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**Object Model for Description of the Logistical
Flow at Volvo Cars Corporation
-A base for simulation containing logistical flows**

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Abstract

This thesis is about creating an object model for the logistical flows in Volvo Cars Assembly Factory in Torslanda. This in order to use the object model as a base for the simulation of the logistical flows with the use of a digital source. This is something that is missing today. The logistical handling is based on experience and the knowledge of the truck drivers instead of rules and guidelines. This is something that Volvo wants to change. In order to make the mapping of the flows, an understanding of the logistical handling must be created. In this thesis the logistical flow within the assembly factory is described through a pre study of the flows. The method used in this thesis is based on the qualitative method. Interviews have been conducted with technicians in order to understand the logistical flows, as well as to experts within the simulation area. This to create an understanding of the prerequisites that a simulation tool has on the mapping that has been created in this thesis. The pre study gives the base for the main section of this thesis, the creation of the object model for the logistical flows. This has been done in Visio with a creating of a stencil with standard objects together with a mapping file. This can then be extracted through an XML file into the simulation environment digitally, which is the main goal of this project.

In the analysis chapter the Visio modeling way is compared to the way of using the FactoryCAD model as an input for the simulation model, presented by Moorthy and Sly (2001).

The conclusion is that when a mapping like this being performed the most important thing is that it is object orientated, not that a certain technique or program is used. The format should be a standard format, excepted among several users so that you do not get tied to any particular solution.

For the recommendations given to Volvo the main idea is that materials that do not have an automated call to the line must be defined, categorized and placed into the layout, in the same manner as those with an automated call. This in order to make it possible to simulate all logistical flows and gain the benefits by adapting to this way of work.

The mapping performed is to be seen as a way of working and not a finished solution or application. The work has much consisted of trying a new way of thinking and the problems that can occur when doing so.

Key Words: Object model for logistical flows, Object oriented modeling, logistical mapping, automated simulation input data, the production system, automotive industry, Volvo, CAD drawing and simulation integration, Visio model building, XML extraction.

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Abbreviations and Acronyms

Word and definitions used in this thesis are explained

Design - Volvos internal definition of a detailed definition of how a machine should be assembled

E6 aisle – the large aisle connecting TV and TC.

Layout – Volvos internal definition of a design

MAS – Material administrative system, IT system that control the material flow. Are located in the terminal in the stackers

Storage 4000 – Alternative name on the crane storage

TA – The body plant at Volvo Cars Torslanda

TB – The paint shop at Volvo Cars Torslanda

TC – The Assembly plant at Volvo Cars Torslanda

TCS – Goods receiving area in TC. About 80% of the near storage material is unloaded here. Also used as storage area.

TV – Storage building built together with TC. Crane storage and pre station is located here

TVS – Goods receiving area in TV

TVV - Goods receiving area in TV. Mostly crane storage material is unloaded here, but also some near storage material.

VCC - Volvo Car Corporation

VCT – Volvo Cars Torslanda

VLC - Volvo Logistics Corporation, a sister company within the Volvo Group

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1 Introduction

In the initial chapter a short background to the subject and the company studied is presented which leads to a problem definition. Based on the problem a purpose of the research is formulated. The chapter is finished with a disposition over the structure of the report.

1.1 General background

As a car manufacturer Volvo must always optimize their production on such an early stage as possible. Since the 80s Volvo has been using simulation as a tool trying to become as efficient and effective as possible.

The last seven years Volvo has been using their simulation department on a full scale. It has been used in two different ways. First, for optimizing the continuous production, and secondly as a tool in different projects. The project work has mostly been related to when there is a new type of car coming into the production. Simulation has been used looking at process changes and effects on the process flow. With the help of simulation they have been able to verify, control or understand production coordinates in a better way than was possible earlier. Faults and risks have also been detected before they appear in the real-time assembly situation.

Volvo has also been using computerized designs or CAD-designs as a tool getting an overview of the plant when performing development projects. In recent years Volvo has started to transfer these digitalized or computerized drawings into the simulation tool for direct use in the simulation model. This is done through FactoryCAD which gives the possibilities to an objectification.

Before any major changes can be realized at Volvo they must be run and validated through a simulation. If Volvo wants to move from a task based or area based system of the material handling into a queue system, where the first free truck takes the next job, data and evidence of benefits of the changes must be shown in a clear manner. This is where simulation has an important purpose. Therefore also the logistical flows must be covered in the simulation models.

1.2 Company background

Volvo was founded in 1926 as a subsidiary company within SKF (Svenska Kullager Fabriken), the famous ball bearing manufacturer by, Assar Gabrielsson as managing director and Gustaf Larson as vice president and head of technology. The two men had by then been able to persuade the management of SKF that manufacturing of cars could be profitable and support the development and sales of ball bearings. Volvo is Latin for “I roll”, which were thought suitable for the new company. The first mass-produced Volvo car ÖV4 rolled out of the plant 14th of April 1927 (Olsson & Moberger, 1995).

Volvo soon started to widen the business and the manufacturing of trucks started. Volvo Trucks were until the 1950's the most prosperous part of the company and it had a crucial role in the company's early success. The trucks were sold in Sweden as well as abroad.

With an increase in production larger premises were needed. The 24:th of April 1964 the factory plant in Torslanda were opened. The next year Volvo took a large step opening another car manufacturing plant in Gent in Belgium, and a truck manufacturing plant in Alseberg. In 1980 Volvo Cars became a subsidiary company to Volvo AB. Two years later many other subsidiaries were created. Volvo Trucks, Volvo Busses, Volvo Parts, Volvo Penta, Volvo IT became limited companies. Today these companies gives Volvo a wide manufacturing of products from construction equipment, busses, trucks, marine engines to aircraft engines.

Innovations have always been a driving force for the development of the company. The company holds many patents that have revolutionized the automotive industry. Volvo invented the seat-belt and developed it up to the lap-diagonal belt that is standard in every car manufactured today. The airbag also started as a Volvo project but later the company Autoliv were sold out by Volvo to continue as a single company. The Volvo brand has become synonymous with safety and environmental care, and that has always been the focus of the company.

In 1999 Volvo Car Corporation (VCC) was sold to the Ford Motor Corporation. The development costs involved with a new model was one reason for the sale. Fierce competition within the car manufacturing field made Volvo believe they need support from a larger owner to be able to grow for the future. Volvo Cars is today a part of Ford Premium Automotive Group (PAG), were the premium brands within the Ford Corporation are located. This portfolio contains the models Aston Martin, Jaguar, Land Rover, Lincoln and Volvo. Volvo Car Corporation have in resent years invested further for developing the safety side of the brand but also to receive a sporty image among the customers.

There are still collaborations between the Volvo Car Corporation and the Volvo companies especially on the technical and service side. One example is between Volvo Logistics Corporation (VLC), a sister company to AB Volvo, and Volvo Cars Corporation. VLC handles the material movements to the manufacturing facilities, as well as the transportation from the assembly plant to the end customer.

In total Volvo Car Corporation produced 443 947 cars in 2005. The manufacturing plant in Torslanda have about 5500 employees and manufactured 184 021 cars in 2005 of the models S80, V70 and XC90. (Volvo Cars 2006a).

1.3 Problem definition

Looking at a manufacturing plant in the size of the Volvo assembly plant at Torslanda, changes and improvements can be very costly to try and perform in real-time. There is no room for a trial and error period. There are always a demand and a production cycle to be performed. Therefore simulation of the production in different possible directions with possible scenarios is an important tool for the continuous improvements of the plant. There are sometimes also a new model coming into the production line with new demands, parts, accessories and ways of assembling the car. Here simulation is a very important tool. The models run and developed considering TC (Volvo assembly plant in Torslanda) do have some problems. The logistical flows and infrastructure within the plant have no digital documentation. Therefore it can not be used in the simulation model in a desired and correct way. There are no digital documentations done over how and why a pallet or other materials are handled from a storage area to the assembly line were the parts are utilized. The

pallets etc. are most often moved in the correct way, but the knowledge of this are often kept in the head of the truck operator. Therefore decisions are often made by experience and not by rules and guidelines. There is no documentation saying that a specific route is the best for a certain movement of material to the line. The routes might differ from time to time and from truck driver to truck driver. This makes the simulation models a little obsolete since they do not consider these important flows in a digital and automated way. The present process model is not defined in a way that allows it to be used as an input for this type of simulation model. Therefore the logistical flows has not been included and evaluated in any way concerning this matter. The models are not at the present situation considering which attributes that influence the decisions for what action to take, or activity to perform considering the logistical flow. At the moment these factors must be put manually into the given model. This is time consuming and can be considered unnecessary work. Volvo hopes this instead can be done automatically with a given input data considering random disturbance in the flow and the attributes of the logistical flow. There is a need to create a network of routes or points and define their attributes. This in order to create information that will become digital and used as a base for the simulation models, with defined objects and parameters, with given attributes. All in order to move Volvos logistical handling from a base of a human knowledge and behavior and instead make it possible to put the triggers of the movement into the simulation model. This can create an optimization that ensures that Volvo is moving in the right direction and are using the right handling behavior of the logistical flow.

To explain the problem briefly through the picture below it will mean to find out what of the alternative routes that cost the least time coming from WP1 and going to the point of consumption for the product at the line (marked with red in the picture).

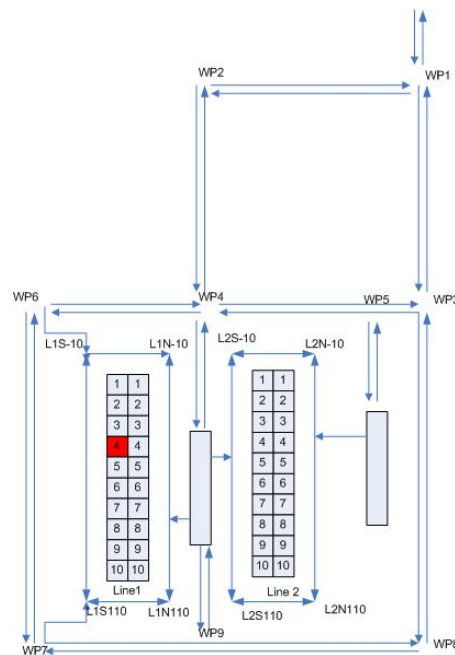


Figure 1: Basis of the problem (own picture)

1.4 Research questions

- ✓ How is the material handled, what happens, from the arrival at the goods receiving area to the point of consumption at the line?
- ✓ How would a mapping of the material flow with intelligent attributes look?
- ✓ How can the information gathered help to improve the simulation studies or the logistical handling of the material within the assembly factory?

1.5 Purpose

The purpose of this thesis is to describe the logistical flows in Volvo Cars Assembly Factory and to create an object model for these flows, which can be used as a base for the simulation model, as well as to evaluate if and how the flows can become more efficient.

1.6 Delimitations

The study will be conducted at the assembly plant at Volvo Torslanda named the TC factory. The thesis will only look at the logistical flow within the assembly plant. This means that parts are first considered when they arrive at the goods receiving area of the plant. This will be applied to materials outsourced to other vendors as well. The routes will be covered considering all resources that utilize that area. The actual manufacturing processes will not be covered in this research. The routes created follow an abstraction level. The route network will show the main routes and not possible side flows and details. This in order to leave out the limitless amounts of possible small routes in the system.

1.7 Interested parties

This thesis turns to personnel working with simulation, both within the Volvo Cars Corporation as well as other corporations. It also turns to personnel that are interested in creating a mapping of a logistical flow and are looking for a way how to do it. The thesis might be useful for management and project leaders as well as external consultants who already have some knowledge within the area.

1.8 Disposition

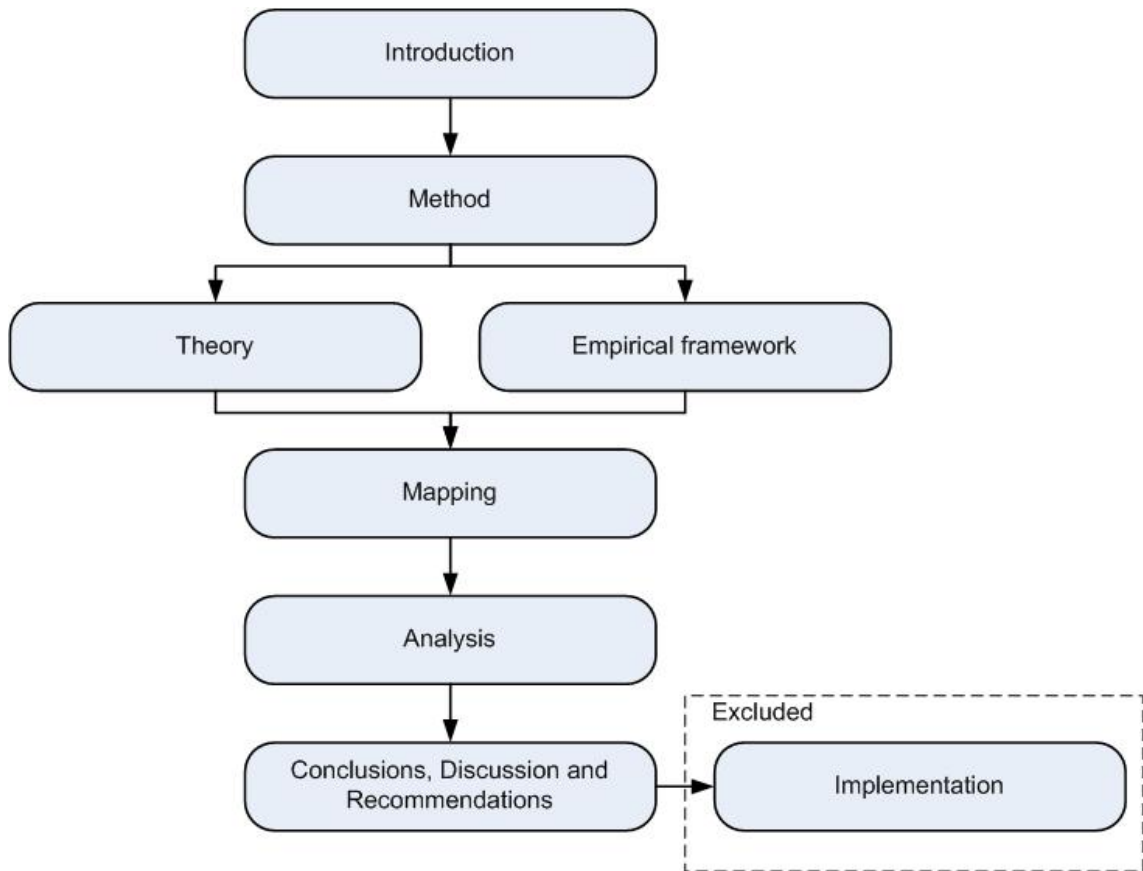


Figure 2: Disposition of the thesis

Chapter 1 - *Introduction*: Is initiated with background and a description of the problem, which leads to the purpose of the report. The chapter ends with a disposition of the report.

Chapter 2 - *Method*: The chapter starts with method selection and approach and continue with a method description. After that credibility, data collection as well as induction and deduction is described.

Chapter 3 - *Theory*: The theory chapter is a support for the research and reach the areas; the production system, simulation, integration between CAD drawings and simulation and Extensible markup language.

Chapter 4 - *Empirical framework*: In this chapter the information gathered through interviews as well as the development of the logistical mapping network.

Chapter 5 - *Mapping*: This chapter describes how the object model of the logistical flows was established.

Chapter 6 - *Analysis*: Here the material collected in the theory, empirical framework and the mapping chapter is analyzed with a feedback to the problem and purpose of the report.

