectivity is reduces due to high transport time during picking. Advantages are that orders are handled separately and therefore are less likely to be mixed. Further, no area or personnel for sorting is required.

Several orders – Part of assortment
Parts for several orders are picked at the same time. In many industries the final assembly is preformed at a line where each station only assembles part of assortment. Therefore, this method is used if there is available space at line. If there is limited space at line picking of one order is more suitable. The advantages are that larger volumes and order sizes can be handled. Orders are also picked faster as several workers pick simultaneous.

Several orders – Complete assortment
The complete assortment is used to pick several orders. The benefit is that transport time for each order is reduced. At the same time, the method requires more handling and sorting which must be considered.

Picking Methods
Picking methods is divided in to three main principles, which are: low level, high level and station picking.

Low level picking
Personnel usually use carriers or picking forklifts depending on size and volume of parts and storage where parts are accessible from the floor. The higher levels in the racks are often used as buffer area.
High level picking
Picking is performed from all levels in the storage. Personnel use high lifting forklifts or other special designed devices to access parts. The method is mainly used where large number of parts is picked in relation to the buffer area needed. Compared to low level picking the efficiency is lower due to transportation between picking stations.

Station picking
Station picking use atomised transporters to distribute material to picking stations. Because picking stations are fixed, it is possible to alter the design to optimize the work. The method is mostly used where large quantities of few parts are handled.

Final work
Depending on combination of method and principle used, more or less work is required as the picking is complete. If several orders are picked at the same time sorting is required to separate the orders. Repacking can also be necessary in order to fulfil customer demands.

6.5.2 Physical Inventory
The purpose of physical inventory is to check if the storage has the same balance as the systems. If differences occur the reason shall be investigated. In order to reduce work load physical inventory shall take place as the balance in storage is low. Usage of unit load also reduces the work load as full carriers are counted instead of single parts.
7 Benchmarking

Benchmarking is a process of comparing performance against similar organisations to identify areas for improvement and receive new ideas. To underlie the benchmark at Chassi, Industrial & Marine and Toyota Material Handling Sweden issues found during the study of present situation where used. Logistics departments where interviewed and studied in order to get a picture of their routines, way of working and future objectives.

According to Swedish Institute of Quality Development (SIQ) the benchmarking model is divided into five steps, shown in figure 7.1. As an initial phase the present situation needs to be described and analysed. It is important to conduct this phase with accuracy and to define delimitations, in order to make the comparers meaningful and to understand differences. By doing so, possible improvement is identified even before the exchange has started. The following step is to find appropriate role models to benchmark against and exchange experience with. Indicators for potential partners are measurements, awards or information from articles. One to three benchmarking partners is suitable to avoid a complex situation. After the partners are chosen and the exchange is preformed, the phase to gather and analyse information take place. The seven basic tools for quality management described by Bergman and Klefsjö (2002) can be used to support the work in a systematic way to guarantee correct conclusions and decisions based on real facts. Development of new routines begins when the analysis is ready. It is important not to implement the role models routines without adjustment based on the situation in the own organisation. Next step is to use the knowledge and proposed routines to underlie the mapping of new objectives and develop an activity plan. The last step include implement and evaluate the new routines. A good start is to test new solutions in a small scale to see if it is working according to plan and thereafter implement it in full scale. Finally, to evaluate the project results are documented and compared to the objectives. The last two steps described are same as basic improvement work preformed in most organisations (Frolin et al, 2002).

<table>
<thead>
<tr>
<th>Describe present situation</th>
<th>Exchange experience with role models</th>
<th>Analyse differences</th>
<th>Map new objectives</th>
<th>Implement and evaluate</th>
</tr>
</thead>
<tbody>
<tr>
<td>Identify areas of improvement</td>
<td>Decide role model profile</td>
<td>Gather and analyse the collected material</td>
<td>Define objectives</td>
<td>Carry out the improvement tasks</td>
</tr>
<tr>
<td>Appoint benchmarking group</td>
<td>Define questions for the role model</td>
<td>Develop proposal for new working routines</td>
<td>Develop an activity plan</td>
<td>Document and evaluate the result</td>
</tr>
<tr>
<td>Define the project</td>
<td>Search for appropriate role models</td>
<td>Report the project</td>
<td>Approve activity plan</td>
<td></td>
</tr>
<tr>
<td>Map and improve the process</td>
<td>Prepare the exchange</td>
<td>Perform the exchange</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Figure 7.1 SIQ’s five step model for benchmarking (Frolin et al, 2002).

Many factors regarding the supply chain affect material handling in terms of right material at right time. The scope of the thesis starts with call off material from suppliers and ends when material are at assembly line; therefore will the benchmarking studies focus on this part of the supply chain. The main questions studied are:
Material control:
- How is the material control managed?
  - What call off methods are used?
  - How is the work with suppliers conducted?

Material supply:
- How is the material supply managed?
  - What methods are used?
  - Are areas of responsibility clearly defined between material handling and production?
- What are the underlying reasons for the current design at each assembly station?
  - How long is the internal lead-time for material?

Production system:
- What positive effects has the production system brought?
- Which areas have standard working routines?
- What different measurements are used for material control?

Future objectives:
- How will future demands be met?

### 7.1 Scania Production System

The following information is gathered from InLine (2007) and oral presentations. The objectives of the Scania Production System are to increase the process capability and to build a platform for a common production system within Scania. By achieving a normal situation through standardisation of work procedure, deviations can be detected and eliminated. The result is systematic improvements of process efficiency and thus a more predictable and reliable production system. Improvements are guided by principles and actions are taken through methods linked to these principles, in order to ensure that the right methods are being applied. In addition, the systematic work with continuous improvements will ensure that the striving for elimination of waste will never end.

Scania values, principles and priorities are defined for continuously detecting and eliminating waste in their processes. Improved performance will come through teamwork with implementation of small continuous improvements based on the principles.

Almost every procedure in the production is described in different documents to guarantee standardised routines with Scania Production System as background. A specific job is described through different tasks, which can be seen as a normal stage. The fact that almost every procedure has a normal stage means that it can be improved. The documents also serve as support in case of insecurity and for introduction of new personnel. Every assembly step is described through instructions where parts and tools are described. An advantage with instructions is that parts can be bound up for a specific truck/chassis at the same time as the instruction is printed.
7.2 Chassi

Chassi is a part of Scania CV AB and produces trucks and K-chassis for buses. The production units are located in Södertälje, Zwolle and Angers. The benchmark is performed at the production unit in Södertälje where the production of trucks and chassis are make-to-order. Production and logistics has been under development for many years by the routines of Scania Production System and can be seen as a good example where standardised routines are applied and deliver reliability is high.

When construction department introduces new parts, the purchasers contact apposite suppliers to find a proper and reliable supplier. A part number is connected to new parts to be used in the different systems (i.e. Scala, KS etcetra). Logistic department calculate appropriate package size based on estimated yearly consumption and information from selected supplier. According to Kent Phil, all information is given align with pre defined routines before department’s work is initiated. The fact that same package size has to be used by all production units, calculation is based on the unit with highest consumption. Cover time for each package unit at line is between 4-80 hours. To decide suitable package instructions similar parts are studied, otherwise it is based on experience. As all suppliers have to deliver their parts in Scania package material these have to be sent to them before the first delivery. Parts are then ordered and checked before it can be fully introduced and used in production. The introduction of new parts is based on routines and checkpoints to guarantee that parts are ready when needed in production.