Chapter 7 - *Conclusions, discussion and recommendations*: In the last chapter the result of the analysis is described. A discussion together with recommendations are created over the drawn conclusions.

Chapter 8 - *Implementation*: This part will not be included within the thesis due to secrecy. This chapter includes the fully mapping file together with the stencil file created in Visio distributed to Volvo Cars Torslanda.

2 Method

The method chapter a description of the selected method, research approach and procedure before and during the research. The chapter also covers the credibility and criticism to the selected method.

2.1 Method selection and approach

Below the selected method and approach are described and the purpose of the selections.

2.1.1 Method selection

At a research a quantitative or qualitative method can be applied. In the research the qualitative method was selected. The purpose of the selected method is that it gives a deeper knowledge of a specific research area. The ambition of a qualitative processing is to try to understand and analyze the wholeness (Patel & Davidson, 1994).

Patel and Davidson (1994) describes that with a qualitative processing text material that arise during discussions or interviews are mostly used. In order to receive information in the best manner it is important for the person to be well prepared in the area selected. Backman (1998) considers that pre knowledge is an important part of the accomplishment of a qualitative method. It is hard, almost impossible to carry out a trustworthy research if there is a lack of basic knowledge.

With the arguments above the selection to do a pre study of the logistical flows at Volvo Cars Torslanda are supported. The purpose of the pre study is to get an understanding and strengthen my knowledge before the research.

2.1.2 Research approach

According to Davidsson (2001) there are different methods to use in a research. It can consist of a deep-study or a breath-study but also as an implementation of a cross-sectional study or a longitudinal study. A deep-study involve data collection through personal interviews, participation observations or case study approach. A cross-sectional study is performed when the study is performed during a short time perspective. A longitudinal is the opposite, when a study is conducted over a longer time period.

The research consists of a deep-study with the intention to receive a deeper understanding and a broader knowledge of the limited area. Since the purpose of the thesis is to investigate what in present time can be covered in the objects of logistical flows through a cross-sectional study.

2.2 Method description

The method description describes the procedure before and during the performing of the research. In the section there is also a description of how the respondents were selected before the research.

2.2.1 Theory

According to Bell (2000) every research involves a study of the theory of what has been documented within the topic. Books try to put together and systemize knowledge within a specific problem area, which lead to that books often give a knowledge about evolved theories and models. Knowledge gathered through books or previous investigations within the area helps the researcher to identify the things that are important for the selected problem area, as well as making the delimitation easier (Patel & Davidson, 1994).

The research started with searching for relevant literature. The study of the material resulted in a deeper understanding of the selected subject. This was done in order to first understand and describe the material handling in the pre-study, but also to understand how the mapping of the flows could be created. The knowledge was required as a base for the pre study and the survey used in the report.

2.2.2 Selection of the respondents

According to Davidsson (2001) the purpose of the study rules the selection of the respondents. The reason is that the data collected from the respondents generate a result that is a reflection of the reality to such a high extent as possible. According to Bell (2000) it is essential with a representative selection unreliable of the scope of the study. Holme and Solvang (1997) argue that a large information content is obtained through a large variation width in the selection. The result of the study can then generalized in relation to a contemplated population (Patel & Davidson, 1994). Holme and Solvang (1997) further argue that the purpose of qualitative interviews is to increase the value of the information and to create a base for the phenomenon that is studied. Therefore the selection of the respondents are neither done at random nor temporarily. The selection is done systematically with consideration of the formulated criteria's. One important aspect to consider at the selection of the respondents is their ability to express themselves and their willingness to contribute as it affects the final result.

The respondents in this study have been selected through a discussion with the tutor at Volvo Cars Torslanda based on who would be suitable to interview. The respondents have all worked with the subject for some years and are considered experts in the field. They were selected based on that they are very skilled in expressing themselves in an easy understandable way as well as showing a high willingness to contribute to the development of the report.

2.2.3 Pre study

According to Patel and Davidson (1994) researches can require some pre knowledge within a specific area. Interviews can be used in a pre study in order to gather information used as a base for the research. Olsson and Sörensen (2004) mean that in a qualitative research the intention can be to identify attributes and meaning of different processes.

In the research the pre study was used to get an understanding of the material handling and the logistical flows at Volvo Cars Torslanda. Since it is a very complex system a pre study was required in order to be able to fulfill the main purpose of creating an object model of the logistical flows. The questions to the respondents of the pre study can be found in appendix 1.

2.2.4 Design of the survey

Holme and Solvang (1997) argue that a qualitative interview, or survey, shall not consist of standardized questionnaires. The intention is to minimize the guidance from the researchers' side. Patel and Davidson (1994) describe that a structured interview leaves a small scope for answering where the alternatives are predictable. A fully unstructured interview leaves a large scope for the respondent. According to Bell (2000) most of the interviews end up as a combination of a fully structured and a fully unstructured, a semi structured interview. The reason is that some structure is obtained and at the same time the respondent is given room to reply. The structure is in some sort a warranty that all the areas of the research is covered in the interview. If an interview is performed without fixed answers a method of open questions is used (Patel and Davidson, 1994).

In this research the use of qualitative interviews with semi structured and open questions have been used. This in order to receive as developed answers as possible and not to lead the answers from the respondents. When discussing with the respondents the aim was not to stick to a rigid plan in order to create spaces for the respondents to answer.

2.2.5 Case study

Bell (2000) describes that a case study is above all suitable when the researcher is working on his own. A case study makes it possible to study a delimited area in depth during a limited period. According to Olsson and Sörensen (2004) a case study is to study a case, a person, a group or a social unit. At a case study many different techniques of data collection can be used dependent of the research perspective you are using. A case study is to follow a course of event or to take part in a course of event. The study can be more or less extensive considering time and extent. Through a case study you can get an insight into unexpected conditions that earlier have been unclear or been interpreted differently.

The case study is delimited to the internal logistical flow of Volvo Cars Torslanda. Technicians have been interviewed in order to see what problems there are in the flows that might cause restrictions in the waypoints created in the study. The questions can be found in appendix 3. Questions have also been sent to Specialists in the simulation tool Enterprise Dynamics in order to create the waypoints in a way that match the requirements from a simulation environment. These can be found in appendix 2.

2.2.6 Analysis and interpretation

Through the analysis the researcher tries to identify patterns and relations in the information and based on the data gathered conclusions and solutions are being made (Eriksson & Wiedersheim-Paul, 2001). Backman (1985) describes that during the analysis the information is reviewed to be interpreted in relation to the original problem definition.

In order to collect as much information as possible a current analysis was done after every interview in the case study. The information was also discussed and evaluated with the tutor at Volvo to ensure that the information could be useful for the simulation department. Thoughts and ideas that arouse during the time were documented to be used later in the final analysis, where the empirical material and theoretical material were compared.

It is not during the analysis that the problem is responded to, that is first in the interpreting phase (Backman, 1985). According to Backman (1998) the interpreting phase gives a large scope for creativity and inventiveness. During the interpreting phase there is a question of finding explanations why the studies are different from each other or why they show similarities. It was during the interpreting phase the conclusions were put together.

2.3 Credibility

Under this section of the thesis, reliability and validity and what was performed in order to strengthen the credibility of the study are discussed. According to Patel and Davidson (1994) reliability and validity in some relation to each other, which makes that you can not focus on just one of them. High reliability is no guarantee for high validity, but a low reliability gives a low validity. If a survey is not reliable, how is it determined what it measures?

2.3.1 Reliability

Reliability is according to Bell (2000) a measure that the research will lead to the same results event if it is performed at different occasions with the same circumstances. Control of how reliable a study is, is done at the formulation of the questions and the handling of the instruments at the interviews. According to Patel and Davidson (1994) the instruments reliability depends on how well the developed instrument resist different occurrences to happen at random. For the text material to be as accurate as possible a tape-recorder or video camera can be used during the interview. The information is then written down in a consecutive text. Reliability, which stands for dependability or trustworthiness, show if the results of the analysis are to trust. The reliability is given by how the measurements are performed and how careful they are processed.

The interviews were written as a clean copy after every interview in order to minimize that important material would disappear during the handling of the text material. To increase the reliability of the research a tape-recorder was used as a complement to prevent misunderstandings. This gave the ability to complete the notes afterwards. The material was then sent back to the respondents in order for them to read through the material to prevent misunderstandings. This also gave them the chance to comment and correct the material

afterwards. The material was also reviewed and followed-up through a discussion with my tutor at Volvo Cars Dennis Andersson.

2.3.2 Validity

Even if the research is not meant to measure something in a proper sense Patel and Davidson (1994) mean that it must prove that the researcher knows what is being done. High validity insures that the things that are being measured are the things that are intended to be measured. To ensure that the research is being done in a credible way a high reliability is also required.

To ensure that the research have a high validity the questions were gone through and in some cases re-written with my tutor at Volvo Cars, Dennis Andersson before they where sent to the respondents.

2.3.3 Criticism of the sources

Patel and Davidson (1994) point out that a fair assessment can only be done if the researcher has a critical attitude to the collected information. Another aspect to consider is that the collected information shall be treated and put together in connection with the event in order to minimize a slip of memory.

To preserve a critical attitude a large theoretical material from different authors was studied. This in order to receive a substantial and trustworthy view of the studied area. At the collection of the material it was put together in order to minimize that relevant information would disappear.

2.4 Data collection

Data collection normally consists of survey or a case study. The data used can either consist of secondary or primary data, or a combination of them both.

The data collected during a study can be classified as primary data or secondary data. Primary data is collected by the researcher himself when conducting a study. Secondary data is collected and recorded by others (Andersen, 1998). The main advantage with primary data is that the researcher is in control of the data collection process which ensures that the data is relevant for the study (Lee, Lee & Lee 2000). The main advantage of using secondary data is that it can save time and costs (Lekvall & Wahlbin, 1993). A problem with secondary data though might be that the data might be irrelevant, out of date, the source might not be reliable or the purpose might not collaborate with the research (Lee et al, 2000).

In the study both primary and secondary data have been collected. Primary data have been used in the pre study and the case study. Secondary data have been collected and used in the theory chapter.

2.5 Induction, deduction & abduction

In order to create theories with the aim of providing as accurate knowledge of the reality as possible, three alternative approaches are available to the researcher. These approaches are known as inductive, deductive and abductive (Eriksson & Wiedersheim-Paul, 2001).

2.5.1 Deduction

According to Patel and Davidson (1994) the researcher works deductively if he follows the conclusive way. A deductive type of work is characterized by from common principles and known theories draw conclusions about specific phenomena. From the already existing theory hypotheses are derived which then empirically are tested in the specific case. This way of work is often called hypothesis-deductive. Olsson and Sörensen (2004) mean that with a deductive research you have a theory which proves how the relations between two different relations appears in reality. The authors further say that often at a deductive way of work a quantitative research method is used.

2.5.2 Induction

Patel and Davidson (1994) mean that if the researcher is working inductively he follows the way of discovery. The researcher can then study the object of research without first having to confirm the research in an earlier established theory. Instead through the information, the empiric, formulate a theory. The researcher is supposed to discover something that can be formulated into a theory. The fact that you are now starting from an earlier theory does not mean that you are working totally unbiased. Also the inductively working researcher has his own ideas and conceptions that will influence the theories that are produced. Olsson and Sörensen (2004) mean that if research work is being performed inductively the researcher starts from discoveries from the reality which are brought together to common principles, which then are brought together into a theory. This way of work is common in some qualitative researches.

2.5.3 Abduction

Deductive and inductive ways of working have often been regarded as the only options available. Even if they are the opposite poles of each other. Practically it is hard to use only one of these approaches in a research, unless the researcher's purpose is to introduce the theories to his study by force (Alvesson & Sköldberg, 1994).

Therefore a new approach has been used in research. This approach is known as abductive approach and it is commonly used in case-study based research. It is based on a high level of collaboration between the theoretical framework and the empirical material (Kjorup, 1999). According to Alvesson & Sköldberg (1994) the abductive approach says that the researcher aims to interpret an individual situation by a general pattern which, if correct, explains the situation. The researcher should then verify the interpretation by doing more observations (The method can therefore be seen as a combination of the inductive and the deductive approaches where the researcher during the progress of the study develops the

empirical material and adapts the theoretical framework. An abductive approach also consists of an understanding of the studied object, something that either of the two other approaches has.

The research has been based on the inductive method. Everything has been based on study of the reality, which then has been analyzed in order to form a theory. This way of work also corresponds to the fact that I have been performing a qualitative study.

3 Theoretical framework

The chapter describes the theories used which gives the base for the report, or gives a background description to the area of study. The production system, simulation, the integration between simulation and computer assisted design as well as XML are here described and discussed.

3.1 The production system

“A production system is sometimes said to be more art than science. This is due to the fact that most of the production systems are so complex that it is impossible to calculate a best solution” (Savén, 1988).

A production system is unique. The differences between two systems can be very large. For example between a functional factory to a fully automated line production. Though large differences there are also important similarities to have in mind.

A system can be defined as an amount of delimited and cooperative objects with relations to each other, with the purpose of a certain function or to reach a goal. The delimitations of a system are selectable, at a certain time you select by yourself what are regarded as a system. The things that are left outside are considered the environment. A production system can then be considered as a department, a line, an automated storage or such. Often is the whole production meant by the definition of a system (Savén, 1988).

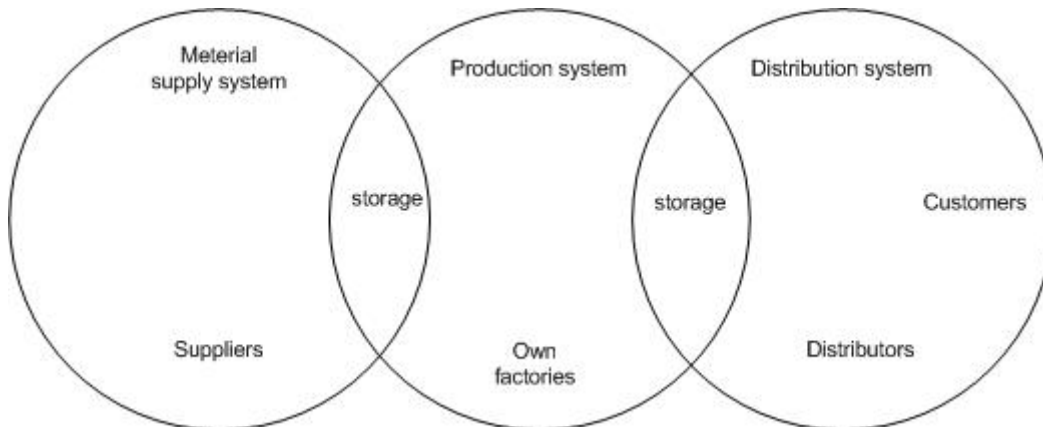


Figure 3: Examples of delimitations (Savén 1988)

The objects in a production system are of two types. First permanent objects (resources) that always are in the system, for example operators, machines, transport equipment, tools, load carriers etc. The second type is temporary objects, which enters and leaves the system. In a production system these are raw material, components, rude components or finished goods. The temporary objects can also be considered as work order or transport assignments which arrive to the system and are executed. The relations between the objects in a production system consist to a large extent of rules. It might be to select the next machine among alternatives or to select the next batch in a queue to a machine (Savén, 1988).