Material controllers handle introduced parts. New orders are made as balance decreases under a pre define level. Since package size is based on highest consuming production unit some parts are repacked in order to save space and suit current demands at line. This work is preformed via guidelines of Scania Production System, where personnel suggest areas of improvement.

To facilitate suppliers capacity planning chassi send forecasts for 365 days forward. Suppliers also receive a more detailed forecast for the coming 20 days where a specified purchase quantity is guaranteed. All orders are sent via EDI and transports are booked in Webstar (Scania online booking system) by the supplier.

As new models and solutions are introduced Scania phase out parts and systems that are inadequate. To avoid new parts being ordered the first action is to remove the reorder level in stock. New orders are then only sent to match the exact consumption until the last unit is produced.

Today chassis uses four different methods for internal material handling: two-bin, program, kit and sequence. Two-bin is used for most parts and consists of two or more positions at line often in a point of use and buffer location. The cover time for each unit is between 4-80 hours, a time interval that indicates normal situation. Acatours replace the empty unit in the point of use location from buffer location based on assembly personnel signal. The empty unit is then replaced with a new from the storage and stored back at the buffer position. Smaller boxes is only stored at one
position and the signal is then sent when the number decrease a predefined level. The cancellation of parts is monitored by the assembly instructions. Program is used for specific parts used on a limited number of trucks/chassis. The parts are delivered on yellow painted pallets and stored at a pre-defined area. Program is used to save storage area at line for parts with irregular consumption or high variance. The last two methods are similar where parts are delivered separately to line for a specific truck/chassis. Sequence parts are ordered and delivered direct from the supplier. Kit parts are ordered separately and packed internal for a specific truck/chassis delivered to the line in production sequence.

Future objective is to replace the automatic warehouse with a manual served storage. To be more flexible towards new introductions and higher customer demands, logistics department is evaluating a new MSM called “silver tray”. Today the majority of parts are presented at line where there is lack of space. The project is based on a “trigger image” with eight points, displayed below:

- No forklifts in the factory
- Fully flexible layout
- All parts in exactly the right position
- No pallets in the line supply flow
- Always an evident/secured choice of parts
- Ergonomic presentation of all parts
- Maximum 1,5m material layout
- 100% synchronized flows logistics-production

The objective is to present material for each truck/chassis in production sequence according to assembly order, close to the assembly position. Today 30 % of the assemblers’ time is used to get parts from racks at line, with risk of making errant choices. At the same time acatours use a lot of time to circulate, looking for signals from the line. If parts are presented on portable carriers’ space is abstricted at each assembly station. Further, the layout is more flexible and the assemblers’ time is used more efficiently. Due to size and regular consumption some parts still have to be stored at line. By doing so Scania intend to be more flexible and efficient, decrease the total flow cost and increase production tact.

### 7.3 Industrial & Marine

Industrial & Marine (I&M) is a division within the Scania CV AB group and produce engines for industrial and marine markets. The production is located in Södertälje where the benchmark is preformed. Production philosophy is make-to-order and the daily tact is 20 engines. As a new assembly line is built, the aim is to increase production tact. Alignment with chassis the work follows the Scania Production System routines with clearly defined responsibilities and standards.

Depending on customers’ requirements products are very divers, and usage of standardised instructions is therefore limited. More responsibility is given to the assembly personnel due to their knowledge. In some aspects the situation is similar to S.P.S, where buses are individually designed.
I&M order parts from suppliers based on delivery schedules, forecasts and lead time. Some suppliers have to be informed earlier to guarantee delivery according to plan because of longer lead time. Orders are made and transports are arranged using EDI and Webstar (Scania transport booking system). When deliveries arrive to GR, material is registered and sorted depending on storage location. Storage personnel collect the pallets and boxes and store them in one out of three different storages locations. Frequently used parts are stored in a high frequent storage, which is floating location storages. Parts in this storage shall have an issue of at least once a week and shall be handled in full carriers usually displayed as two-bin at line. Less frequent used parts are stored in storage where parts are picked based on orders from line. Small parts with high frequency are stored in separate paternoster (carousel) storage. Those parts are also picked based on orders from line.

All parts registered are marked with a coloured label displaying part number, delivery date quantity etcetera. The colour of the label changes every quarter and is used to visualise the time parts been stored. Parts with a low turn over rate can easily be detected and studied in order to change storage location or parameters to improve the work. Less frequently used parts are usually stored at the highest positions to increase efficiency in the storage.

Storage personnel receive picking lists from assembly line. Picked orders are placed at marked buffer areas and collected by acatours, responsible for the delivery to line. The acatours transports empty carriers and finished engines as they return to the storage; finished products are placed in the same area as the storage.

7.4 Toyota Material Handling Sweden

In the year 2000 BT Industries where acquired by Toyota Industries Corporation and in 2007 the name change to Toyota Material Handling Sweden (TMHS). The organization is since 2000 the leading actor in material handling where TMHS contributes with knowledge concerning storage forklifts, service, rental and relations to large costumers mostly located inside Europe. The production unit visited is located in Mjölby, Sweden. The acquirement have implicated to work by The Toyota Way. Since Scania Production System is based on Toyota production system (TPS) the benchmark is concentrated to study changes and routines implemented and improved after the acquirement and the work concerning material handling.

The Toyota Way is based on a number of principles preformed by the routines of TPS. Next follows a few keywords in the philosophy.

- Genchi Genbutsu
  “Look yourself” – all decisions is based on primary information and everyone shall have the same information.
Kaizen is a combination of the word Kai (way) and Zen (good) and is about the quest for constant improvements both in the company and on a personal level. An important point is that no process is perfect. Improvements can always be made.

Jidoka is used to reduce problems in the process. As issues occur the process is stopped and adjusted. This guarantee that errors cannot pass the process and therefore it is improved, Kaizen.

Muda means trash or waste concerning activities not adding value to the customer. All processes have Muda that can be reduced by the methods of Kaizen and Jidoka.

Despite implementation of TPS several years, changes take long time to put into operation and work with. According to Ingvar Pettersson it is not until recent the real benefits are shown.

Today, TMHS turnover approximately 5 000 different parts. To order parts four MCM are used depending on consumption, price and supplier. Most of TMHS’s suppliers have a lead-time of two weeks and deliver one to three times a week. With this in mind focus is aimed to increase turnover rate. The MCM are:

Kanban
TMHS use kanban for parts with steady consumption, high value and where the supplier is located close to the production. Despite the fact that only 3-4 % of the parts are ordered with kanban, this group represent 25 % of the annual dollar volume. Further, the turnover rate increased from 20 to 37 including a 54 % saving of pallet locations in storage, as kanban was introduced.

MRP
Based on delivery schedules the majority of the parts are ordered with MRP. The average turnover rate for this group is 18 to 20 times with objectives to increase to 25.

Sequence
Parts with special requirements concerning paint, design, and price etcetera TMHS use sequences.