According to Savén a production system consists of the following parts;

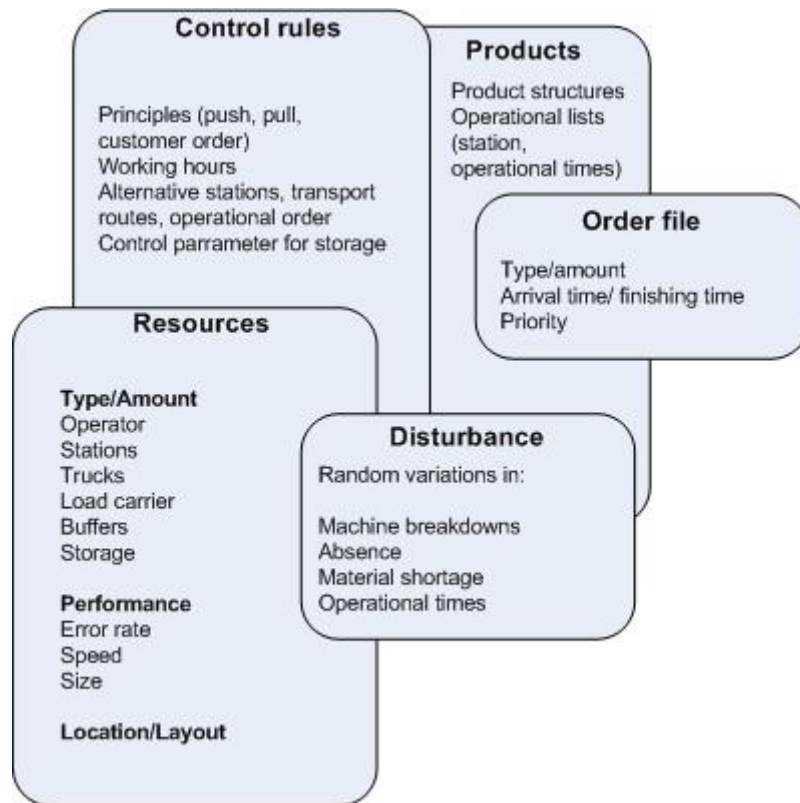


Figure 4: Parts in a production system (Savén 1988)

“The essential in a production system is the cooperation between people, machines, transport equipment, cues and storage. It is important to be able to study the wholeness, how the parts cooperate. Simulation gives that possibility” (Savén, 1988).

3.1.1 Production layout

According to Andersson, Audell, Giertz, & Reitberger (2002) the production layout used depends on the demands of the market and organizational factors. A common trend for all production layouts is that they want to reduce throughput time, high capacity utilization, high flexibility and short internal transport routes. The different types are better in some parameters and worse in others. Therefore it is important to find a good balance which fits the organization.

Olhager (2000) means that the largest impact that the chosen production layout has is on the tie-up of assets, mostly product in process. Since a shorter throughput time gives fewer products in process this have an indirect reduction of stock and warehouse. There are five different base types of production layouts. These are functional factory, flow groups, line, stationary and continuous manufacturing. The most common within manufacturing is functional factory, flow groups and line manufacturing. Therefore these three will be further explained.

Functional factory

According to Andersson et al, (2002), in a functional factory the machines with the same type of functions are put together in sections. The products are sent between the sections which complicates the internal transports. The complex material flow gives long throughput times. Long lead times give high tie-up of assets. In a functional factory many orders are being done at the same time which requires a large administrative planning. The benefits are that the production is flexible considering product and quantity mix. It is easy to introduce new products into the production if the right machines are available. A production layout of a functional factory is good when the demand varies. It is common layout for companies delivering components for larger companies or in organizations which have specialized their manufacturing.

Flow groups

Andersson et al, (2002) argue that flow groups are more product orientated in their layouts compared to a functional factory. The machines are lined up in the order of how the articles are being produced in order to create shorter transportation routes. The throughput times are shorter than in the functional factory. There is also more variety in the work for the operator since they can switch between the different machines within the flow groups. The personnel within the flow groups are responsible for the planning of the products and how the resources are to be utilized. This gives operations of better quality and productivity. Usually the flow group is a planning point which makes the administrative work easier. On the negative side the system is less flexible than a functional factory at a new product introduction. All the machines in the group are not being used at a maximum capacity as the speed is determined by the bottleneck in the group. The alternatives of the utilization are low when only one group is to handle the product. Flow group manufacturing is appropriate when the product variety is low and the volumes are high.

Line manufacturing

According to Andersson et al, (2002), in an assembly line manufacturing the resources, machines and assembly equipment, are placed in the order the operations are to be performed on the product. The transport between the operations can be automated or with the help of conveyor belts etc. The advantage with a line manufacturing is that there is an easy flow of material which leads to short throughput times and therefore also low work in progress. A line manufacturing gives easy assignments where the operators are easy to replace. Drawbacks are that the line is very sensitive for disturbances. If one part of the line breaks the other sections of the line stop as well. A line is also adapted to one specific product which makes it very hard to adapt to a variety in products. A line manufacturing is suitable for very large volumes with small variations.

3.1.2 Production philosophy – Lean & Just-In-Time

Lean Manufacturing and Just-In-Time are two concepts that are closely connected with each other. They are widely used within manufacturing, especially the automotive industry. Therefore the two concepts are here described;

Lean Manufacturing

According to Womack and Jones (2003) processes often suffer from being time consuming and not efficiently value adding. Often low customer satisfaction is also achieved due to the incapacity to deliver the right products at the right time, although the warehouses are full of goods. In simple words it can be said that lean describes a method that eliminates waste in business processes. There are seven types of wastes defined by Womack, Jones & Roos (1990). These are;

- ✓ Overproduction - making more than what is needed, or making it earlier than needed.
- ✓ Waiting - products waiting on the next production step, or people waiting for work to do.
- ✓ Transporting - moving products further than is minimally required.
- ✓ Inappropriate Processing - Having more expensive and high precision equipment than the process needs in order to be sufficient.
- ✓ Unnecessary Inventory - having more inventory than is minimally required.
- ✓ Unnecessary Motion - people moving or walking more than minimally required.
- ✓ Defects - the effort involved in looking for and fixing defects

According to Taylor (2002) lean distribution leads to a change of value within the supply chain, as well as improved processes. The change of value creation brings new value adding processes by merging the earlier separated processes of production and distribution. This leads to postponement of value-adding activities. This makes it easier to meet actual customer demand with the least resources utilized. Tied-up capital can also be reduced with will decrease the overall costs.

Just-In-Time

Tarkowski & Ireståhl (1988) argue that JIT (Just-In-Time) is the name of a way of production, or an attitude to production, that means you are trying to reduce the production costs by eliminating all kinds of wastes. Examples of waste can be capital tied-up in goods not being in process, unnecessary material handling and storage. JIT means to produce each unit exactly when it is needed or demanded. By this storage costs are reduced and the production becomes more flexible and can faster be adapted to customer needs and demands. According to Lumsden (1998) JIT is that deliveries arrive at the right time in the right shape within a time window. This is connected to the manufacturers' smaller buffers of semi-finished goods and shorter long-term planning. JIT does not require fast and short deliveries. A transport can be long and slow, on condition that the planning is reliable. O'Grady (1988, reviewed in Lumsden, 1998) means that JIT is not a strict method, but instead a philosophy that leads to continuous and considerable improvements. The philosophy is based on four principles;

Attack basic problems – Solve basic problems to avoid that the management of the company becomes a “fire brigade”.

Eliminate waste – Get rid of the activities that do not add value to the product.

Strive for simplicity – All method defect in the system need to be simple in order to function. JIT simplifies the flow of material in order to implement a simple operating system.

Design a system that detects problems – In order to solve a problem they must be detected. A JIT-system shall include functions that discover problems.

Lumsden (1998) further argues that many companies working with the JIT-philosophy integrate the suppliers to their production planning. This pushes stock further down the manufacturing chain. This gives stock, handling and capital advantages to the company. Better quality is often also reached since many suppliers become responsible for the quality controls of the product. Better flexibility is reached since the company only orders the products that are needed.

3.1.3 Principles for Material Supply

According to Imants BVBA (2005) two main manufacturing principles for control exist. These are pull and push manufacturing.

Pull manufacturing is a visual replenishment of goods which are only produced if they are needed. Pull manufacturing comes from the American grocery business. The only products that were put on the shelves were those who was consumed by the customers. The visual signals are the most important pull planning method. According to IVF Industrial Research and Development Corporation (2006) a pull flow means that a production in a station, group or section is started by the consumption in the sequencing section. There are many different techniques for this type of ordering, a two-bin system and a kanban system are two examples.

According to Imants BVBA (2005) push manufacturing is manufacturing to forecast. Batch processing and lot sizing are important parts. The manufacturing parts are run at maximum capacity, therefore the material is pushed downstream. The planning methods within push manufacturing include Material Requirements Planning , record points and optimum order quantities.

The direction of the information flow is the main difference between a push and a pull system. In a push system the information flows downstream, the same direction as the product, whereas in a pull system the information flows upstream, from the customer to the supplier.

If a pull manufacturing are used in a correct manner it can give many benefits, such as;

- ✓ increased customer satisfaction
- ✓ reduced total costs
- ✓ reduced inventory levels (raw materials, work in process and finished goods)
- ✓ reduced lead times
- ✓ increased productivity
- ✓ smoother production flow

- ✓ higher production visibility

3.1.4 Ordering system

Within the automotive industry a pull system is the most common. The ordering systems often rely on a kanban or/and a two bin system. Since there often are such large varieties of the components the distribution is often done in sequences, in kits or directly from the supplier. The concepts are here further explained;

Kanban

According to Aronsson, Ekdahl and Oskarsson (2003) a Kanban card is placed on the load carrier. When the kanban card shows during the picking it is sent to the inventory and functions as a order of new material. When refilling is needed the production personnel can signal this through some kind of visual signal, for example through putting on a light or to extend a colored flag. When the truck driver sees the signal he registers the article number, fetch the material from a storage, fill the buffer and restore the visual signal.

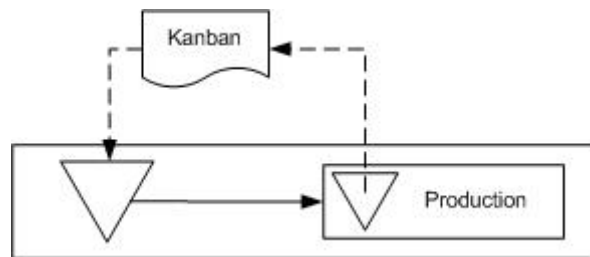


Figure 5: Ordering through a Kanban (Aronsson et. al 2003)

Two-bin system

Aronsson et al, (2003) argues that in a two-bin system the production buffer consists of two bins placed behind each other. When the first one is empty it is placed in a refilling area. The empty bin is taken to the storage, refilled and placed again in the buffer area of the article.

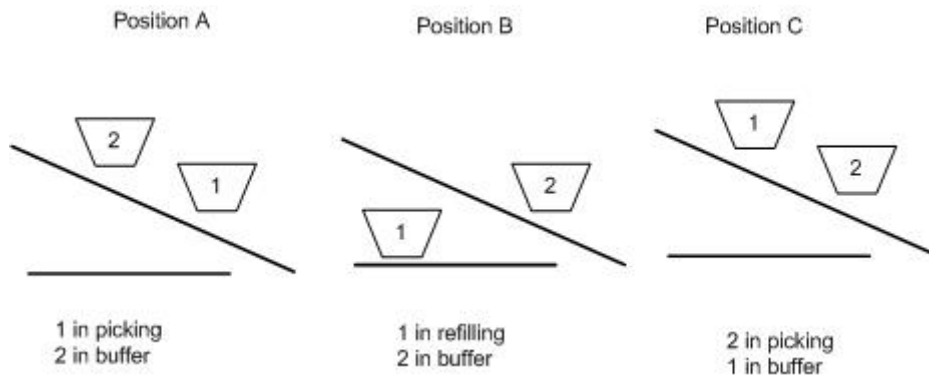


Figure 6: The principle of a Two-bin system (Aronsson et. al 2003)

Aronsson et al, (2003) means that the amount in every bin is adapted so that bin 1 will return before bin 2 gets out of articles. A two-bin system is a combination of a kanban ordering and a visual signal. The bin is actually both a kanban card and a refilling signal to the truck-driver.

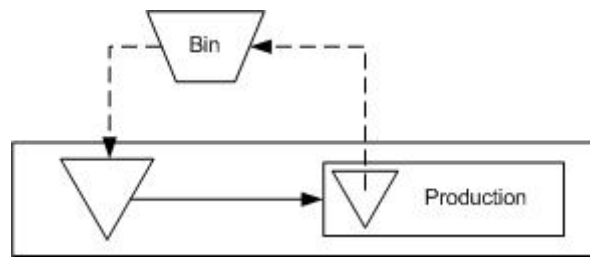


Figure 7: Ordering through a two-bin system (Aronsson et. al 2003)

Sequence deliveries

Aronsson et al, (2003) argues that at a line manufacturing with large varieties it is important to match the right component to the main product. The automotive industry is a clear example of this. Almost every car manufactured is unique due to the choices that the customer can do. Every car is identity marked early in the flow and must be provided with exactly the components that the customer has selected. To every assembly station components for example the next three cars is delivered in the exact order of the cars in the flow.

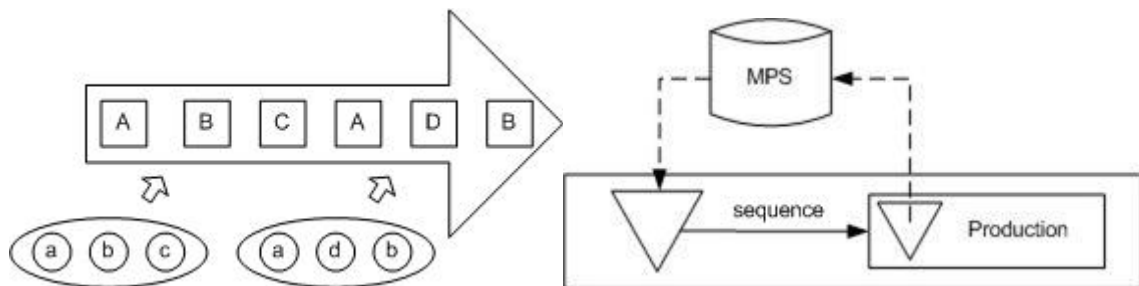


Figure 8: Sequence deliveries (Aronsson et. al 2003)

Kitting

According to Aronsson et al, (2003) kitting is one type of JIT delivery. The exact material required for a production order is put together and delivered as a kit to the production step as close to the demand in time as possible. To function in practice a MPS system is required to break down the production order into lists of the included material.

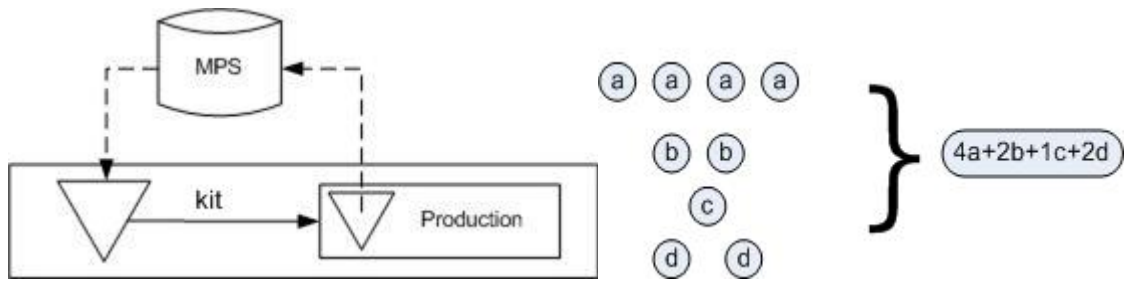


Figure 9: The material kit (Aronsson et. al 2003)

Deliveries to the production direct from the supplier

According to Aronsson et al, (2003) a general trend is that suppliers are getting more and more responsibilities for deliveries directly in to the production. The reason is most often to avoid storing within the company itself. Kanban ordering to the suppliers is quite common, both as a kanban card and as a two-bin system. JIT is also frequent, mostly in the final assembly where there are many customer specific products. Within the automotive industry it is not unusual for the suppliers to be expected to deliver sequence material many times a day to the same step in the manufacturing line

The authors further argues that another principle is to use a external company that consolidates the deliveries from many suppliers. This is a form of Third party logistics (3PL). The company then takes home material from different suppliers, stores it, and delivers it to the customer when it is demanded. This makes possibilities for small, frequent deliveries even from suppliers located far away, which otherwise would have been economically impossible. The same effect can appear in the storage but often does the 3PL- company in many cases perform this work at a lower cost compared to if the companies would do it themselves.