VMI
For small and cheap parts vendor managed inventory (VMI) is used as MCM. A resource from Mattsson, a company responsible for availability and balance at line. According to Pettersson it is a very suitable solution due to the fact that there are no shortages and that specialised personnel plan and order the parts.
As the gods arrive to the production unit it is arranged according to storage location. Parts with quality problems are separated and checked by the quality department. Suppliers are informed how to label pallets, which include the quality marking where suppliers with quality issues are notified. In this way pallets are easily arranged to the right location. The pallets are later collected by storage personnel and stored at appointed location. Parts ordered from assembly line are collected and placed in predefined buffer zones, to be distributed by acatours. Each delivery to line shall cover at least one shift.

TMHS also use “max levels” in production. In order to level the flow between different areas in production, only a pre-defined amount of parts are allowed to produce in advanced. According to Petterson there is no need to have large work in process if there are delays further in the chain. This is generally displayed and monitored with marked areas where pre-assembled parts are placed and no new one are allowed to be assembled until there are a free space.

**7.5 Benchmarking Analysis**

During the visits at the three different benchmarking partners several findings have been discovered which will be useful when giving suggestions and recommendations to S.P.S Common for all companies is usage of standard procedures where different departments and areas inside the company have defined responsibilities. In this way are the different areas seen as supplier and customer with different duties and obligations. As the boundaries are defined it is always clear what to do and when.

Today almost 80 % of the parts at S.P.S are picked in spite that many are used on a majority of the buses produce, which gives a possibility to make this procedure more effective. Chassis handle almost all parts as unit loads in two-bin system, which reduces the picking. Due to large variance of the buses produced at S.P.S is this not a suitable solution in full scale as the available space at the assembly line is limited. However, this is an appropriate solution for some parts with high and steady consumption. An implementation would also reduce storage personnel’s workload.

Another issue discussed where Chassis future objectives regarding project “silver tray”. In order to save space, have a more flexible production and reduce the options for the assembly personnel is this project under evaluation. Due to the different presumption regarding structure breakdown and assembly instructions the proposal is to await and follow the evaluation. One area regarding the project is to pick parts for fewer trucks, which might be appropriate for S.P.S as space is needed to be able to implement two-bin. Another benefit, as fewer parts are delivered each time, is the direct feedback where missing parts more easily are detected and possible to adjust.

The production at I&M is similar to S.P.S with a large variance between orders and less detailed assembly instructions. However, I&M have divided the parts based on consumption which is handled by different methods and stored in different storages. As the consumption at S.P.S where studied similarities where found. This result in
opportunities to develop the routines at S.P.S. High frequently used parts at I&M are handled as two-bin and stored separately. In the same way as S.P.S small and cheap parts and parts with lower consumption are picked and stored separately align with theories in chapter 6.5. To implement this at S.P.S proper parts must be detected and studied. Package instructions must also develop to be used from supplier to assembly line.

The usage of colour coding is an easy and inexpensive solution to visualise turnover rate and time parts have been stored. This would assist both storage and material control personnel to take action without searching systems regarding parts not following predicted presumptions. In order to implement this at S.P.S pallets must be changed as new deliveries arrive. Today most parts are picked from the incoming pallets or carriers to the fixed locations in storage. In this way the same pallets are used, resulting in a situation where the label not follows the parts. Another benefit gained if the pallets are changed is that FIFO can be applied. Today, as the old pallets are refilled, are old parts always stored below the new parts and not consumed first.

I&M also use clearly defined buffer areas in the interface between receiving, storage and production. Both incoming and picked parts are placed in marked positions waiting to be handled by storage personnel or acatours. At S.P.S this interface is clear between receiving and storage but less clear between storage and assembly. Therefore, it is important to define the different responsibilities between those areas.

TMHS use kanban as MCM for some parts and suppliers. Kanban is used for high value parts with steady consumption and although just a few parts are monitored by kanban the annual dollar volume large. As kanban were introduced for those parts where the turnover rate increased and pallet locations needed in storage decreased. As some of S.P.S suppliers are located near the production unit and supply S.P.S with high value parts kanban is a suitable solution. In order to implement kanban an extensive evaluation and discussion with the supplier must take place.

Parts arriving to TMHS are quickly moved to storage with the assistance newly implemented pallet flow lanes. Another interesting issue is the usage of quality labels. Marked pallets are moved to a separate area to be checked by the quality department before being used. The fact that the suppliers are informed about the quality check results in increased awareness of the situation.

Material handling at S.P.S GR is not a problem today so there is little need of improvements. However, information and check regarding quality problems is valuable improvement areas to increase suppliers’ knowledge.

The usage of “max level” in production is worth taken in to account at S.P.S as the communication between pre assembly and assembly can be improved in some areas. If there are delays at assembly, pre assembly also must decrease their tact as larger number of assembled chassis, frames and ceilings bound costs and storage area.
8 Analysis

In this chapter empirical findings will be analysed based on theories and principles found in frame of reference (Chapter 5). In the same way as frame of reference is structured the analysis will follow the supply chain, starting with the flow from supplier to store at S.P.S. In the next section, an analysis of the storage at Scania Production Slupsk will be conducted and finally the flow from storage to assembly line will be scanned. Often the reasoning in this chapter is on a higher level of detail, aiming at highlight areas of improvement, leading to a reliable solution.

8.1 Problem Breakdown

The thesis included three main questions:
- How should MCM and MSM be tied together in an efficient way?
- Is it possible to decrease logistics related deviations? Through:
  - Clearly defined parts segments with appropriate call off method or
  - Standardised working routine concerning introduction of new parts or
  - A combination of the proposals above.
- Is present material flow suitable for future demands?

To be able to answer these main questions the structure of the analysis will be recursive, aiming at unfold the material flow process from supplier to assembly line and fold it back again. By conducting this work method the main questions will be divided into sub questions. These sub questions are at a lower level and therefore easier to analyse and find solutions to. Once answers are found on these levels the problem hierarchy will fold again and a cause and effect relation will be detected. In conclusion, the intention is to find underlying factors, with a pragmatic attitude, that have an impact on the outcome concerning MCM and MSM.

8.2 Supply Chain Process

8.2.1 General

Throughout mapping of present situation it showed that the interface linking departments is not fully integrated with working processes existing at S.P.S. One reason to this issue is probably the distance between connected departments situated both in Södertälje and Slupsk. Even though they have different responsibility a working interface is crucial. Above all, S.P.S has to find a normal situation so feedback can flow in both directions. During the thesis, a working group had begun investigating the possibility of process owner, aiming at finding a normal situation and maximum capacity within departments. Another positive effect, in this work is that present timetable is challenged and questioned, all according to continuous improvements (Scania Production System).

8.2.2 From Supplier to Storage

During the visits to some of S.P.S’s suppliers it showed that some of them did not use the forecasts they received. This matter results in a situation where MC personnel put effort in something that is of no use. In excess, the suppliers also require longer lead
time due to the fact that raw material in some cases is not purchased until the definitive orders are received. Lack of trust towards forecasts is usually originated in historic setbacks where forecasts have been modified. To increase the usages of forecasts improved communication or new routines are required. Scania Chassi sends forecasts for 365 days, in order to assist the suppliers’ capacity planning. Further, more detailed forecasts for 20 days are sent that guarantee purchase of a specific quantity. In that way the supplier is able to plan their production for the coming period. Even if demand changes at Chassi the guaranteed quantity is purchased, which results in a security for the supplier.

Another issue, suppliers’ prefer drawings in a specific format more suitable for their production. This could easily be solved and perhaps result in shorter lead-time where the supplier do not have to redraw or adjust the received drawings.

Lead-time from S.P.S’s suppliers where studied it showed that 76% of the parts used during the late six month had a lead-time of six weeks or more. Concerning batch parts the share where 93%. This indicates that six weeks lead-time is the default value as new suppliers are introduced. As lead time where discussed with the different benchmarking partners (Chapter 7) it showed that their average lead times where shorter.

In summary it is obvious that many of the discussed areas above are linked together. In order to reduce the lead-time and receive the benefits described in chapter 6.2.2 plus improve relation with suppliers’, good communication is needed as well as correct and trustful information.

Material Control Method
At S.P.S there are no material planners (MP) and there exits no standard routine regarding decision making of MCM, making the connection between MCM and MSM static. The perception is that manuals are important to able work according to standardised routines. In that way responsible personnel can follow guidelines and easily obtain a recommendation regarding decisions for MCM. During interviews a necessity of material planners was pointed out, due to future demand on higher production rate and broader product range. A MP would solve the issue with responsibility and be able to evaluate call off methods closer. Finally, it is important that responsible personnel are aware that guidelines are just guidelines and not rules to follow.

Reorder Point
From investigations concerning ROP the problems arouse from the fact that some ROP parts does not exist in the structure breakdown. Those parts have in common that the yearly consumption is difficult to determine, leading to a situation where the consumption is roughly estimated. The perception is that parts with roughly estimates consumption are hard to adjust to a steady and even material flow. Potential improvements in term of order quantity and frequency of delivery exist. Concerning
lead-time the majority of parts, using ROP as MCM, has four weeks of lead-time which seems a bit long. Lower lead-time would primarily decrease inventory levels.

Regarding optimal order quantity (Chapter 6.2.4) the perception is that present EOQ needs further evaluation. Today, calculation does not include ordering cost and holding cost. Neglecting such parameters gives inaccurate order quantities and additionally increases inventory levels. Nevertheless, all parameters need to be overviewed over time to maintain accurate calculations and optimal order quantities. Even though parts using ROP are categorised as low value parts, it is important to continuously work with improvements, due to the fact that these parts are of same importance as any other part for the final result.

During parts and storage analysis (Chapter 4.6) another discovery was made. In some cases it seems like best price per unit has been a priority, instead of total cost, resulting in high order quantities and a high level of stock. The perception is that even flows is worth striving for, since it probably could make production and material control easier for both S.P.S and its suppliers, regarding both order quantities and safety stock (Chapter 6.2.5). However, when working with material flows it is important to first make estimation of the flows of greatest importance.

Batch
During mappings of batch flows nothing special has been found. It is hard to draw any general conclusions when 80% of the material is ordered according to batch, described as MRP in chapter 6.3.1. However, parts that need to be evaluated exist, in order to find a more suitable material control method. For example, low value parts with high consumption are found among batch flows. One solution is to regulate present definitions and make a more distinct boundary between batch and other MCM. Finally, lead-time is set to six weeks for all batch parts affecting both turnover rate and inventory levels. When introducing new parts it is crucial to challenge presumptive suppliers and together agree on proper lead-time for individual parts.

Sequence
When MCM sequence has been investigated there is little to point out. Scania Production Slupsk has made effort to enable sequence parts to work well and this might be a reason why there seldom are disturbances involving sequence parts. Another reason might be that all sequence parts are dedicated to a certain chassis or bus when ordered and therefore allow traceability if disturbance occurs. However, the number of sequence parts with no movement over the last six months is notably (Chapter 4.6), especially since sequence parts are order for unique buses.

Kanban
Today S.P.S does not use MCM Kanban but some conditions exits for implementing such call off. The perception is that kanban flows should be used for suppliers within close range and supply S.P.S with expensive parts with low variant mix. The method described in chapter 6.3.3 is developed by Toyota where most of the suppliers are located nearby the production site. This fact has to taken in consideration if kanban
ought to be used as a MCM. The observation indicates that it would be suitable for some parts, further displayed in chapter 9.1. Regarding suitable suppliers for kanban flows the choice ought to be restrict and awareness of benefits versus drawbacks needs to be made. Nevertheless, as described in chapter 6.2.1 a fully working kanban loop increase turnover rate, decrease inventory levels and allows more frequent deliveries without incurring higher cost.

8.2.3 Storage at S.P.S

Goods Reception
The GR seems to work well. Parallel with the thesis have the managers and personnel at goods reception have developed standard routines concerning the daily work. Together they decided about the number of consignments they shall handle per day. Each consignment shall be checked, registered and placed at buffer area. The number of handled consignments is registered at a board inside the GR where deviations (i.e. repacking) also are listed. In that way it is possible to see if the daily work has meet defined objectives. Regarding deviations it is important to do follow-ups, as most of those are non-value-activities. Most are related to repacking because of; problems with supplier lack of packing instructions or repacking to Scania package material, even if parts are placed in another carrier inside the storage. The suggestion is to continue and develop those routines.

Concerning the incoming deliveries which is handled by first come first serve and where transporters arrive as they please in comparison with other parts of Scania where allotted slot times is given. Future objectives concerning higher tact may result in more deliveries where allotted slot times might be necessary in order to level the daily workload. Due to a large share of the deliveries arriving by boat from the hub in Ystad there is a large concentration during the first hours. Therefore it would be good to relocate other deliveries to the afternoon.

Colour Coding, discovered during the benchmark at I&M (chapter 7.3), requires some implementations at GR. All incoming consignments are labelled with a coloured sticker/paper depending on quarter of the year. For GR, this result in a minimum of extra work load. The only issue is to change to colours of the paper in the printers and inform storage about coming changes; all other activities are performed as before.

Storage Management
The storages role regarding the improvement of the material handling is important. In order to be able to introduce two-bin system (Chapter 6.4.3) at S.P.S in line with visited benchmarking partner’s some changes have to be made in the storage. The routines and implementations regarding unit load and package instructions needs to be improved as it is the foundation in two-bin system where parts are transported in the same carriers from the supplier to line. According to present situation all parts in storage have fixed locations where a large share of new deliveries is refilled into old carriers. In this way is LIFO applied instead of FIFO, which is preferred (Chapter 6.5). The implementation of unit load and the transition to FIFO is also important if the recommendation regarding Colour Coding (Chapter 7.5) is to be implemented.
Another important aspect is that all parts need clearly defined packing instructions in order to always receive parts in the same type of carriers to be handled by the same routines. The work to implement packing instructions is under progress and in order to increase the number of parts with valid instructions it would be appropriate to send enquire to the suppliers regarding proposals of instructions. Many suppliers already work with packing instructions against other customers, among them other companies within the Scania organisation.