3.1.5 Material Planning System

According to Aronsson et al, (2003) if a company have some kind of buffer before the production a order point can be used for the supply. A prerequisite for an order point system is that the production personnel have access to the company MPS system. Then the order can be sent through this system to the warehouse where the material is picked and delivered. The order can be sent automatically through the system or by the personnel which keep track of the order point and then make the order. In order to make the automatic alternative to work the production workers have to register every withdrawal from the production buffer in the MPS system.

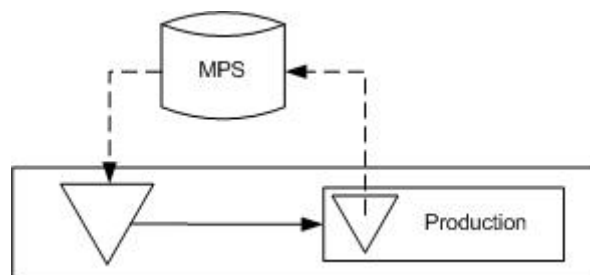


Figure 10: Ordering through a MPS-system (Aronsson et. al 2003)

3.2 Simulation

The thought when simulation first was introduced differs among authors. Dutton (1978) means that it has been used since the 40's and 50's and Savén (1988) that it was first used in the middle of the 60's. At that time simulation was only possible in main frame computers. Nowadays with the power of the computers, simulation can be made on laptop personal computers which make it possible to be used in a much broader extent.

According to Savén (1988) simulation can be defined in many ways;

“Simulation is a experiment on a model”.

“ Simulation is a method for studying how a system that contain random attributes works, without having to deal with the real system. Simulation means to build, run and manipulate a model and the analysis of the results that follows”.

”Computer simulation is to construct and build a mathematical-logical model of a real-time system and to experiment with this model in a computer to determine how the system behaves with changes in the structure or the environment”.

According to Banks, Carson and Nelson (1996) means that simulation is a study of the behavior of a system as it changes over time. The study implies a development of a simulation model based on assumptions concerning the system. The development and validated model aims to facilitate an examination of the system.

The simulation model can be used as an analysis tool for investigation of the behavior of the system in case of various changes. The model can also be used to predict the performance of a new system (Banks et al, 1996). According to Harrell and Tumay (1995) the model does not generate solutions, but do enable system evaluations.

Andersson (2006) argues that it can be said that simulation is a powerful tool if it is used in a correct manner. A simulation project often has the function of building a model over a system or a process. The model often shows a real system, but it might also represent a non existing system. It is a way to see how a system acts under given circumstances. To give reliable results it is very important that the model is built in a correct way. When the model corresponds to the system it is supposed to imitate then changes can be put in the model. Then results of these changes are easy to see.

Some examples where simulation can be applied to make a system more effective and efficient;

- ✓ A factory's utilization of machines, people, storage area and conveyor belts.
- ✓ A bank office where the customers which all need different types of assistance.
- ✓ A shopping centre with parking places, stores and restaurants.

3.2.1 Types of simulation studies

When a simulation model is built there is an early need to decide what type of simulation that is to be used. There are three alternatives;

Static or Dynamic – Time has no significance in static model but in dynamic. To use a static model is very rare.

Time continuous or Discrete – In the time continuous model things can be changed along the whole simulation time, for example with a tank and it's in and out flow. In a discrete simulation model the simulation can skip the points in time when nothing happens. For example the time between the serving of two customers. Continuous simulation is used to model system whose state changes continuously over time regards to time. For instance, it can be used for off-line programming of robots. Discrete Event Simulation (DES) is used for modeling dynamic systems which change state at discrete points in time as results of specific events. These events are decided by random sampling from an input probability distribution. A manufacturing system is most often a Discrete Event system.

Deterministic or Stochastic – Models without a random flow of data are deterministic. An example might be a dental practice with pre-decided time gaps between the patients (Banks, 1998).

3.2.2 Advantages and disadvantages of simulation

According to Banks 1996 the following advantages and disadvantages can occur when simulation is used;

Advantages:

Choose correctly – Simulation lets you test every aspect of a proposed change or addition without committing resources to their acquisition.

Compress and expand time – Simulation lets you speed up or slow down phenomena so that you can investigate them thoroughly.

Understand why – You can reconstruct a scene and take a microscopic examination to answer the why phenomena occurs.

Explore possibilities – You can explore new policies, operating procedures, or methods without the expense and disruption of experimenting with real system.

Diagnostic problems – Simulation allows you to better understand the interactions among variables in a complex system.

Identify constraints – By using simulation for bottle neck analysis you can discover the cause of the delays in work in process, information, materials or other processes.

Develop understanding – Simulation aid in providing understanding about how a system really operates rather than indicating someone's predictions on how the system will work.

Build consensus – Using simulation to present design changes creates an objective opinion. It is easier to accept reliable simulation results which have been modeled, tested, validated,

and visually represented, instead of a person's opinion of the results that will occur from a proposed design.

Prepare for change – Simulation can answer and prepare an organization on all what if questions.

Invest wisely – the cost of a simulation study is about 1% of the implementation costs of a design or a redesign. This makes simulation a wise investment.

Train the team – With simulation a team or individual can learn by their mistakes and learn to operate better.

Specify requirements – Simulation can be used to specify requirements for a system design. By simulating different capabilities for a machine the requirements can be established.

Disadvantages:

Model building requires special training – It is an art learned over time and through experience. If a model is constructed by two different individuals there are unlikely to be exactly the same.

Simulation results may be difficult to interpret – Most simulation outputs are mostly based on random variables. Therefore it might be hard to determine if an observation is a result of system interrelationships or randomness.

Simulation modeling and analysis can be time consuming and expensive - To cut down on resources for modeling and analysis may result in a simulation model and/or analysis that is not sufficient to the task.

Simulation may be used inappropriately – Simulation are sometimes used when a analytical solution is possible or even preferable.

3.2.3 Data collection for a simulation study

According to Savén (1988) the difficulty of collecting the right data is often a reason that speaks against simulation. It is often a time consuming part of a simulation project. The quality of the result is totally dependent of the quality of the input data. What input data that are required are controlled by what results that is required to reach the objectives. The data collections main purpose is to gather information about production planning, operational sequence, times and variations to make the model building possible. The other part is to gather information about the performance of an existing production system as a base for the model test. At a simulation of an existing system a lot of data is often stored in registers in an MPS-system. A lot of data is often available, but the information you need might be;

- ✓ Missing
- ✓ Available, but in the wrong format
- ✓ Available, but out of date

Usually the data gathering requires some detective work. Numerical values as well as managing rules are required. Some people with practical experiences of the production system should be interviewed, and the answers verified. In some cases observations as frequency

studies or direct studies are needed. The input data are often defined as time. These can be setup times, part times, transport times, time between failures, repair times as well as working hours. By simulation of pure transport systems the production plan is often given in a transport matrix and the distance between the fetch/leave positions as a distance matrix.

3.3 Integration between CAD drawings and Simulation

Moorthy and Sly (2001) argue that facility layouts of proposed or existing systems often forms the basis of the of a dynamic simulation. Before the simulation engineer are able to model it the CAD drawing needs to be duplicated in the simulation environment. This work can become very difficult, time consuming and error prone. Especially in sophisticated manufacturing systems like conveyor systems, material handling systems, automotive plants and power train facilities. Therefore an application and interface was needed to prove an automated integration of the layout and simulation technologies for manufacturing.

AutoCAD created by Autodesk is the application which is most commonly used around the world for creation of factory layouts. USG then created FactoryCAD in order to increase the intelligence of the AutoCAD based layouts. These objects allow the factory designer to minimize the effort and duplications when designing and modifying the facility layout. These objects contain everything from containers, fencing, tables, conveyors, racks and cranes. These objects contain data that are relevant for simulations, such as Cycle times, Time to Repair, Time to Fail, Conveyor speed, Conveyor junctions and merges and Aisle paths etc. An extraction routine then exports the object details such as type of object (buffer, conveyor, and machine), object location and other physical parameters together with data that are relevant for simulation into an XML (Extensible Markup Language) file. This eliminates the need in the simulation package to recreate physical and run control information.

The file created has become a common data format named SDX (Simulation Data Exchange). This file can serve as an input to automatic generation of discrete event simulation models. It is used as input information to generate and run a simulation model of an entire layout or on specific windowed areas. The content of the file is header information which specifies drawing source data, simulation model units, run control and shift information. After the header section any object can be defined. Objects with geometrical shapes like part, path network, buffer, machine, conveyor and vehicle can be defined. There are also other objects like runtime, shift and statistics. Depending of the object type a number of related details describe all the object attributes that are needed for the simulation model.

Moorthy and Sly's (2001) ideas of what object types in the layout drawing that contain simulation relevant information can be viewed in appendix 4.

3.3.1 The SDX process

According to Moorthy and Sly (2001) the information can be manually put, imported in or derived from a default file into the SDX file. After the extraction the model is translated into a new simulation model, or used as an append or modification of an existing model.

Recommendations and changes in the data can be made. The information can also be reported back into the FactoryCAD model.

According to the authors the process looks as the following;

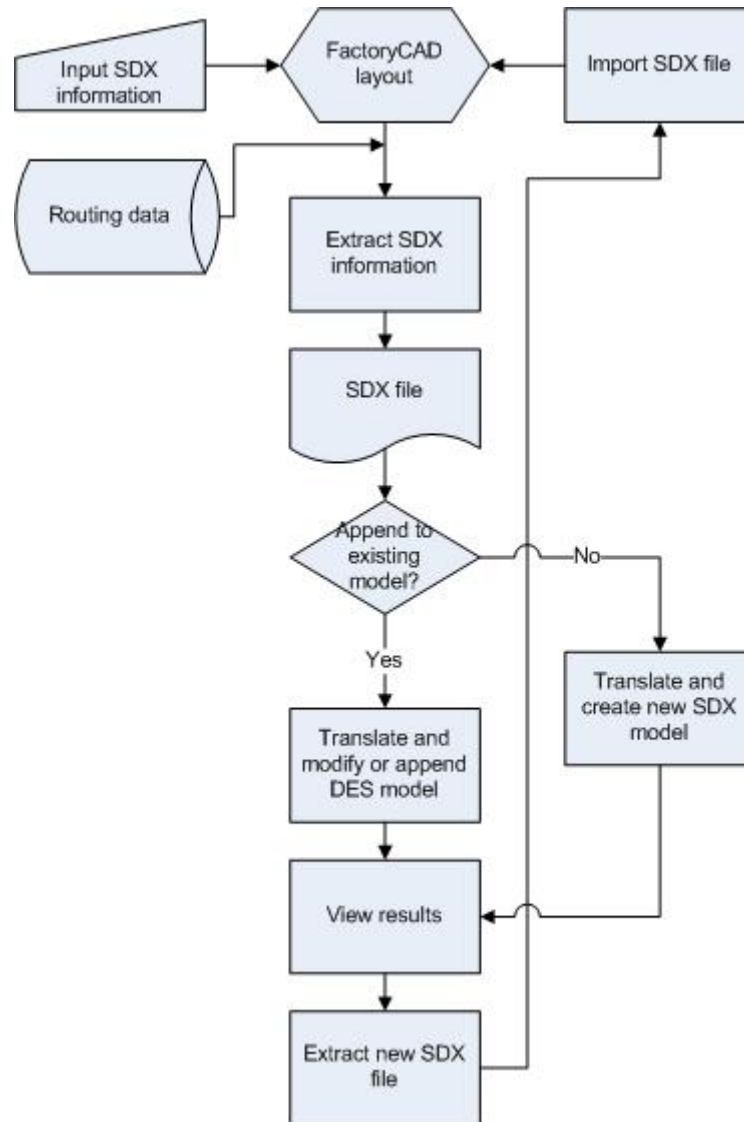


Figure 11: Basic SDX process (Morthy & Sly 2001)

The SDX process corresponds to theories about a process that have been brought up by numbers of authors. According to Willoch (1999) a process has two important distinctive marks. They cross the organizational boundaries internally or externally, and they have customers, there is a receiver of the process results. A Davenport definition of a process is “*a specific ordering of work activities across time and place, with a beginning, an end and clearly identified inputs and outputs*”. According to Rummler and Brache a process is “*a series of steps designed to produce a product or service. Some processes may be contained wholly within a function. However, most processes are cross-functional.*”

Moorthy (1999) argues that in a system where the information is automated and the interactions are digitalized as far as possible, the SDX architecture would look like the following;

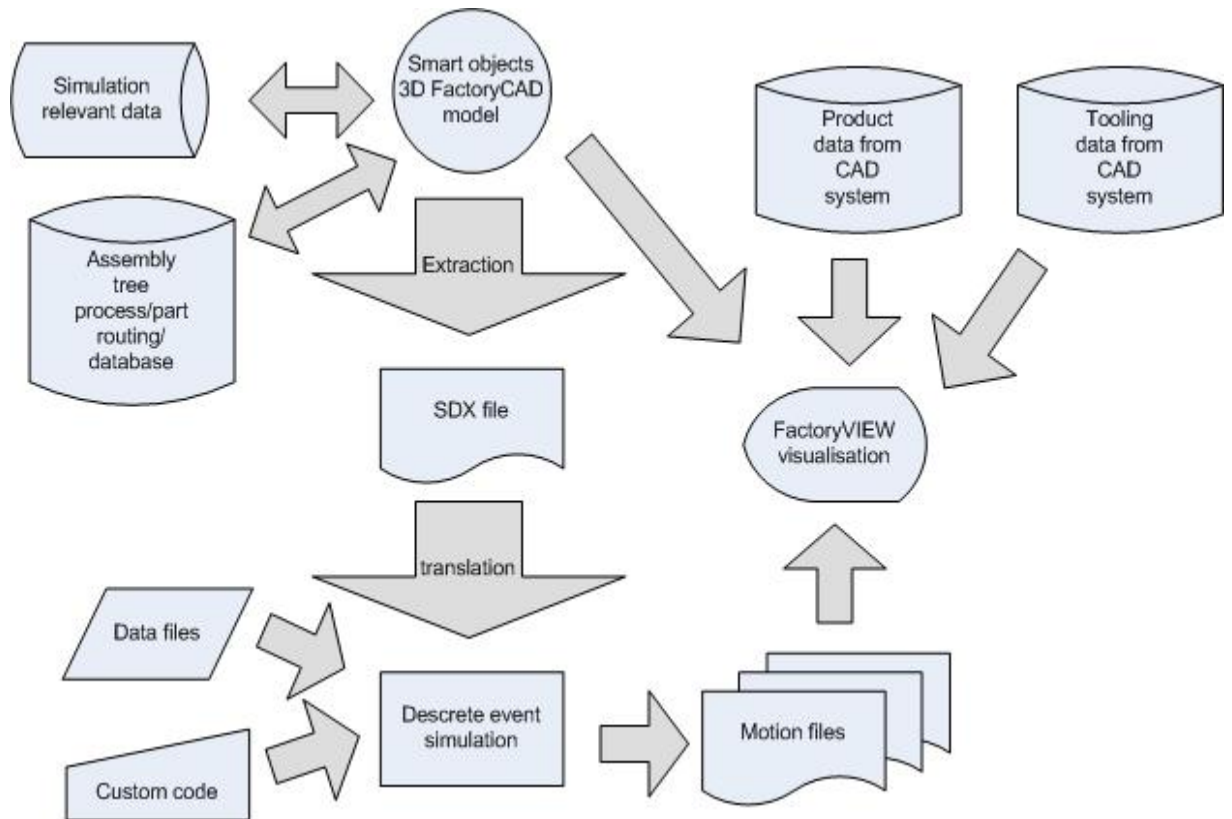


Figure 12: Simulation Data Architecture, (Moorthy 1999)

The architecture explains how the data are imported into the CAD model and then extracted into an SDX file which through a translator are put into the simulation model. The data and results of the simulation, together with other data from the CAD system, can then be put into another tool for easier visualization so that people from different departments, knowledge and background can get an easier understanding of the simulation results.