The work to refill fixed pallets in storage is seen as non-value-adding activity, where the handling is time consuming, increase the risk to damage parts and seclude FIFO. New deliveries should instead replace old consignments inside the storage. If old parts are not consumed new delivery should be place in a buffer location until all old parts are consumed. A contingent problem regarding unit load is that one area inside the A-storage at S.P.S have lanes designed for one forklift. In that way is only one forklift able to operate in each ally at the same time. As pallets are changed, the old pallet is first removed and transported to the delivery zone where the new pallet is gathered and transported to its location. Today there is only one forklift designed to handle those tasks, where space is rather crucial. One solution is to place pallets with high turnover rate in the area where the allies are wider where several forklifts can operate without affecting each others performance.

Parts controlled by batch is today placed depending on the assembly station where it is used, in line with the theory in chapter 6.5, which is preferred as each station send pick lists separately. In order to improve the efficiency parts with high consumption should be placed in low positions to optimise transportation time. The Colour Coding proposed also work to improve the efficiency where parts with low turnover rate are visualised and location can be changed.

The work with sleeping parts is under steady progress and important as those parts both bound costs and hold space inside storage. It is important that design inform MC as soon as possible about parts being phased out to avoid situations new orders are made based of wrong information.

If more parts are handled in unit loads is more buffer areas needed which results in a need of more storages space. It is therefore significant that all departments work together; storage personnel inform about sleeping parts, MC focus on lowest total cost instead of lowest unit price and design inform in an early stage about parts being phased out.

8.2.4 From Storage to Assembly Line

MSM
Today S.P.S uses three different methods to supply assembly line with parts which are kanban, picking and sequence. Parts are given a valid station address but no specific location within the station. This result in a situation where personnel have to be familiar with the station setting and traceability is difficult if parts have been misplaced. Another issue, responsibility between acatours and assembly personnel is a
bit vague. There are not any clear buffer locations between storage and assembly line, which could be used to temporary store parts, waiting to be used at line. Further, responsibility of station racks is unclear where both assembly personnel and acatours refill delivered parts.

**Kanban**
During investigations regarding internal kanban no remarkable findings has been made. As long as the production rate stays at current level there is no reason to change the kanban loop.

**Picking**
Today, all parts controlled by batch are picked based on orders from the assembly line. The orders usually consist of parts for five to nine buses. Depending on type and size of the parts are more or less area needed at the racks. If two-bin is introduced area is needed where one solution might be to reduce the number of buses picked each time further described in chapter 6.5.1. A reduced number may also contribute to a better control and quicker feedback of orders and structure. Another issue is that large number of parts has balance at line even though orders should be based on exact needs resulting in empty racks as busses are assembled.

**Sequence**
Parts controlled by sequence are delivered to a specific bus, it is important to have a balanced flow according to production tact. Due to the relation to a specific bus it is possible to store those separately according to principles discussed in chapter 6.5.

An imperfection noticed related to the sequence flow is that windscreens are repacked from wooden boxes, package material from supplier, into metal racks in order to detect deviations. However, extra control is time consuming and increases the risk of damaging the parts, both considered as non-value-adding activity. According to philosophies about unit load that supports Scania Production System the aim is to use intact package material as long as possible to enable a material flow with little disturbance. Since the lead-time for sequence parts are fairly long there is little time to order new parts. One way to exclude this working moment is to involve the supplier and together come up with a solution concerning package material to avoid additional work.

**Two-Bin**
During the study of parts consumed over the last six month it occurred that almost four percent of all batch parts where used on more then 70 % (on average one per shift) of the buses produced. In order to reduce material handling both at storage and line unit loads (Chapter 6.4.2) as two-bin (Chapter 6.4.3) would be appropriate. Finally, implementation of two-bin would reduce workload during physical inventory (Chapter 6.5.2) as full units are counted.
9 Solution

In this chapter a solution will be presented. Initial, definitions of material segments will be presented and explained. Thereafter, a comparison between present situation and recommended changes is explained.

9.1 Definitions

To clarify the boarders between different segments definitions needs to be stated, similar to ABC-classification mentioned in chapter 6.4.1. The intention is to separate ROP, batch and sequence parts but also give recommendations regarding potential introduction of MCM kanban. Additionally, the definitions suggested will not include all parts and the reason is not to control all parts strictly based on price or consumption. Responsible logistic personnel must base decisions on the characteristics of the part controlled. For parts with unit piece between suggested borders other criteria’s must be taken in to consideration (i.e. size, consumption, supplier location etcetera). Those criteria’s must also be checked as other parts are introduced but then as and inferior input.

Figure 9.1 Description of how MCM and MSM can be tied together.

Some parts will not fit those definitions and therefore must be decided by responsible personnel where other criteria’s (i.e. size, supplier etcetera) are taken into consideration. The reason is to have clearly defined segments and parts that fall outside the definitions need additional evaluation. In doing so standardised working routines can be found and over time the boarders between segments can be narrowed.

ROP

MCM ROP is suitable for low value parts where the consumption is hard to estimate, according to chapter 6.3.2. Analysis showed that parts with those attribute both where found by parts controlled by ROP and batch. In order to have a standardised approach the suggestion is that all parts with unit price under 5 PLN and an estimated consumption over 10 % shall use MCM ROP. An exception of this statement is parts that only appear in the ZZC-list, which shall be controlled by batch. In the same way as the present situation shall parts controlled by MCM ROP be stored separately and use MSM kanban.
Batch
Parts not using MCM sequence, which have unit price above 20 PLN, recommends to be ordered as batch. In comparison with the present situation all parts using MCM batch are picked based on orders from production, two-bin is introduced as a complimentary MSM. Analysis has shown that a share of the parts is consumed on a majority of buses produced, making two-bin a suitable MSM. Parts that are consumed on at least 70% of the buses produced (on average one per shift) shall change MSM to two-bin. To implement two-bin as MSM packing instructions must be designed in order to suit the assembly stations demands and tact. The rest of the parts controlled by MCM batch shall use picking as MSM where orders are sent from assembly in the same way as the present situation.

Sequence
In the same way as parts with special demands, large variance and high unit value are controlled with MCM and MSM sequence shall this routine continue, as no disturbance are found.

Kanban
Kanban is not used today by S.P.S but is a possible MCM as normal situation is determined. As the method is suitable for parts with high and steady demand, high unit price and where the supplier is located close to S.P.S, only a few suppliers are imaginable. In order to have frequent deliveries and reduce buffers, Kapena SA is a potential supplier. The objectives is then to reduce the stock levels at both S.P.S and the supplier and increase the turnover rate which makes future possibilities worth taken in to account.

9.2 Comparison
To see how the definitions presented adept with the presented situation information from chapter 4.6 is compared. Information about consumption regarding parts controlled by MCM ROP is in some areas fallacious as all parts are not included in the structure.

ROP should be valid for parts with unit price under 5 PLN and consumption above 10% of the buses produced. Depending on the information source is between 815 and 1521 parts consumed or has valid balance at S.P.S. If the new definitions are implemented and used to control parts at S.P.S some changes have to be made shown in table 9.1 to 9.3. Table 9.1 shows the number of parts controlled by ROP and the share according definitions. The information regarding parts with balance does not consider consumption. According this information some parts shall change MCM.