3.3.2 Extensible Markup Language (XML)

According to the World Wide Web Consortium (1999) XML (Extensible Markup Language) is a set of rules for how textual formats shall be constructed, formed so it will let you structure your own data. XML is not a program language and you do not have to be a programmer to understand it. XML makes it easy for a computer to generate data, read data and to guarantee the data structure to be unambiguous. It is expandable, platform un-dependable which makes it very flexible.

According to Nicholson (1999) XML does not have a fixed tag as HTML, instead the developer can define as many new tags as he wants since there is a strict separation of form and content. XML makes it natural to use information as a series of components, assign

metadata and search within an information set. By combining a component management system with XML organizations can manage collaboration better. They gain access control, versioning, information reuse dynamic document assembly and can distribute it to many types of media easier.

XML makes the data intelligent. It breaks the data into smaller components of information. The more specific the components are, the more reusable and addressable they are. A component can be described as a piece of information that can be used independently in a variety of different information types. Examples might be a paragraph, instruction procedure, part number, order quantity or a warning note. XML also adds value to information through attributes, also called metadata. This adds “information about information” and through that the user can describe it further. The reuse of information can make an organization to save a lot of time instead of gather it manually from different locations. With XML information can be reused across documents.

Companies save money because they can produce technical publications without redundant labor while increasing customer satisfaction by delivering information assembled to support unique configurations.

4 Empirical framework

The chapter starts with a pre-study of the material flows at Volvo Cars Torslanda. This was done to get an understanding of how the material and articles are moved and transported. Since it is a very complex system this has to be done to enable the mapping of the logistical flow which will be the next, and main section in this chapter.

4.1 Pre study of Volvo Cars Torslanda

The pre study is based on the questions in appendix 1. These were asked to personnel at the logistical department at Volvo Cars Torslanda which were selected after discussion with the tutor of the thesis at Volvo Cars. Three persons were selected and interviewed over time to get an understanding of the flows. The persons were Jerry Magnusson, Edin Santa and Fredrik Karlsson, all working in the VCT logistic department. Random workers were also asked during the study.

4.1.1 Description of the material handling in the assembly factory

In the assembly factory there are no manufacturing of components. All the material comes in and is assembled directly on the car or is stored in a pre-station before the assembly. At the moment the S80, V70, V70XC and XC90 are produced on the same line. The assembly line keeps a speed of 42 cars produced per hour. It takes about seven hours for a car to from the beginning of the line to the end where it is finished.

Since it is a line production with a continuous feeding of material all the material for all the models must be available and connected to the line. The result is a very large amount of components that have to be located on a limited space. This requires a highly developed material handling to ensure that the material always is available. Along the line there are rows of available material on both sides. This is called the material address.

The assembling at Torslanda earlier consisted of two separate lines. The layout of the present line is derived from when the two lines were rebuilt into one. At this occasion one of the lines were under full production and could not be affected by the reconstruction. This prevented the new line to become as straight as desired, and the narrow stacker passages between the lines were kept as they were. The narrow passages affects the material handling negatively. On the narrowest point it is just enough room for the stackers to meet if they are equipped with wide loads, even if the material address is only one meter deep. It is very hard to make the material addresses deeper. There is also a limitation on the material address extension along the line. The production is divided into stations with a length of six meters. The materials are to be positioned as close to the assembler as possible. Every step less for the assembler saves a lot of money for production. This is something that the logistic department have to adjust their feeding of the line to. This might not be the ultimate solution with a logistical view, but it is the overall best for the company.

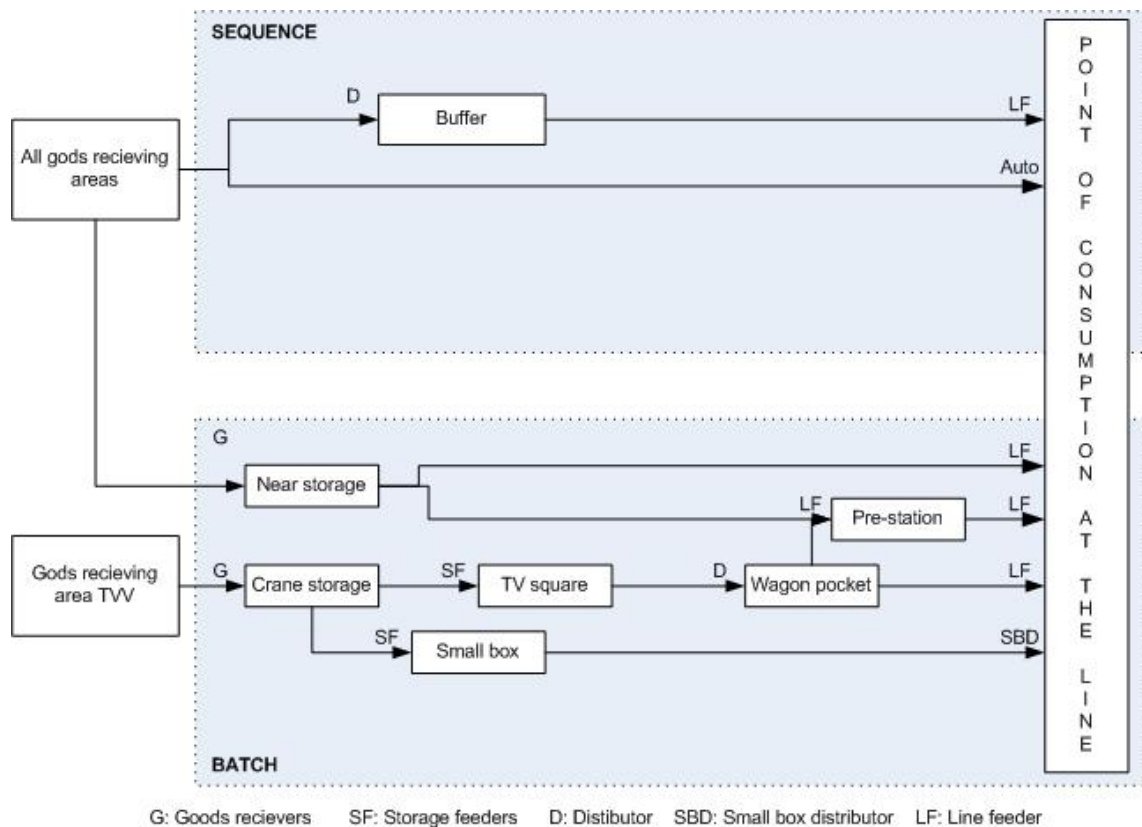


Figure 13: Material flow to the line (Own picture)

4.1.2 Material administrating system (MAS)

In most of the stackers there is a terminal with Volvo Cars material administrating system called MAS with a barcode scanner connected to it. The scanner helps to make the work less time consuming and makes error less occurring in the input of data. It is though possible to call a pallet manually through manual input. MAS is the base for the stacker drivers' work and through the system they receive the information to perform their regular work.

MAS which was put into operation 1989 is created by Volvo IT. It is a system that contains information about all material in the plant, for example the amount of material at the material address, forecasted demand for the near future, the status at the crane inventory as well as ordered material. The system is connected to about twenty other systems, one of them is SAP/R3. About 450 persons have access to the system within logistics, production, Volvo Business Services and the development departments. They do though have different rights to access the system.

4.1.3 Actors of the system

The material handling in TC and TV are divided into three geographically separated departments. Within these departments there are different types of jobs performed, and the workers all drive different types of stackers. Here follows a direction of what types of what assignments there are;

4.1.3.1 Goods receivers

Materials are delivered daily to TC and TV and they are spread over the day. The goods are delivered as batches on pallets or sequential according to fixed plans. The batches go into the automated crane storage or are placed into a near storage in connection to the material front. All material that come on trucks comes into the TX-gate, where the delivery notes are registered. When that is done the MAS (materials handling system) gives a proposal where to unload the cargo, based on the articles main storage. A list of the unloading is also created to assist the unloading. At the unloading area the goods are put on the floor or into wagons. The goods receiver identifies and registers each package. Then the packages are distributed to quality control, storage or operation areas.

The supplier of sequence material does not have to perform any reporting at the arrival. Instead the material is delivered into a buffer or directly into the assembly depending on how far from the goods receiving the point of consumption is located. The material arrives at the goods receiving office that is nearest to the point of consumption. Exceptions are done when due to consolidation or other reasons it becomes more efficient and effective to unload the material at other goods receiving offices.

There are five goods receiving areas for material into TC and TV. The first two letters refer to the building where it is located and the third one refers to the cardinal point of the building where it is located.

The goods receiving offices responsibility area, except unloading and reporting of incoming goods into the computer system, are loading into storage and loading and dispatch of return packing. The return pickings go into a recycling flow and are to be returned to the supplier. The packages are collected and loaded out to Volvo Logistics or through direct return to the supplier. If needed break down, packing and dispatch are done by Volvo Logistics.

At the quality control some articles are taken out at random and put into laboratory and functional testing after the package have been registered at the arrival. Procedures are done following a list and after the control the results are reported. If a defect of the package is discovered it is blocked and the next shipment will also be controlled. The person responsible for the article and the delivery watcher decide together with the supplier if the blocked lot should be adjusted at Volvo.

4.1.3.2 Storage feeders

Storage feeders handle all outgoing material from the crane inventory. This means that they move pallets containing small boxes for storage in a automated small box storage, but also take care of the loading of the wagons in TV that go into TC. The assignments are given through a computer terminal in the stacker. Through that they know from where to where the pallet are to be transported.

4.1.3.3 Distributors/Draggers

Many transports are done on wagons which can store three pallets next to each other. They can each be stacked with up to twelve collars in height. A pallet is equal to one collar. The wagons are driven like a train with four at a time.

The distributors are taking care of the loaded wagons from the TV-square to wagon pockets in TC. These are areas where the wagons are put in near connection to the point of consumption. They can be seen as buffers for the material before it is transported to the material address. They also transport return packing from the wagon pockets to the goods receiving area TVS, where it is left for further transportation to Volvo Transports transshipment terminal in Arendal, three kilometers from Torslanda. The distributors are also responsible for the unloading and transportation of the sequential material from the trucks to the areas of serving. These assignments are driven in scheduled loops.

4.1.3.4 Line feeders

The personnel supplying the line with material are called line feeders. The line feeders are tied to a specific area in TC called inventory. Within the area they call pallet material from the crane storage when a demand arises. The line feeders supply the line with material from wagons, near-storages and pre-stations. They are also responsible for the handling of fixtures and similar material.

The line feeders have a limited area decided in square meters since it is very time consuming to guard and provide the area with material in the right time. They have to have full control over all material, both pallets and sequence material, within their area. To make the material available for the assembler is also part of the line feeders' responsibilities. This might for instance be to remove covers, collars and inner packing on the pallets along the material address. They are responsible for that all material, except the small box material, are available within their area. The line feeders divide the work among themselves since they handle the observation of the material consumption.

4.1.3.5 Resource personnel/ Shortage hunters

The resource personnel's main objective is to solve or prevent situations where shortages in supply occur. Their main assignment is to help out in situations that distinguish themselves from the continuous operations. One of their tasks is to find goods that have gone astray, or to inform the production about the problem and as soon as possible fix it. The resource personnel have the authority to make special calls, a so called Kavrop (package call). This makes a packet to be prioritized in the waiting list at the crane storage as well as special treatment in the rest of the system. It is the task of resource personnel to make it available at the assembler as fast as possible.

4.1.3.6 Small box distributors

The distribution of small boxes is performed with special small box stackers. These are driven in loops where the material is called and delivered. This is a closed system, handled separately from the other flows.

4.1.4 Sequence material

A production program is established 60 days before the production starts. Based on this a preliminary production plan is decided eight days in advance. The final plan is decided four

hours before the assembling of the car has started. This means that the suppliers of the sequence material first at this point will know the exact sequences. Since it takes about seven hours for the car from the start to become fully assembled at the end of the line, the location along the line the material is to be assembled at, will decide how long time the different suppliers have to deliver the material.

The sequence material is packed on special built sequence racks. In these there are clear marks regarding what products that are in line to be assembled. The racks have to be changed often as they have low volume utilization. Use of two bin system are reducing the risk of the suppliers not being able to change them at the right time. The advantage of sequence deliveries is that that you only have to handle the material that are demanded in the near future. Each rack requires also a smaller area at the line compared to if the material were to be divided according to article number at the line instead.

The sequence material arrives at the goods receiving area closest to the point of consumption. After unloading the racks are put on the wagon which later are driven to a wagon pocket in TC, or in a buffer just inside the gates, depending on how far from the goods receiving area the point of consumption is located. At the unload and movement of the sequence material it is very important to place it in the right order to keep the sequences.

The sequence material is not called. Instead the line feeders control when the material needs to be changed and then perform it. The suppliers get aware of the demand of the material when they are notified of the fixed sequences.

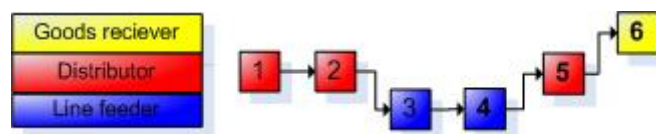


Figure 14: Process mapping of sequence material handling at VCT

Picture explanation;

1. Unloading
2. Transport to buffer
3. Transport to material address
4. Return packing to buffer
5. Return packing to buffer in goods receiving area
6. Loading of return packing to truck

4.1.5 Batch material

Most of the pallet materials arrive at the main goods receiving office in TVV and are stored in the automated crane storage, 4000. Other pallets are those with high frequency goods on. These are placed in near storages which are located in close connection to the point of consumption. Some pallets in the crane storage are also repacked into small boxes.

4.1.5.1 Near storage

Pallet materials with high frequency do not go through the crane storage. Instead they are placed in a near storage in TC in close connection to the line. The materials are loaded on wagons that are moved into delimited spaces. When materials are starting to be consumed at the line a line feeder collects at the near storage and moves it directly to the material address. This material is not called since it is supposed to always be close to the material address. There is also a safety stock level that the amount never is allowed to fall below.

The empty pallets are then placed on the same carriage that brought the material into TC. The handling of the return pallets are then the same for pallets stored in the near storage and in the crane storage.