<table>
<thead>
<tr>
<th>ROP</th>
<th>Present situation</th>
<th>ROP according definition</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Present ROP</td>
</tr>
<tr>
<td>With balance</td>
<td>1521</td>
<td>1143</td>
</tr>
<tr>
<td>With balance, moved after 2007-01-01</td>
<td>1240</td>
<td>945</td>
</tr>
<tr>
<td>Consumed according to structure</td>
<td>815</td>
<td>598</td>
</tr>
</tbody>
</table>

Table 9.1 MCM ROP according new definitions.
In conformity of the reasoning above table 9.2 shows the information regarding parts controlled by batch.

<table>
<thead>
<tr>
<th>Batch according definition</th>
<th>Batch</th>
<th>Present situation</th>
<th>Present ROP</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Present Batch</td>
<td>Present Batch</td>
<td>6618</td>
<td>4 511</td>
<td>113</td>
</tr>
<tr>
<td>Present ROP</td>
<td>Present ROP</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td>Total</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>With balance</td>
<td>With balance</td>
<td>5096</td>
<td>3 355</td>
<td>90</td>
</tr>
<tr>
<td>Present situation</td>
<td>Present situation</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Present Batch</td>
<td>Present Batch</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Present ROP</td>
<td>Present ROP</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td>Total</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Consumed according to structure</td>
<td>Consumed according to structure</td>
<td>4856</td>
<td>3 326</td>
<td>76</td>
</tr>
</tbody>
</table>

Table 9.2 MCM batch according new definitions.

Regarding parts using MCM batch both MSM picking and two-bin can be applied. Information about MSM decision is only based on consumption, shown in table 9.3.

<table>
<thead>
<tr>
<th>Batch according definition</th>
<th>Batch</th>
<th>Present Batch</th>
<th>Present ROP</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Present ROP</td>
<td>Present ROP</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td>Total</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Picking</td>
<td>Picking</td>
<td>3 163</td>
<td>56</td>
<td>3 219</td>
</tr>
<tr>
<td>Two-bin</td>
<td>Two-bin</td>
<td>163</td>
<td>20</td>
<td>183</td>
</tr>
<tr>
<td>Total</td>
<td>Total</td>
<td>3 326</td>
<td>76</td>
<td>3 402</td>
</tr>
</tbody>
</table>

Table 9.3 MSM regarding MCM batch according new definitions.

In excess of the share presented above some parts are named 00, 99 or blank fit the definitions but are excluded. Parts controlled by MCM sequence shall still be sequence.

9.3 Manual

As the new definitions are about to be implemented and used during daily routines has a manual been created shown in Appendix I. In excess of the definitions presented in chapter 9.1 a short description of the underlying theories is included, based on substance in chapter 6. The objective is to give responsible personnel guidance to make decisions as new parts are introduced. But, also to study and improve the present situation and assist in situations that is a bit unclear.

Structure

The manual is divided into three sections. The first section is an introduction where the objectives are displayed and the background is presented. The introduction also explains who the manual is valid for and how the process is organised. The next section describes the underlying theories, which are MCM ROP, batch, sequence and kanban and MSM kanban, two-bin, picking, and sequence. The theory is presented in shortly gathered from the frame of references (Chapter 6) and benchmark (Chapter 7). The last section describes how information regarding new parts shall be used to determine the best suitable MCM and MSM. This information is both presented in text and as a flow chart.
10 Conclusions and Recommendations

Conclusions and recommendations will back feed on all previous chapters and string together the thesis in a pragmatic way. First, a recap of the objectives aligns with the findings for respective steps. The next section, recommendations will be listed and thereafter a short review on how to implement new standard routines.

The thesis included three clearly defined objectives:

- Map the present situation at Scania Production Slupsk regarding material flow from supplier to assembly line including a part and storage analysis.
- Benchmark the current routines at Scania Production Slupsk with other successful companies. Furthermore, conduct literature research in order to find theories and philosophies that support problem analysis and thesis solution.
- Develop standard routines for MCM and MSM.

A complimentary objective is to work as a catalyst during the time of the thesis.

The mapping of the present situation showed that MCM and MSM are very tight connected to each other. It was questioned whether this structure, that was a result of unclear routines, was the best way to manage the material flow. The parts and storage analysis was used to measure efficiencies in material handling and showed that the inventory can be divided into three segments; sleeping parts, slow moving parts and operating parts. Even though, it is not possible to draw any conclusion at this stage.

The benchmarking (Chapter 7) studies showed conditions for different way to manage the material flow; unit load, kanban and random location in storage to name a few. Some of those conditions are not in place at S.P.S today and limit the possibilities to have additional MCM for the moment.

With respect to frame of reference (Chapter 6) and present situation (Chapter 4) new definitions where developed concerning MCM in order to make connections between MCM and MSM looser. A comparison between previous definitions and recommended definitions showed that some parts needs to be handled differently. Furthermore, a manual was created regarding decision making of MCM and MSM when introducing new parts.

A complimentary objective has been to work as a catalyst and doing so some involvement have been made concerning material station setting. Together with responsible personnel suggested material segments have been discussed. This work is important in order to find a normal situation and make improvements in production. Continue to evaluate the work impact on recommended material flows. Also, integrate assembly personnel in the process align with Scania Production System. Finally, observe the “sliver tray” project in order to find positive effects that can be implemented at S.P.S.
10.1 Recommendations

Primary recommendations are that logistics manual shall be used when new parts are introduced into the Scala system. Responsible personnel are suppose to give suggestion concerning decision making of MCM and MSM and with help of the logistics manual the work can be more efficient, resulting in a material flow that is flexible and have potential for improvements. Additional work has to be conducted to move parts that are misplaced according to the new definitions. Also, those parts that fall outside the definitions needs to be studied and evaluated one by one in order to find suitable MCM and MSM.

Secondary, to avoid material handling in some extent implementation of two-bin system is recommended. Other recommendations involved in the two-bin system is to handle material according to unit load and FIFO, enable traceability and higher turn over rate together with a more even and steady material flow.

Further recommendations are to investigate the possibility of introducing kanban flows to decrease inventory levels. As first supplier Kapena is suggested due to its nearness and the kind of parts they deliver. Instead of high inventory level at both Kapena and S.P.S material ought to be delivered according to JIT described in chapter 6.2.2.

10.2 Logistics Manual

Logistics manual (Appendix I) is the main contribution of this master’s thesis and the perception and recommendation is to implement it in the daily work. Important aspects is that personnel working with logistics decision making is aware that guidelines should be treated as guidelines and not rules to follow. There will be exceptions and factors that will effect the decision making, but in those cases the logistics manual can be used as an information base. Further, as all documents the manual should be validated and reworked when improvements are found. Finally, effects of logistics changes is described in chapter 6.1.1.

10.3 Colour Coding

In order to implement colour coding a manual have been developed (Appendix II). Discussions with Pacocha have been conducted; he finds the method simple and suitable for presumptive two-bin parts to start with. However, if an implementation is to be made MC department needs to state their responsibility regarding this issue. Further, FIFO and replacement of carriers is required. The intention is that storage personnel gives feedback to responsible MC who takes action when parts have been in storage to long. The recommendation is that discussion ought to be established, aiming at introduce colour coding and find positive effects for both departments.