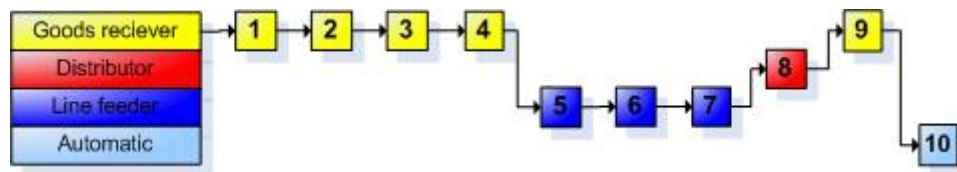


Figure 15: Process map over the handling of pallets stored in near storage in VCT

Picture explanation;

1. Unloading
2. Registration in the system
3. Transport to storage
4. Goods put in storage
5. Goods taken out of storage
6. Transport to material address
7. Return package to buffer
8. Return package to buffer in goods receiving office
9. Loading of return packing to space
10. Loading of return packing to truck

The logistic department at Volvo Cars Torslanda is using a system of coordinates to explain where a near storage is located. The vertical axes shows the east-west direction and the horizontal north-south. The coordinates are given by first stating the placement along the vertical axel, for example 11xx, and then the horizontal, for example XX40. Combined they give an address to a square in the coordinate system which is 1140. The near storages are then named based on the coordinates. In some cases the near storage goes as far as two squares in the coordinate system.

4.1.5.2 Pre-stations

Much of the material placed in sequential racks at the line arrives to VCT on pallets. The material is repacked into the sequential racks in pre-stations placed in TC. The main part of the pallets at the pre-stations comes from the crane storage. Pallets with pre-station material stored in the crane storage goes the same way as other pallets, from the crane storage to wagon pockets in TC where a line feeder moves them to the pre-stations material address. The internal sequencing is done to reduce the amount of material at the material address. These pre-stations do though take up a lot of space which contribute to the shortage of space which is a problem in the assembly factory.

4.1.5.3 Small boxes

All materials that are to be handled in small boxes arrive to VTC on pallets. The small boxes come in two different sizes. They can either be stacked two or four next to each other on a pallet, and the height is about one collar.

The small box storage is automated and located next to the crane storage. The amount of small boxes that can be stored here is about 14000. When this storage have to be refilled an automated signal is sent to the crane storage where the right pallet is collected. The pallet can then go in two ways. Most often the suppliers already have packed the material into small boxes. Then the package is divided into more small boxes in the computer system after an automatic down stacking and storing of the pallets. In the other case the material must be repacked from pallets to small boxes. This is mostly applied to attach elements. A pallet comes directly from the crane storage and at the same time information appears on a computer screen at the repacking station, showing how many items to put in each tray. They small boxes are then stored automatically in the small box storage.

The material addresses of the small boxes are built according to a two-bin system. The trays are placed on a leaning levels where the assembler always picks from the tray in front. When the material in a tray has been consumed the assembler places the empty tray on top of the rack as a signal that it needs to be changed.

The trays are distributed in loops by the small box distributors on specially made wagons. On these wagons fourteen small or seven large trays can be put at the same time. The wagons are equipped with a table with rolls on. These can be adjusted horizontally, so no lifts have to be performed to move the small boxes. They can instead be pushed over to the material address. The distributors belong to their specific area in TC and at the loops materials that are needed at the line are called through the scanning of the barcode on the empty trays. The information is then sent directly from the stacker to the small box storage where a wagon is prepared so it will be ready when the stacker comes back. When the wagons are collected they are marked with new barcodes with a new specific assemble address. It is these barcodes that are scanned when the trays are empty.

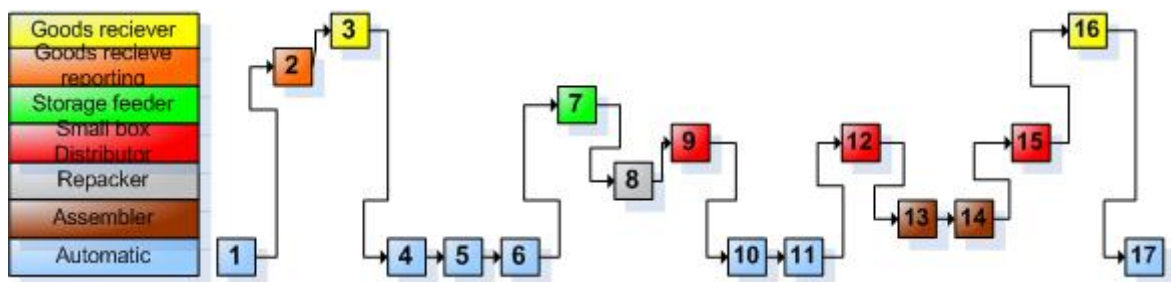


Figure 16: Process map of small box handling in VCT

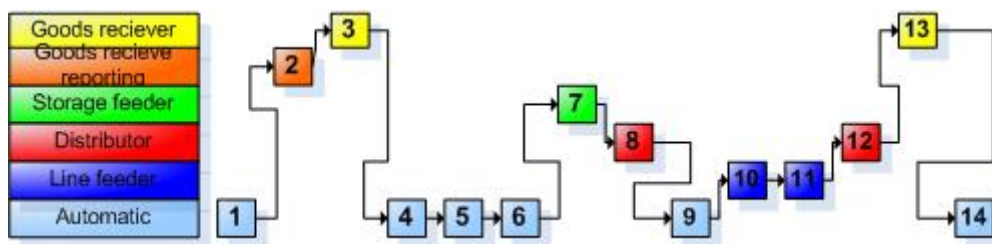
Picture explanation;

1. Unloading
2. Registration in the system
3. Transport to storage
4. Goods put in storage
5. Call to storage
6. Goods taken out of storage
7. Transport to small box storage

8. Repacking of small boxes
9. Goods put in small box storage
10. Call to small box storage
11. Goods taken out of small box storage
12. Transport to wagon
13. Transport to material address
14. Move to picking position
15. Return packing to buffer
16. Return packing to buffer in goods receiving area
17. Loading of return packing to space
18. Loading of return packing to truck

4.1.5.4 Crane storage

A large amount of the total articles are stored in the automated crane storage which is located in TV. When the material address is getting out of a certain article number an automated call is done, and the crane storage takes out the correct pallet. The material ordering is described in the next section. The materials are placed on special wagons that are lined up on a place called the TV-square. The storage feeders get information on the terminal in their stacker from where and to what wagon the pallets are to be put. The crane storage can store 7890 pallets of the type L-pallets and larger packing. The capacity of the in and out storing is 130 pallets/hour. The filling ration is about 60% for L-pallets and 70% for larger packages.



Picture explanation;

1. Unloading
2. Registration in the system
3. Goods transported to storage
4. Goods put in storage
5. Call to storage
6. Goods taken out of storage
7. Transport to wagon
8. Transport to buffer
9. Call to buffer
10. Transport to material address
11. Return packing to buffer
12. Return packing to buffer in goods receiving area
13. Loading of return packing to space
14. Loading of return packing to truck

4.1.5.5 TV square

In The TV-square there are 18 trains of four wagons lined up. Each wagon has a certain destination within the factory. They can all store three L-pallets next to each other with a height of twelve collars, where a pallet represents one collar. The distributors take care of the movement of the wagons from the TV-square to the wagon pockets in TC. The wagon trains are pulled by counter balance trucks on scheduled loops. This is done every second hour. The wagons are named A, B, C, and D. When the storage feeder collects a pallet from the crane storage his terminal shows through MAS where to put the pallet. For example 2. AB means that the pallet is to be put on the wagon train 2 on wagon A or B. The wagons are open on the left side, looking in the forward direction. It is an important detail since they must always be driven and placed so that the open sides are facing the aisle so that the material can be picked and placed in a correct manner.

4.1.5.6 Material ordering

Every car body has a unique serial number on the line. Along the line there are cameras placed that read this number as the body passes. Each article has a specific number along the line, the material address. This is tied to a camera. A material address can be for example, 1017N026. The second number here is a zero. This means that the material is consumed at the line. If it is another number, it is consumed at a pre station. The address above gives the consumption point of line 1.7, north side 26 meters in. The material address is also always connected to a Call address which is one of the buffers where the line feeders pick up the material.

The need of articles is counted from the serial number that latest passed and 140 numbers upstream. This represent the demand for the next three hours. The demand of a certain article is calculated with help of these 140 numbers reservation of the article. The demand calculation is performed every fourth minute. When the demand exceed the current balance at hand plus the earlier called amount, an automated call is sent to the crane storage. The package is then distributed to the call address where it is picked up by the line feeder.

For material in the near storage no automated call is done. They must instead be manually gathered by the line feeder. Through the terminal the line feeders are monitoring the near storage articles amount and at need pick up new ones. The article number with the shortest time to replenishment appears on top of the screen. The pre stations order materials in the same way as the line, automated from the crane storage and manually monitoring through terminals of near storage material.

When the line feeder delivers a package at the point of consumption, an update of the balance at that point is done. This is called a calibration. The line feeder scans the bar code on the flag of the material. Then a sign of the goods is created. After that the balance of the article at the point of consumption is done. This is equal to the amount of the calibrated package plus the amount still at place. The articles that are still in the old package are then moved to the new one.

- ✓ Handle the fact that in some corners the traffic is unable to meet
- ✓ Handle restrictions
- ✓ Handle disturbances

5.2 Objects in the mapping

The mapping of the flow has three key stones. These are waypoint, way and route.

Waypoint - Is defined as a description in the layout of a certain point. The attributes of the waypoint will give the attributes of the isles in the factory. A waypoint is carrying the following attributes;

- ✓ Width
- ✓ Height
- ✓ Max speed allowed
- ✓ Visibility
- ✓ One-way or two way traffic
- ✓ Overtaking allowed YES/NO
- ✓ X,Y,Z position and location in the layout
- ✓ LineRef (Reference point to the line)
- ✓ Traffic light/Traffic rule
- ✓ Reserved area

Three alternatives of how the waypoint should be defined have been worked out;

Single point waypoint - The waypoint is seen as a single point. This means that in an intersection going in four directions four points are required. In a aisle with two-way traffic two point will be lined up describing the same area but with traffic in opposite directions. The waypoints can be named so that this indicates the position of the waypoint with a relation to the waypoint in the same area. To explain this in the picture below this gives for example that WP2W is placed west of WP2E, and vice versa. Where the attributes of the road changes, for example become one-way as in WP1, a waypoint is placed.

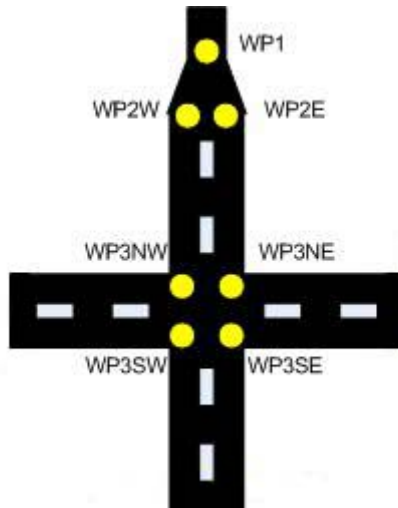


Figure 18: Own picture of waypoint alternative 1

This alternative gives;

- Many waypoints in the layout.
- + An easy way to understand what routes are used.
- + No collisions will occur.

Long waypoint – This alternative sees the waypoint as a long object where two waypoints are placed with traffic going in opposite directions.

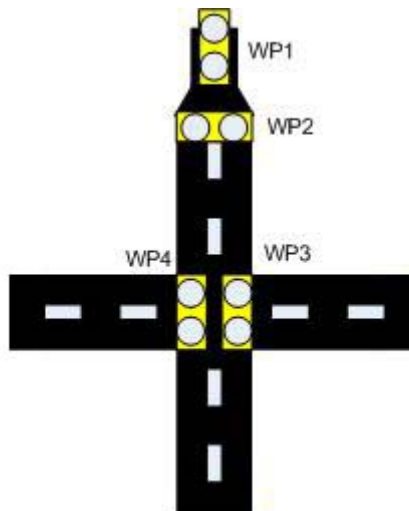


Figure 19: Own picture of waypoint alternative 2

This alternative gives;

- + Easier placement of the waypoints in the layout due to less amount of points used.

- Not easy to solve the problem when traffic goes from both directions into one-way traffic.
- A problem how to allow traffic in two directions in the simulation tool in order to prevent collisions.

Cross waypoint - With this alternative the waypoint is seen as a cross in the four-way intersection with one waypoint containing four points. This gives a better description of the aisle area.

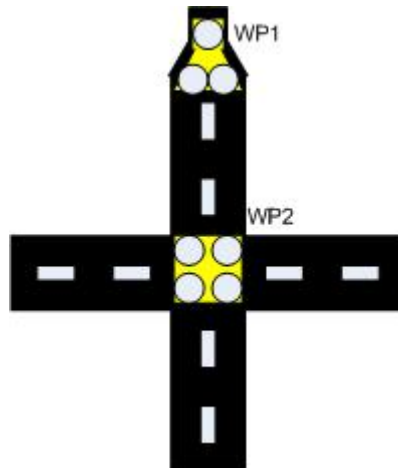


Figure 20: Own picture of waypoint alternative 2

This alternative gives;

- + The least amount of waypoints used
- + Describes the area within the waypoint
- A problem with translation into simulation tool with traffic in both directions

After discussion and request from the retailers of Enterprise Dynamics in Scandinavia, since the material gathered will be used in the simulation tool Enterprise Dynamics, the use of the waypoint as a single object was decided. The attribute Reserved area in the waypoint was also created. With this attribute it means that the resource utilizing the waypoint can reserve and area ahead. By doing so it will solve the problem that some corners are too narrow for two vehicles to meet when they are going in opposite directions.

Way - Is defined as a path consisting of one or many waypoints with limitations or attributes given by each individual waypoint that the way is utilizing. The distance between the waypoints will be given automatically when placed in the layout. Then the waypoints receive their X, Y and Z value. The start and ending point can for example be from a main storage or near storage to the material address at the line, or from the line back to the Main Storage.

Route - Is defined as one or many starting and ending points, consisting of one or many ways. The small box loop can be seen as one route, the wagons filled at TC-square, distributed and then returned to the buffer can be seen as other routes.

5.3 Trucks used in the system

Within the system three different trucks are used. These are counter balance trucks, pull trucks and small box trucks.

Counter balance truck - The counter balance truck is used to drag the wagons. The length of the wagon train is 15m with a maximum Speed of 11 km/h.

Pull truck - The pull truck pull materials in and out as well as line feeding. It has a length of 2,5 meter and a maximum speed of 9 km/h.

Small box truck - Is used in the loops of the small boxes.

5.4 Restrictions

The attributes or restrictions of the waypoints in a way are compared to the resources utilizing the way. If a waypoint has an attribute saying that the maximum speed is 5 km/h over this waypoint, a counter balance truck with a maximum speed of 11 km/h must adapt to the restriction of the waypoint and only move in 5 km/h. If the size of a unit is wider than the waypoint allows it to be, the unit must be transported over another waypoint creating ways and routes automatically due to the restrictions. The attributes of the waypoint are always superior, with exception to traffic rules, and the equipment utilizing it must adapt to these restrictions. This will give that if a Counter balance truck with the maximum speed of 11 km/h wants to overtake a pull truck with a maximum speed of 9 km/h, it can only be done if the waypoint first tells that the maximum speed allowed is greater than the speed of the pull truck and that overtaking is ok.

5.5 Disturbances of the flows

This section is based on the questions in appendix 3 asked to personnel in the logistics department at Volvo Cars Torslanda.

When distributing goods and material within the Torslanda factory there is a length of time that every job is supposed to take. On every job there is a time adding that acts as a buffer if random disturbances occur. This is called distribution time and it is an adding of 20% of the original time, 15% for disturbances that can occur and 5% for personal matters like going to the bathroom etc. These are all fixed and the same for every movement in the factory.

Disturbances that might occur in the flows are;

- ✓ Some corners are too narrow for two wagon trains to meet so one of them has to wait until the other one has passed.
- ✓ For the line-feeders people walking or using a bike is a problem.

- ✓ Drop of a pallet is a problem since the aisle gets blocked as well as the material might break and can not be used as planned causing disturbance of the flow to the line.
- ✓ Wrong balance in the pallet causing extra work since the shortage hunters must level up the wrong balance.
- ✓ Wrongly flagged material, the content is not what the label says, causing another shortage hunter assignment.
- ✓ Wrongly packed material
- ✓ Rules of traffic: right-hand traffic and trucks in reverse have always priority, traffic lights with green light frequency.
- ✓ A truck brakes down
- ✓ A port in a lock breaks down
- ✓ A camera at the line for auto call breaks down
- ✓ At the unloading of some sequence material that occurs at the lunch break there might be a lot of people walking in the aisles. This is a problem especially in the E6 aisle. Otherwise lunchtime is not a problem at VCT since all personnel dine at the same time.

5.6 Model building in Microsoft Visio

Microsoft Visio has been used for the creation of the objects in the mapping. This since the files created in Vision can be saved as XML files. The “data about the data” can then be extracted through the use of a script file that collects the data wanted as input data in the simulation environment. This is done since all data that are saved in the XML file are not relevant for the simulation of the logistical flow. The script simply collect the wanted information and makes it easy to use as simulation input data. In short you can say that the data is cleaned up and ready to be used.

The following picture shows the baseline of the mapping in Visio;

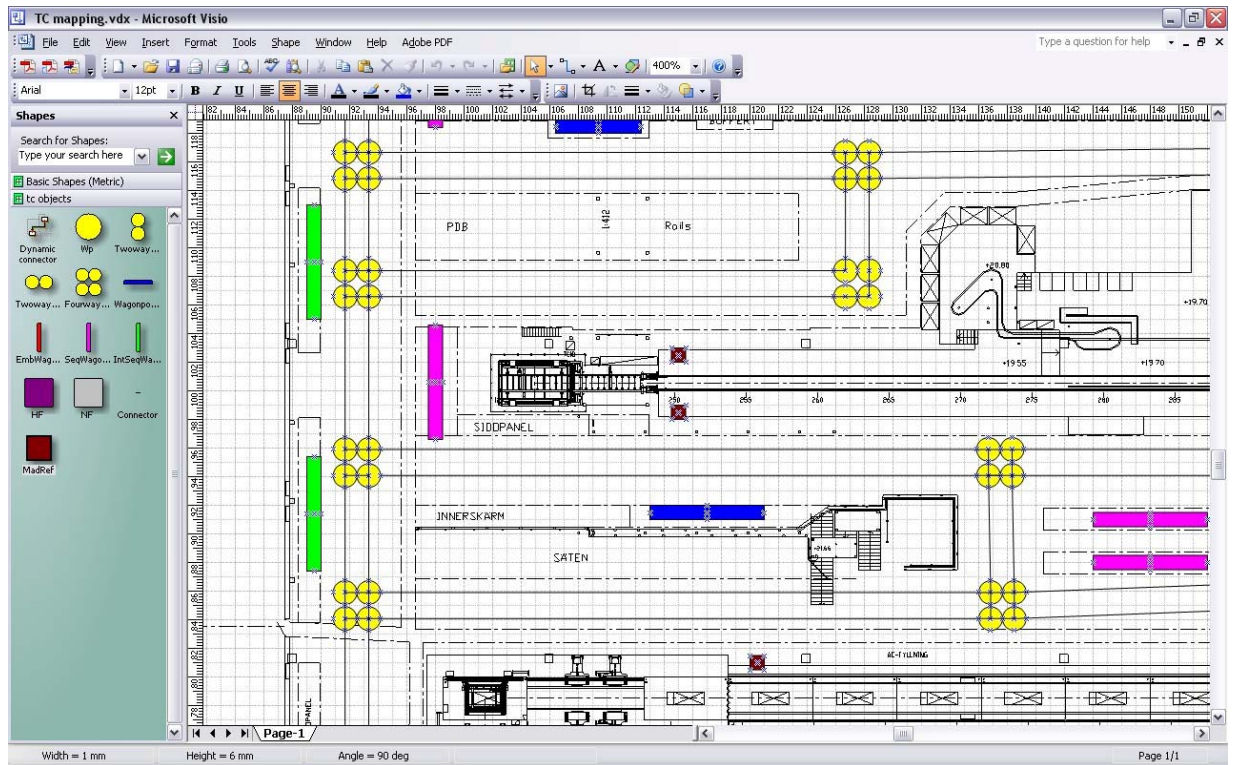


Figure 21: The Visio workspace of VCC Assembly Factory (Own creation)

5.6.1 Objects in Visio

The objects used in the mapping have been saved in Visio as a stencil, which makes them easy to use with the drag-and-drop technique in the layout. The attributes are given from the start when they are placed in the layout, but the attribute data must be filled in. The scale in the layout is 1:1000 which makes that 1 millimeter in the Vision layout represent 1 meter in reality.

The yellow circles shown in the picture above are the waypoints in the mapping. They are connected to each other through a connector object. Every connector represents all the possibilities for goods to be moved within the assembly plant.

The rectangles placed in the layout represent the places where material are placed or taken care of within the assembly factory. The blue represent the wagon pockets, the green represent the wagon pockets of the internal sequences and the pink represent the wagon pockets of the sequential material from the third party suppliers.

The wagon pocket have the following attributes;

- ✓ X,Y,Z position and location in the layout
- ✓ InRef
- ✓ UtRef
- ✓ VagnA

- ✓ VagnB
- ✓ VagnC
- ✓ VagnD

The InRef and The UtRef are the references to the nearest waypoint considering how the wagons are driven and placed in the wagon pocket, in order to make the open side of the wagon facing the aisle. The VagnA, VagnB, VagnC and VagnD attributes represent the wagons that are placed at the wagon pocket, and the internally used term “lokal” that they belong to. Through that all the material using the wagon pocket and the material address at the line can be collected through the MAS system for the simulation studies.

The smaller brown boxes at the line in the layout represent the first material address at the line for that section of the line. These are called MadRef and contain the following attributes;

- ✓ MAD
- ✓ WpRef
- ✓ WpAvst
- ✓ MadAvst

The MAD is the material address in the system and also the name of the object. This to follow the standards used at Volvo, but also to enable to locate the object easily if it should be changed in any way. The WpRef is the waypoint that is located closest to the MadRef and used for the distribution of the material. The WpAvst is how far the MadRef is located from the waypoint. The MadAvst is how far the MadRef, considering the width, is located from the same waypoint.

The references attributes used in both the wagon pockets and the MadRef objects have been created in order to make sure that the mapping cover the main routes and not every little route that is possible. If that would have been done instead it would lead to unlimited amounts of possible routes and connections. By using reference attributes instead it is easier to keep it simple and more visible.

5.6.2 XML extraction

As stated earlier the XML file created in Visio must be cleaned up in order to use the data as input for a simulation study. This is done through a Visual Basic script that scans the file until it finds the data with the information that it is looking for.

A small part of the XML file and the information that the Script is to locate looks like the following;

```
<Shape ID='1' NameU='Wp28NW' Type='Shape' Master='2'
<XForm><PinX>2.362204724409449</PinX><PinY>9.05511811023622</PinY>
<Width>1.574803149606299</Width><Height>1.574803149606299</Height>
```

The Shape ID is the internal id for a shape in Visio. The NameU is the name of the object in Visio. This one is waypoint number 28 located in a four way crossing in the north-western corner. Type is the type of object created in Visio. This is shape master 2 which represent a waypoint. PinX and PinY is the location of the waypoint in the Vision model.

Another example of the XML file is this, containing the attributes of a waypoint;

```
<Prop ID='6'><Value Unit='BOOL'>0</Value><Prompt F='No Formula'></Label>Overtaking</Label><Format F='No Formula'></SortKey F='No Formula'></Type>3</Type><Invisible F='No Formula'>0</Invisible><Verify F='No Formula'>0</Verify><LangID>1053</LangID><Calendar F='No Formula'>0</Calendar></Prop>
```

The Prop ID is the unique id in Visio. The Value Unit shows that the data is Boolean (Yes or No) which also is the data type of the attribute. This attribute is about if overtaking is allowed in this waypoint or not. Since the value is zero this means that overtaking is not allowed in this waypoint.

5.7 Test of data

In order to validate the data for the simulation a simple static test was done. This in order to see how much time it costs to deliver to a material address using two different routes with different restrictions and attributes. The three different trucks used in the system were used, in order to see if the data collected can be used for this purpose. The rule that if a truck speed is 11 km/h it is only allowed if the waypoint allows it was also tested. The data and calculations used looks like the following;

Waypoint	X-coordinate	Y-coordinate	Meter	Aisle width	Speed	m/sec
WP1	37	26		5	11	3
WP2	36	27		5	11	3
WP3	28	27		5	11	3
WP4	26	26		5	11	3
WP5	26	20		5	11	3
WP6	26	8		5	11	3
WP7	26	5		5	11	3
WP8	17	5		3,2	10	2,78
WP9	14	5		3,2	10	2,78
WP10	11	5		3,2	10	2,78
WP11	8	5		3,2	10	2,78
WP12	8	12		3,2	10	2,78
WP13	17	26		5	3	0,83
WP14	21	26		5	3	0,83
WP15	21	21		5	11	3
WP16	16	3		2	3	0,83
WP17	14	3		2	3	0,83
1PL1N-10	17	21	-10	3,2	3	0,83
1PL1S-10	14	21	-10	3,2	10	2,78

1PL1N120	17	8	120	3,2	10	2,78
1PL1S120	14	8	120	3,2	10	2,78
1PL2N-10	11	21	-10	3,2	10	2,78
1PL2S-10	8	21	-10	3,2	10	2,78
1PL2N120	11	8	120	3,2	10	2,78
1PL2S120	8	8	120	3,2	10	2,78

Way1 To MAD 1PL2N30			distance	m/s	wp->wp time		counter bal- ance	
WP1	37	26			small box	pull truck		
wp2	36	27	1,4142136	30	3	0,565685425	0,565685425	0,471404521
wp3	28	27	8		3	3,2	3,2	2,666666667
wp4	26	26	2,236068		3	0,894427191	0,894427191	0,745355992
wp14	21	26	5	0,83		6,024096386	6,024096386	6,024096386
wp13	17	26	4	0,83		4,819277108	4,819277108	4,819277108
1pl1N-10	17	21	5	0,83		6,024096386	6,024096386	6,024096386
1pl1S-10	14	21	3	2,78		1,2	1,2	1,079136691
1pl2n-10	11	21	3	-10	2,78	1,2	1,2	1,079136691
			31,650282					
			40			16	16	14,38848921
						39,9275825	39,9275825	37,29765965

Way 2 To MAD1PL2N30			distance	m/s	wp->wp time		counter bal- ance	
WP1	37	26		30		small box	pull truck	
wp2	36	27	1,4142136		3	0,565685425	0,565685425	0,471404521
wp3	28	27	8		3	3,2	3,2	2,666666667
wp4	26	26	2,236068		3	0,894427191	0,894427191	0,745355992
wp5	26	20	6		3	2,4	2,4	2
wp6	26	8	12		3	4,8	4,8	4
wp7	26	5	3		3	1,2	1,2	1
wp8	17	5	9	2,78		3,6	3,6	3,237410072
wp9	14	5	3	2,78		1,2	1,2	1,079136691
wp10	11	5	3	2,78		1,2	1,2	1,079136691
1pl2n120	11	8	3	120	2,78	1,2	1,2	1,079136691
			50,650282					
			90			36	36	32,37410072
						56,26011262	56,26011262	49,73234804

The results show that for this short way there are different costs in time if you are using one route or another. In this example the resource utilization of the unit load are compared to the attributes of the road. Three types of trucks are utilizing two different routes, leading to the same material address. The counter balance truck is the best selection in this example since it has a higher top speed than the other which it can use where it is allowed. It does not have the same restrictions to consider as the pull truck, which is a much longer vehicle. Since the test is correct the data and attributes used in the mapping are valid.

Due to secrecy the main part of the mapping can not be included in the thesis. The XML extraction and the validity of data section above shall be seen as examples of the large time spent creating the object model and how the data can be used.

6 Analysis

In this chapter an analysis is performed where theory is compared with the empiric, that have been gathered through personal communication and studies of the reality, as well as the creation of the object model. The chapter is divided into two sections, one about material handling, and the other about mapping of flows with a discussion about improvements and validation of data gathered.

6.1 Analysis of the pre study – thesis purpose part I

According to Savén (1998) a system can be defined as an amount of delimited and cooperative objects with relations to each other, with the purpose of a certain function or to reach a goal. A production system can then be considered as a department, a line, a automated storage or such. Often is the whole production meant by the definition of a system. At Volvo the Assemble factory can be seen as a system, with the line as one part and the functions that feed the line as another.

Savén means that the objects in a production system are of two types. First permanent objects (resources) that always are in the system, for example operators, machines, transport equipment, tools, load carriers etc. The second type is temporary objects, which enter and leave the system. In a production system these are raw material, components, rude components or finished goods. For Volvos logistical part of the assembly factory this would mean that the permanent objects are all the actors in the system and all the equipment used to move the materials. The materials that are moved can be seen as temporary objects since they enter factory at the goods receiving area and leave the system at the point of consumption at the line.

According to Andersson, Audell, Giertz, & Reitberger (2002) the production layout used depends on the demands of the market and organizational factors. A common trend for all production layouts is that they want to reduce throughput time, high capacity utilization, high flexibility and short internal transport routes.

In an assembly line manufacturing the resources, machines and assembly equipment, are placed in the order the operations are to be performed on the product. The advantage with a line manufacturing is that there is an easy flow of material which leads to short throughput times and therefore also low work in progress. Drawbacks are that the line is very sensitive to disturbances. (Andersson et al, 2002). According to Edin Santa, Fredrik Karlsson and Jerry Magnusson the line production at Volvo Cars Torslanda, with its continuous feeding of material, all the material for all the models must be available and connected to the line. The result is a very large amount of components that have to be located on a limited space. This requires a highly developed material handling to ensure that the material always is available. The assembling at Torslanda earlier consisted of two separate lines. The layout of the present line derives from when the two lines where rebuilt into one. At this occasion one of the lines were in full production and could not be affected by the reconstruction. This prevented the new line to become as straight as wanted, and the narrow stacker passages were kept as they were. The narrow passages affect the material handling negatively. The seven wastes of the Lean Manufacturing defined by Womack, Jones & Roos (1990) are also something that are important for Volvo for their continuous improvements.

Lumsden (1998)'s thoughts that Just-In-Time is that deliveries arrives at the right time in the right shape within a time window can be supported at Volvo. Just-In-Time is used for the most of the sequence materials within the assembly factory. His thought that a transport can be long and slow, on condition that the planning is reliable can also be supported. This since some of the material comes from suppliers located far away from the assembly factory. Four hours before a new car enters the production at the line, the suppliers get a signal when their material is needed. Since it takes seven hours for a car to be finished at the end of the line, the suppliers all get different exact times when their material is needed. This can be done by supporting Lumsdens (1998) thoughts of integrating the supplier into the production planning. This gives better quality for Volvo since many suppliers become responsible for the quality controls of the product. Better flexibility is also reached since the company only orders the products that are needed. The sequence deliveries from the suppliers follow Aronsson, Ekdahl and Oskarsson (2003)'s ideas of sequence deliveries and kits. The whole sequence material flow are based on the principles of putting the material in the delivery in the exact order that it is to be assembled at the line, or to have the exact material for a production order put together in a kit.

Volvo is clearly a pull manufacturing system looking at the ideas of the concept brought up by Imants BVBA (2005). Pull manufacturing started in the American grocery business. The only products that were put on the shelves where those who was consumed by the customers. In the same way Volvo does not produce a car unless it has been ordered by a customer. This makes it a pull system where the main idea is that goods are only produced when they are needed.