10.4 Continuous Work

The fact that some parts do not fit within the new definition is made in awareness. The intention, as mentioned in earlier discussions, is to avoid additional work and to find a standardised situation for each MCM and MSM. But, as the material segments gets
clearer the boarders in between ROP, batch, sequence and maybe kanban can be narrowed and in that way improved according to Scania Production System.

10.5 Other Aspects
When evaluating material flows or implement new routines it is important to base decisions on valid and accurate data. During the thesis information has been found in various systems. The perception is that many issues can be solved if accurate information is gathered and analysed.

In order to make final decision especially concerning implementing kanban further evaluation is required. Regarding two-bin concept actions has already been initiated. Pacocha and Garbacz are working with parts, which intends to be managed as two-bin. Some recommendations have already been made and further work will be interesting to follow.
11 Future Research

In this chapter some ideas for further research is presented. The intention is that there are possibilities for more interesting evaluation regarding curtain aspects. The suggestions can be preformed as case studies or new thesis.

A new potential MCM has been detected. As described in solution (Chapter 9), kanban may be used for some parts, aiming at decrease inventory levels. Nevertheless, to implement external kanban further research needs to be made. It would be interesting to see if any conclusions could be drawn on how the kanban system would be built up. Thereafter, other suitable suppliers can be involved in the kanban system.

Regarding EOQ, no calculation has been made due to the time frame of the thesis. However, it would be interesting to conduct such calculation and hopefully see the positive effects in having more optimal order quantities. As mentioned in previous discussions (Chapter 6.2.4) it is not the calculation that is time consuming, but investigating underlying factor as ordering cost and holding cost. It is not only a recommendation made from this thesis but also align with Scania Production System.
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LOGISTICS MANUAL

This manual describes material control methods (MCM) and material supply methods (MSM). The manual is divided in three parts, Introductions, MCM and MSM and Definitions to give the user information regarding structure, theories and definitions.

Introduction

Background
To support production in terms of right material in right time without holding a high level of inventory, it is important to tie together MCM with MSM in an efficient way. In order achieve this objective knowledge about different methods and understanding about the benefits and withdrawals of each method is crucial. This manual should assist and give recommendation when new parts are introduced and MCM and MSM are decided. Furthermore is it important that this manual is updated and kept alive over time.

Valid For
Introduction of new parts and control of existing parts into the system

Process
Process owner for “choosing MCM and MSM” is responsible to suggest an appropriate method to use, shown in figure 1.

![Figure 1: Process for decision making concerning MCM and MSM](image-url)
MATERIAL PLANNER

Input
Reliable data as input is important in order to make an accurate decision. Before the process of choosing MCM and MSM can be made, certain input needs to be handed over from previous departments (i.e. Design and Purchase), shown in table 1.

<table>
<thead>
<tr>
<th>Input</th>
<th>Document</th>
<th>Department</th>
</tr>
</thead>
<tbody>
<tr>
<td>Price, Supplier</td>
<td>Form01, Matris or Scala</td>
<td>Purchase</td>
</tr>
<tr>
<td>Yearly consumption</td>
<td>Form01, Matris or Scala</td>
<td>Design</td>
</tr>
<tr>
<td>Customer order item</td>
<td>Kom30F ZZC-list</td>
<td>Design</td>
</tr>
<tr>
<td>Roughly estimated parts list</td>
<td>Estimated parts in design structure</td>
<td>Design</td>
</tr>
</tbody>
</table>

Table 1: Input for choosing MCM and MSM

Output
The output from the process is a recommendation according MCM and MSM.

Support
Production, as support functions, is useful concerning wishes and demands regarding how to present material in the racks at line, due to their knowledge about the station settings. It is important that material is supplied in the right way to assembly line. To achieve the benefits of assembly and material handling personnel need to communicate. Furthermore, purchase and design is involved to provide information regarding price, supplier, estimated consumption and other important information concerning new parts.

Documents
Form01, ZZC-list and roughly estimated parts list

General instructions
- Gather all necessary information
- Consider price and estimated consumption as well as size and weight of parts as MCM, MSM and storage location shall be determined

MATERIAL CONTROL METHODS
Below are MCM described in detail. Reorder point, batch and sequence are already used as MCM (August 2007)

REORDER POINT
Basic
In reorder point (ROP) purchase order or production order is initiated when inventory reaches a predefined level. An important factor is to bring open orders into the calculation, especially if the order quantity is less than the consumption over lead time. Therefore, should inventory level and open orders sum up to get an accurate purchase signal. Regardless of previous, reorder point level always classified as safety buffer and anticipated demand over lead time, described in figure 2.
Parameters

**Economic order quantity (EOQ):**
EOQ weights holding costs against ordering cost, and therefore can calculate the most economic order quantity. A benefit with the EOQ model is its relative insensitivity towards inaccurate estimations of parameters.

\[
EOQ = \sqrt{\frac{2 \times O \times D}{P \times H}}
\]

\(O\) = Ordering cost  
\(D\) = Annual demand of the product  
\(P\) = Purchase cost per unit  
\(H\) = Holding cost

**Reorder point level (ROP):**
When this level in store is reached a new call off is automatically made to respective supplier. The level is predefined based on average consumption, total lead time and safety stock level.

\[ROP = \text{Total lead time} \times \text{Average consumption} + \text{Safety stock level}\]

**Total lead time:**
Total lead time is the time from call off until parts are delivered.

\[\text{Total lead time} = \text{Supplier lead time} + \text{Transport time} + \text{Security stock days} + \text{Material handling time}\]

**Average consumption:**
The average consumption for the part based on daily consumption.

**Safety stock:**
The purpose of safety stock is to compensate for random variations in consumption over the lead time. Random variations can depend on deviations concerning forecasts, lead time, physical inventory and quality issues. Based on service level safety stock is determine.
Criteria’s
MCM ROP is based on consumption. Therefore, it is recommended that parts controlled have the following characteristics:

- Low unit price
- Limited volume value
- Steady consumption

Forecast
ROP is using the same deliveries schedules as batch parts. Therefore, no adjustments need to be done at the suppliers’ material planning systems. Each delivery schedule will contain one fixed call off and is sent when reorder point level is reached.

BATCH

Basic
MCM batch is used for parts irregular consumption and/or high value and are ordered based on actual demand. The total requirement is calculated from a long term prognosis and the net requirement is determine by subtracting physical inventory level.

Depending on the system and structure breakdown demand is calculated and compared to inventory balance. Further, actual need is compared with minimum order quantity from suppliers.

Criteria’s
- Consumption is based on actual need
- Irregular issue from storage

Forecast
Based of expected demand is forecasts sent to suppliers, both on short and long term basis.

KANBAN

Basic
Kanban is an information system for production and material handling, aiming at controlling and reducing work in process levels. The main philosophy with kanban as part of a just in time (JIT) system is that material should be supplied when production have a demand. The method has been implemented in vary enterprises and the main benefits are:

- Improvements in productivity and greater control between various production stages
- Lowered levels of raw material, work in process and finished goods inventory
- Reduced production cycle time
- Improved turn over rate

Withdraws with JIT systems are that it requires small frequent deliveries, which increases cost for transports since deliveries will increasingly be done by less-then-truckload. Furthermore, it
can result in a higher cost per unit, since production of smaller lot quantities may raise setup and production costs. In that aspect, distant to presumptive supplier is crucial.

Kanban is only meaningful if production is repetitive with high consumption. Also, to fulfil the requirements for JIT philosophy demand ought to be steady and high. Another aspect to achieve benefits with low inventory levels and short frequent deliveries is that suppliers are situated close to production. Finally, products included in a kanban flow needs to be more or less standardised. Hence, the level of complexity increase with number of variants.

Criteria’s
- Expensive parts
- Low variant mix
- Short distance between production and supplier

SEQUENCE
Basic
Sequence is used to control parts with large variance where most orders are unique. Each order shall be dedicated to a unique bus body or chassis. MCM sequence is typical used for custom made parts, parts with special paint or use of special fabrics. Possibility to have safety stocks limited as each part is dedicated to a specific unit. In case of deviations the quality issue is important as new parts have to be ordered separately. The lead time of sequence parts is often long due to the fact that supplier purchase material or design parts as the order are received. This results in a situation where it is important to verify and order parts as early as possible in the order process.

Criteria’s
- Expensive parts
- Variant dependent
- Large bulky parts that needs extra handling

Forecast
Due to the fact that most sequence parts are specific to the unit it is used on forecasts is aimed to allocate production instead of procurement of material.
MATERIAL SUPPLY METHODS

In the same way as MCM, different methods are used for MSM representing the flow from storage to line. In order to reduce the workload in storage, save space and reduce shortages at line the most appropriate method is chosen, depending of consumption, price, size and supplier.

Next follows a short description of the current MSM.

**Kanban**

Kanban system has balance at both line and in storage. As parts reaches a pre defined level at line a signal is sent to the storage in order to refill balance at line. The signal is represented by a kanban card or carrier. The number of cards or carriers needed depends of the demand, lead time from storage, safety factor and number of parts in each carrier, described below:

\[
\text{Cards/carr} = \frac{\text{Demand} \times \text{Lead time} \times (1 + \text{Safety})}{\text{Parts in carrier/transport}}
\]

Kanban card/carrier:

Both the kanban card and carrier holds information regarding part number, refill level and station address. Some carriers can be designed to hold a certain number of parts where the card only gives information regarding the amount.

The method is useful for low value parts with roughly estimated consumption where it is hard to order parts based on structure breakdown. By usage of kanban balance at line is always under control as parts are only ordered based on needs. Therefore, the method is used where the objective is to reduce work in process. The turnover rate at line is also increased if the quantity of parts in each carrier is correct.

**Picking**

By picking parts variations in production and distribution is handled. Parts with low consumption are picked in order to save space at line. High value parts can also be picked in order to decrease bound costs at line.

The signal, to storage, to pick parts is either initiated by the planning department or production. The picking instruction holds information regarding part number, quantity, station address and delivery time. In order to send orders in time and guarantee parts at line when needed, it is important that the delivery time is known.

To simplify the access of parts and make it easy to pick the packing instructions shall be correctly designed.
Two-bin
Two-bin are used for parts with high and steady consumption. The method uses full units which are sent to line and placed in two locations. The point of use location is close to assembly line and easy to access, and the second location is a buffer, often located above. When parts in the point of use location are consumed the unit is replaced with the unit from the buffer location. A new unit is then collected from storage and placed in the buffer location. In this way FIFO (First In First Out) is applied as new parts first are placed in the buffer location and moved to point of use location.

The fact that the carriers not are divided during the supply chain from supplier to line, it is important that packing instructions are designed according to consumption, cover time and rack design. The reason to use two-bin is to reduce the material handling and transportation of parts and enable full units handling in the supply chain.

It is important to have systems to bind consumed parts to produced busses, due to different transaction points; one in storage and one at line. This is done by usage of assembly instruction from structure breakdown. Finally, as inventory take place it is vital to check balance at both storage and line.

Sequence
Sequence is used for specially designed and expensive parts and is strictly connected to the material control method. Sequence parts are bound to a specific body number and station address. Further, it is important to deliver parts according to production plan.

Definitions
Definitions are initially presented in short text descriptions followed by a flow chart (figure 3).

ROP
MCM ROP shall be used on parts with unit price under 5 PLN and where the estimated consumption over 10%. An exception of this statement is parts that only appear on the customer order list (ZZC-list) which shall use MCM batch. Parts controlled by ROP shall be stored separately and use MSM kanban.

Batch
Parts that are not using MCM sequence which have unit price above 20 PLN will use MCM batch. Depending of estimated consumption is MSM picking or two-bin is applied. Parts with high consumption, over 70% of the buses produced (on average one per shift), shall use two-bin. Parts with lower consumption shall be picked based on orders from assembly line.

Sequence
Parts with special demands, large variance and high unit value shall be controlled by MCM and MSM sequence, decide in an early stage of the supply chain.
Kanban

MCM Kanban can be used as normal situation is reached. The method is suitable for parts with high and steady demand, high unit price and where the supplier is located close to the production unit, leading to frequent deliveries and reduction of buffers. Parts and suppliers suitable for MCM kanban must be investigated accurately. If the MCM is implemented turnover rate is increased and storages area is unbound.

Flow chat regarding decisions of MCM and MSM

![Flow chat regarding decisions of MCM and MSM](image-url)
LOGISTIC DEPARTMENT

COLOUR CODING

Description
This manual describes the process of colour coding.

Background
Due to high load in storage it is difficult to determine how long material has been stored before usage. Information can be found in systems but without clear responsibility it is both time consuming and hard work.

To make it more visual and in that way easier for storage personnel and responsible MC to take action different colours are used to label incoming goods. Each colour represents a quarter and the sticker is added by personnel at goods reception. This means that storage personnel can easily scout deviations in storage in terms of material with low turn over rate. Additionally, colour coding facilitate continues physical inventory when it comes to material that needs to be phased out.

Valid For
GR personnel, storage personnel, MC

Definition
Every quarter storage personnel switch colour of the paper and stickers for labelling incoming pallets or boxes. Bright colours are used for easy read. The number of colours is limited to four, due to turn over rate objectives in storage. The colours and comprehensive period are:

- Blue: 1 January - 31 Mars
- Red: 1 April - 30 June
- Green: 1 July - 31 September
- Yellow: 1 October - 31 December

Instruction
- Change colour according to following dates:
  - 1\textsuperscript{st} of January
  - 1\textsuperscript{st} of April
  - 1\textsuperscript{st} of July
  - 1\textsuperscript{st} of October
- GR personnel mark incoming pallets and boxes with coloured label on the front side as displayed in picture 1 and 2.
- Storage personnel place pallets and boxes with labelled side visual.
- Information board in GR and storage displaying colour codes.
Routine
One week before change:
- GR personnel guarantee the right material for labelling is available
- GR informs the personnel concerned about the coming changes

After every period:
- Move material with low frequency (old colours) away from primary locations, do not forget to update SCALA.
- Storage personnel notify responsible MC when material has not been consumed for more than three periods.

Material that are two periods old:
- Inform responsible MC for initial check

Material older then three periods:
- Notify responsible MC for part follow up and parameter check.
Colour schedule

Blue: 1 January - 31 March

Red: 1 April - 30 June

Green: 1 July - 31 September

Yellow: 1 October - 31 December