Aronsson, Ekdahl and Oskarsson (2003)'s ideas of Kanban and two-bin systems are also used at Volvo. The two concepts are used jointly in the small-box loop where the empty two bin becomes a Kanban signal that refilling is needed.

According to Aronsson et al, (2003) if a company have some kind of buffer before the production a order point can be used for the supply. A prerequisite for an order point system is that the production personnel have access to the company MPS system. This is confirmed at Volvo. An order can be sent through this system to the warehouse where the material is picked and delivered. The Volvo Material Administrating System (MAS) is the base for the stacker drivers' work and through the system they receive the information to perform their regular work. It is a system that contains information about all materials in the plant, for example the amount of material at the material address, forecasted demand for the near future, the status at the crane inventory as well as ordered material.

6.2 Mapping of logistical flows – thesis purpose part II & III

Saven's (1988) ideas that a lot of data for a simulation study might be available, but the information might be missing, available but out of date or in the wrong format, can be confirmed at Volvo Cars Torslanda. Some data have been missing, some data have been available but not in a format suitable to be used for simulation studies. Especially not for studies of the logistical flows.

Moorthy and Sly (2001)'s ideas that facility layouts of proposed or existing systems often forms the basis of the of a dynamic simulation is also true at Volvo Cars Torslanda. They have an important rule to uphold in every simulation project. It is not the simulation model that describes the process, but the layout. Since this is the base, much duplication of work

is done building the simulation model. In this thesis the FactoryCAD layout is also the base for the mapping in Visio, where it has been placed as a separate layer where the objects created then could be placed in the accurate positions.

According to the same authors, by using FactoryCAD relevant simulation data can be saved in XML format which eliminates the need in the simulation package to recreate physical and run control information. The file created has become a common data format named SDX (Simulation Data Exchange), and can serve as an input to automatic generation of discrete event simulation models. The same result can be achieved by using an object oriented software such as Microsoft Visio where objects can be defined, described and saved in the XML format, in order to achieve the same results.

Moorthy and Sly further mean that the content of the file is the header information which specifies drawing source data, simulation model units, run control and shift information. After the header section any object can be defined. Objects with geometrical shapes like parts, paths networks, buffers, machines, conveyors and vehicles can be defined. There are also other objects like runtime, shift and statistics. Depending on the object type a number of related details describe all the object attributes that are needed for the simulation model. The same applies to a Visio object that can freely be created and given attributes.

Both ways follow Rummler and Brache definition of a process; *“a series of steps designed to produce a product or service. Some processes may be contained wholly within a function. However, most processes are cross-functional.”*

7 Conclusions, Discussion & Recommendations

7.1 Conclusions

The final chapter begins with issues that are responded with my conclusions that comes from the research. After that a discussion is held and recommendations are given. The chapter is ended with suggestions for further researches.

The purpose of this research is to describe the logistical flows in Volvo Cars Assembly Factory and to create an object model for these flows, which can be used as a base for the simulation model, as well as to evaluate if and how the flows can become more efficient. Based on the analysis the following conclusions were made in order to fulfill the purpose;

How is the material handled, what happens, from the arrival at the goods receiving area to the point of consumption at the line?

Conclusion

The logistical system at Volvo is a very complex system with a lot of actors involved in the processes of feeding the line. There are two main flows of sequence and batch material, where the sequence material represent a handling involving 3PL, Just-In-Time and sequence deliveries. The batch flow involve Kanban and Two-bin in the small box loops and Just-In-Time feeding of the line combined with a material handling using different buffers and pre stations. The material is handled in the best way known. The material handling is difficult and at the present situation and not optimal from a logistical point of view. This due to the fact that some aisles are too narrow as a result from the joining of the two lines into one. The logistical handling is structured in order to save as much space as possible at the line. This since unnecessary movements here are considered very expensive. The logistics department has to adapt their handling fully to what the production is saying. The smaller the packing the better, as long as the material last for two hours at the line. The logistical handling within Volvo Cars Torslanda stretches over a lot of logistical concepts, with a help of an MPS system to keep track of it all.

How would a mapping of the material flow with intelligent attributes look?

Conclusion

There are many alternatives to how a mapping can be performed. One way can be to use the layout through FactoryCAD, another is to do it though Microsoft Visio. Most important is that it fits to the organization as well as being easy to use and understand. It is also important not to tie yourself to one supplier which can create unwanted dependabilities. It is important to use standard formats if possible. XML is a brilliant example of this. The intelligent attributes shall be based on this format. The study shows that it is not important what tool you are using to describe the intelligent attributes as long as you do it in a object oriented way.

How can the information gathered help to improve the simulation studies or the logistical handling of the material within the assembly factory?

Conclusion

The information can be used both for static as well as dynamic calculations for improvements of the logistical flow. Statically it can be compared to information used today. It can be compared to the distribution time in order to see if they are using the best alternative for the route selection. It can also statically be used as inputs for the balances, and therefore influence how the car is assembled and how the materials are brought to the line. Dynamically the information can be used in a simulation tool to simulate new ways for the distribution, for example to answer questions if it is more efficient to distribute a material by wagon or if it should be distributed by a truck. By this it can be seen if the best routes are used or if they should be changed. The simulation tool can solve problems and eliminate bottlenecks before they appear in real-time.

A great advantage with this is as a contribution to make simulation more understandable for people not involved or working with it in their daily work. They can interpret and understand simulation in an easier way. By understanding it better they can also better understand the unlimited contributions and improvements that a simulation study can give if it is preformed in a correct manner. It can also give a better joint understanding of a problem, and by doing so also increase the chances of solving it. By creating standard objects in XML that can be translated into the simulation environments, the model building can also become easier. This gives possibilities for a technician at Volvo to build a simple model over the part that he wants to simulate. This can then be interpreted or put directly in the simulation environment by the person working with simulation studies. This can be done since the objects can be predefined with given attributes. The model can be built very easily in a small scale. The only things that have to be added are the data for the attributes that the objects consist of. All in all it might lead to better collaboration among departments at Volvo Cars Torslanda and a better joint and common understanding of a project or a change.

7.2 Discussion and Recommendations

As stated in the conclusions there are many ways off how a mapping can be performed. I think though that using Visio is a good way to do it. The program is easy to understand and the objects are easy to create. One important aspect to considered is to make sure to save the objects in a stencil. This makes them very easy to use, but also to change and modify. I have unfortunately not been able to do the mapping by using the FactoryCAD alternative, as it was not easily available. Although I would like to say for smaller companies and those who do not have access to FactoryCAD and are interesting of doing a mapping Visio is a good alternative. The costs of the program also speaks as a benefit by using Visio.

The mapping that I have performed shall be seen as a way of working and not a finished solution or application. It is though a beginning and a push in the right direction, which can be a start of something good. The work have much consisted of trying a new way of thinking and the problems that can occur when doing so.

In the Volvo case there are some pieces of the puzzle that have to fall into place in order to get this way of performing simulation studies to work in the big picture. Some information must become systemized. The material that do not have a automated call to the line must be defined, categorized and placed in the layout, in the same way as the wagon pockets which have their defined material address as well as "lokal". A near storage shall be called a

near storage or similar in the layout. How or if materials are stored in the created area or distributed directly to the line needs to be investigated. This in order to create the logistical flows and enable to evaluate it in a simulation model.

7.3 Suggestions for further research

- ✓ Taking the data created in this research and use it for a real-time simulation.
- ✓ Look a how Toyota handle their logistical flows since they serve as some kind of model for the rest of the automotive industry, and compare it to the Volvo way.
- ✓ Look at a some other company's logistical handling and compare it how Volvo is doing.

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Interviews

Interviews from tour and informal communication with personnel at Volvo Cars Torslanda

Appendix 1

Interview questions for the pre study

- ✓ What flows are there?
- ✓ What happens to the material internally?
- ✓ How is the material distributed and delivered?
- ✓ Who delivers?
- ✓ What actors are there in the system?

Appendix 2

Letter with Questions sent to the retailers of Enterprise Dynamics in Scandinavia

The picture below shows the basis of the project. There are two lines with a feeding loop (two-way) around it, connected with a buffer or near storage. Then there is a network of nodes giving the alternatives that the material can be distributed to the line.

As shown there are many ways to transport the goods coming from WP1 going to Line 1 4 meters in (Material address L1S4).

One alternative: WP1, WP2, WP4, WP6 and then L1S-10.

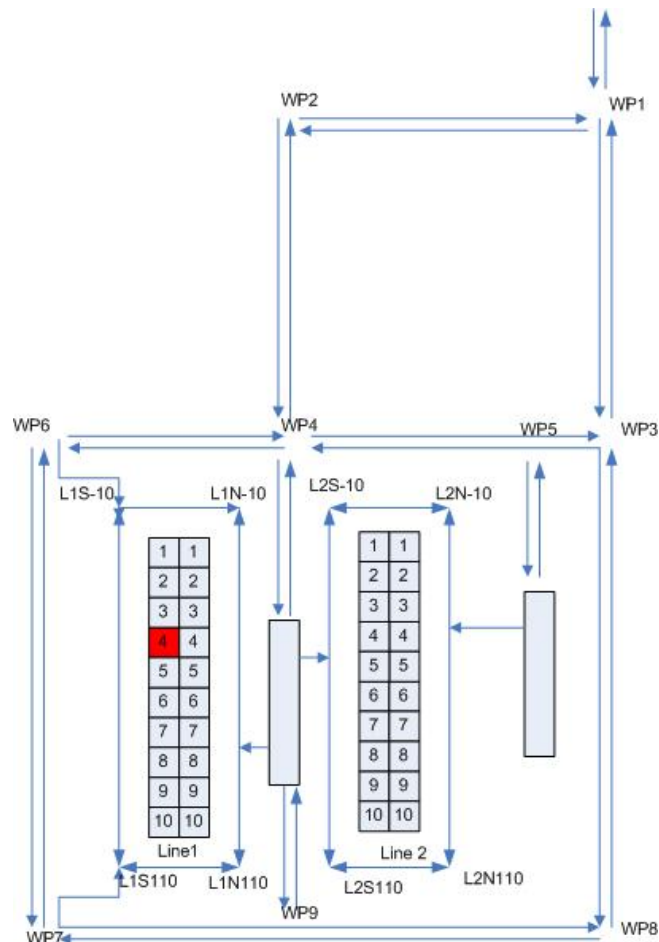
Another: WP1, WP3, WP5, WP4, WP6 and L1S-10

Third: WP1, WP3, WP8, WP9, WP7 and L1S110

As said some might use near storages, buffers etc along the way. What we know is that ex::

Part 7819 uses goods receiving office 1, Main storage 25, near storage 24 and Material address L1S4 (point of consumption at the line).

From this the best route or logistical flow are to be decided, or alternatives considered.



How shall this be documented in order to get Enterprise Dynamics to understand it?

When ED understands it, how can we optimize it by selecting the best way considering the cost (time) of transport??

There will be restrictions created. For example some material is 5m wide and can naturally not be distributed through a node where the maximum is 3 meters. Therefore the material must take another route.

Shall the attributes be put in the node or in the aisle?

What attributes are possible to put in the nodes in ED?

Is it possible to make them more advanced? Containing ex;

- ✓ Width
- ✓ Speed
- ✓ One way/ two way
- ✓ Overtaking yes/no
- ✓ Visibility
- ✓ Reference to the line (just connection point ex. L1S-10)
- ✓ Traffic rules

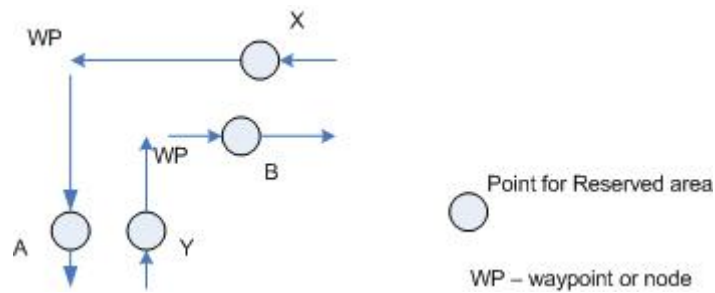
Must every aisle be described using to one-ways going in both directions or can a way handle traffic in both directions without causing any collisions in the model??

As said the basis is from the CAD layout. The attributes for the nodes or aisle are most likely to be put in a database for digital input and use.

Complement questions

There is a restriction in some of the corners saying that it is not possible for two resources to meet in that corner. The problem is that some corners are too narrow for a wagon train and a truck to meet. This makes one of them have to hold before the other one has passed.

For example: This makes, that if a resource has passed point X another resource traveling in the opposite direction must hold at point Y and wait until the other resource has passed point A.



What are your suggestions to solve this “restriction”?

Can you use some kind of reserved area that belongs to the waypoints/nodes when material enters the area that “scans” the reserved area point in the opposite direction, and if nothing is there gives an OK to enter the area??

The reserved area lengths will vary considering different attributes of a truck and a wagon-train, (2,5 and 16 meters) making the reserved area to have some connection to the resource utilizing the network.

For a straight aisle the reserved area will be treated as zero (the turn restriction and length set to zero).

Appendix 3

Questions for interview with technicians at Volvo Cars Logistical department

- ✓ What might disturb the logistical flows? / What makes it take longer time to deliver?
 - How often?
 - Where?
 - Frequency?

- ✓ How do you define obstacles and interruptions?

- ✓ How do you handle interruptions?

- ✓ What attributes on the road have an influence on the logistical flows?
 - Road choice?
 - Obstacles?
 - Rules of traffic?

Appendix 4

Objects in the layout containing simulation relevant information according to Moorthy & Sly (2001).

1. LOAD
 - Active
 - Passive
2. SHIFT
3. OVERHEAD POWER AND FREE CONVEYOR
 - Overhead Accumulating
 - Inverted Accumulating
4. MONORAIL
 - Overhead Non-Accumulating
5. FLOOR CONVEYOR
 - Non-Accumulating
 - Accumulating
6. CROSS TRANSFER CONVEYOR
 - Non-Accumulating
 - Accumulating
7. VERTICAL LIFT
 - Non-Accumulating Floor Conveyor Type
 - Non-Accumulating EMS Type
8. PIVOT
 - Non-Accumulating
9. ELECTIFIED MONORAIL SYSTEM
 - Overhead Accumulating
10. TRANSPORTER
 - Fork Truck
 - Automated Guided Vehicle
 - EMS Transporter
 - Tugger
11. PATH
12. AISLE
 - General
 - Automated Guided Vehicle
 - Pedestrian
 - Departmental
13. CARRIER
 - Inverted Power and Free Carrier
 - Overhead Power and Free Carrier
 - Monorail Carrier
14. BUFFER
 - Last In First Out
 - First In First Out

- Restore Sequence
15. MACHINE
- Batch Operation Machine
- Assembly Machine
 - Production Machine
 - Single Operation Machine
 - Multi Station
16. RUNTIME
- No Animation
 - Partial Animation
 - Full Animation
 - Normal
 - Trace
17. PART ROUTING DATA
18. ASSEMBLY TREE
19. OBJECT TO OBJECT CONNECTION
20. WORKCENTER
21. STATION ON COVEYORS AND MACHINES
- Load Station
 - Unload Station
 - Process Run Station (load does not stop)
 - Process Stop Station (load stops)
 - Idle station
 - Decision station
 - Marriage
 - Disassembly
- Assembly
22. OPERATOR
- Self Relief
 - Tag Relief
 - Mass Relief
 - Material Handling
 - Maintenance
 - Setup
23. DOCK
24. STATION_AREA
- Main Line Station
 - Off-Line Sub-assembly
25. INDUSTRIAL